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Auckland Light Rail

Economic Assessment

Final - Version 1

Contents

Document Information

Date	Version	Comments	Author
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1 INTRODUCTION

This note sets out the proposed approach to undertaking an economic assessment of the ALR project preferred option.

At a high level, the project will provide the following:

- Transport benefits to those using the corridor;
- Transport benefits to the wider network through reduced congestion on the surrounding network;
- Wider economic benefits; and
- Economic benefits associated with increased development along the corridor

2 DO MINIMUM

From a transport perspective, a set of do-minimum assumptions has been agreed for the ALR project. The project will be added to the network to assess the economics effects of the project.

A dynamic land use has been developed as a result of implementation of this project. Two land use scenarios will be considered.

- A do minimum land use - assumes no project is in place.
- A project land use – assuming ALR is in place and intensification occurs along the corridor.

More details on the do minimum assumptions can be found in the Do Minimum Note.

3 MCBM BENEFIT STREAMS CONSIDERED

The following benefit streams will be considered for the ALR project:

- **Public transport user benefits** – new PT users who have either transferred from another mode or are a new generated trip. Benefits are based on the difference between the proposed and the maximum user charge (at which no one would use the service). The result is then divided in half, based on the rule of half. The project is expected to reduce congestion for existing services and reduce crowding on existing services.
- **Public transport user experience benefits** – PT users experience an improved quality of facility and service.
- **Road traffic benefits** – The project will reduce vehicle travel providing benefits in vehicle travel time, congestion, and vehicle operating costs.
- **Reliability benefits** – The ALR projects provides public transport users with a more reliable service than the existing bus services. A reduction in traffic on the remaining network will result in some reliability benefits for vehicles.
- **Safety benefits –** The project will reduce vehicle KM travelled on the road network with a transfer to the ALR project. High Quality PT services are inherently better performing from a road safety perspective.
- **Impact of Mode on Physical and mental health** – Users of a public transport corridor typically walk more than a comparative vehicle journey. The Physical and mental health benefits of this increased walking will be considered using MBCM.
- **Emissions benefits –** The project is expected to lead to a reduction in vehicle emissions.

Further to the traditional benefits identified, Wider Economic Benefits will be considered including:

- **Agglomeration** – ALR is expected to result in additional density of firms and workers becoming more productive as a result.

- **Imperfect competition** – The ALR project is expected to cause output to increase in sectors where there are price-cost margins
- **Increase labour supply** – The ALR project reduces commuting costs, removing a barrier for new workers to access areas of employment.

4 SCENARIOS / OPTIONS

Assessment has been carried out in two phases. Initial assessment was carried out on the long list options considered including the following:

- Option 1A - LRT Sandringham
- Option 1B - LRT Dominion
- Option 2A - LM Sandringham
- Option 2B - LM Dominion
- Option 3 - Hybrid

Each of the above options was tested with a land use scenario assuming a nominal increase in development in the immediate catchment (approximately 5000 additional dwellings) over the do minimum scenario.

Following the initial testing, the options were narrowed down to three short list options:

- Option 1B - LRT Dominion
- Option 2A - LM Sandringham
- Option 3 - Hybrid

The above three options were tested using a high growth land use scenario which increased density within the project corridor further than assumed in the first round of modelling. The following uplift was modelled for each option:

- Option 1B – additional 15000 dwellings
- Option 2A - additional 35000 dwellings
- Option 3 - additional 35000 dwellings

5 ASSUMPTIONS

5.1 Evaluation period

An evaluation period of 60 years has been selected based on MBCM guidance. The ALR project is considered to qualify for use of this evaluation period given the significant costs and benefits associated with the project and long-lived nature of infrastructure and effect on land use.

5.2 Base year / Year 0

The assessment has been based on a base year of 2021, year 0 of 2021. Benefits are assumed to begin accruing in the 2032 year.

5.3 Discounting

A standard 4% discount rate has been applied as per MBCM requirements.

5.4 Annualisation factors

Annualisation factors have been applied based on standard annualisation factors from the MSM model. Daily factors for the interpeak period vary between mode as set out in Table 5-1.

Table 5-1: Annualisation factors

Period	Model period	Car Hr per day\	PT vehicles hours per day	PT person hours per day	Days per year
AM	AM	1.00	1.00	1.00	245
PM	PM	1.00	1.00	1.00	245
Weekday IP	IP	5.10	3.60	5.40	245
Weekday evening	IP	1.90	1.90	1.90	245
Weekend / Holiday	IP	6.50	3.60	5.40	120

5.5 Benefits ramp up

The benefits from the LRT project are not expected to be realised in full from the opening day of implementation. Given the benefits of such a scheme are largely linked to a change in travel behaviour (people changing transport mode) and changes in land use (intensification) around the corridor, it follows that benefits from the scheme will ramp up over time. Given the project will be constructed over a number of years (5+) and land use zoning will already be in place, the benefits ramp up for the ALR project is expected to occur faster than typical for such a large-scale project. Table 5-2 sets out the assumptions on benefits ramp up.

Table 5-2: Adopted benefit ramp up assumptions

Year since construction completion	% of benefits realised
0	0%
1	50%
2	100%

Sensitivity testing will explore the effects of a slower ramp up period for benefit realisation.

5.6 Benefits distribution

The traditional benefits streams have been calculated based on two modelled years being 2031 and 2051. Given the projects expected construction timeframes, 2031 benefits are likely to represent the initial benefits generated by the project. Benefits have been prorated between the 2031 and 2051 years to account for the intervening years. After 2051, benefits are assumed to follow a similar growth / decline as experienced in the period prior to the end of the evaluation period.

5.7 Benefits capping

Benefits have been caped in each scenario according to the maximum capacity of each mode. Figure 5-1 to Figure 5-3 show the modelled demand vs capacity for each mode based on two different land use scenarios. The Max cap has been used to cap benefits from an economic perspective. The modelled cap represents an artificial capacity based on operational assumptions. In reality additional services can be added to provide up to the maximum capacity.

Within the MSM model itself, benefits start to diminish once the modelled cap is exceed and crowding is applied to a proportion of PT trips.

Figure 5-1: Light rail (Dominion) demand and capacity

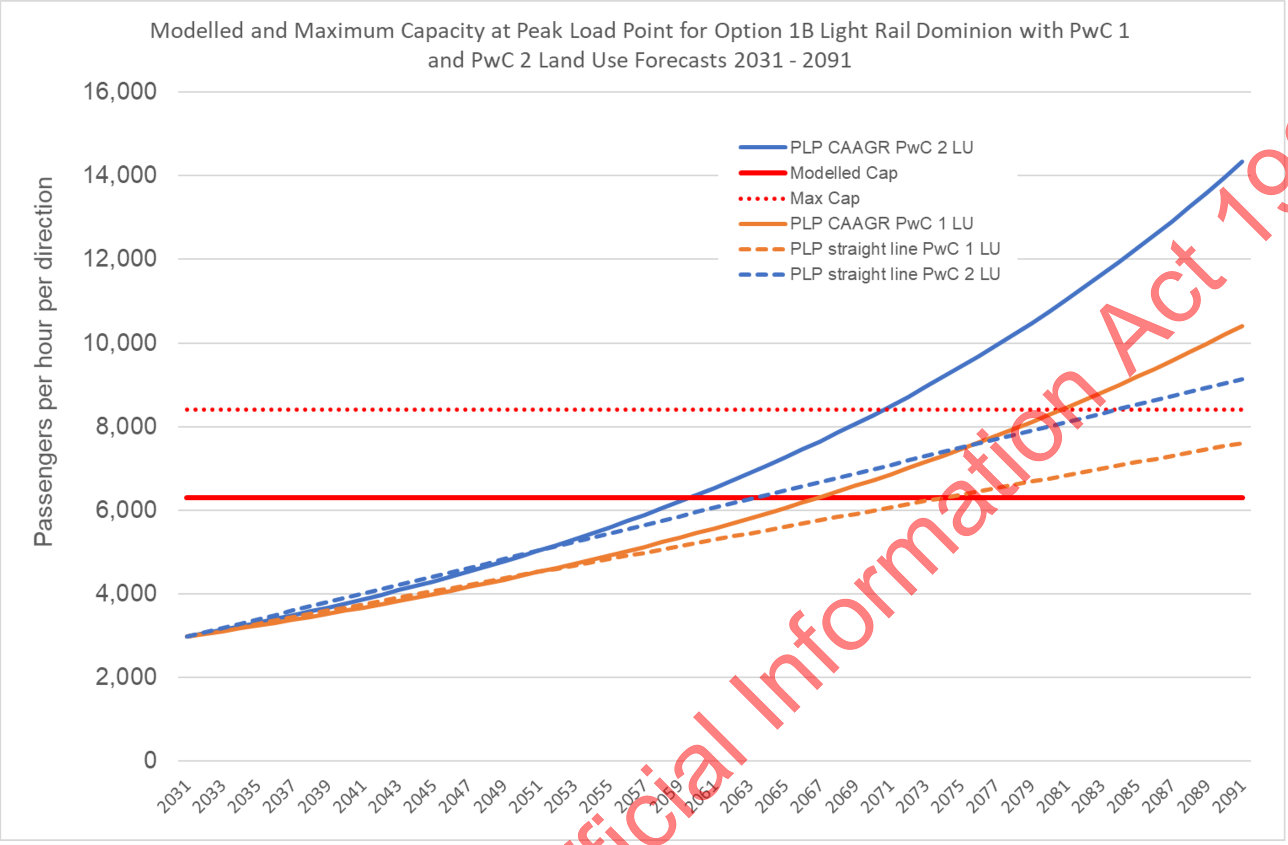


Figure 5-2: Light Metro (Sandringham) demand and capacity

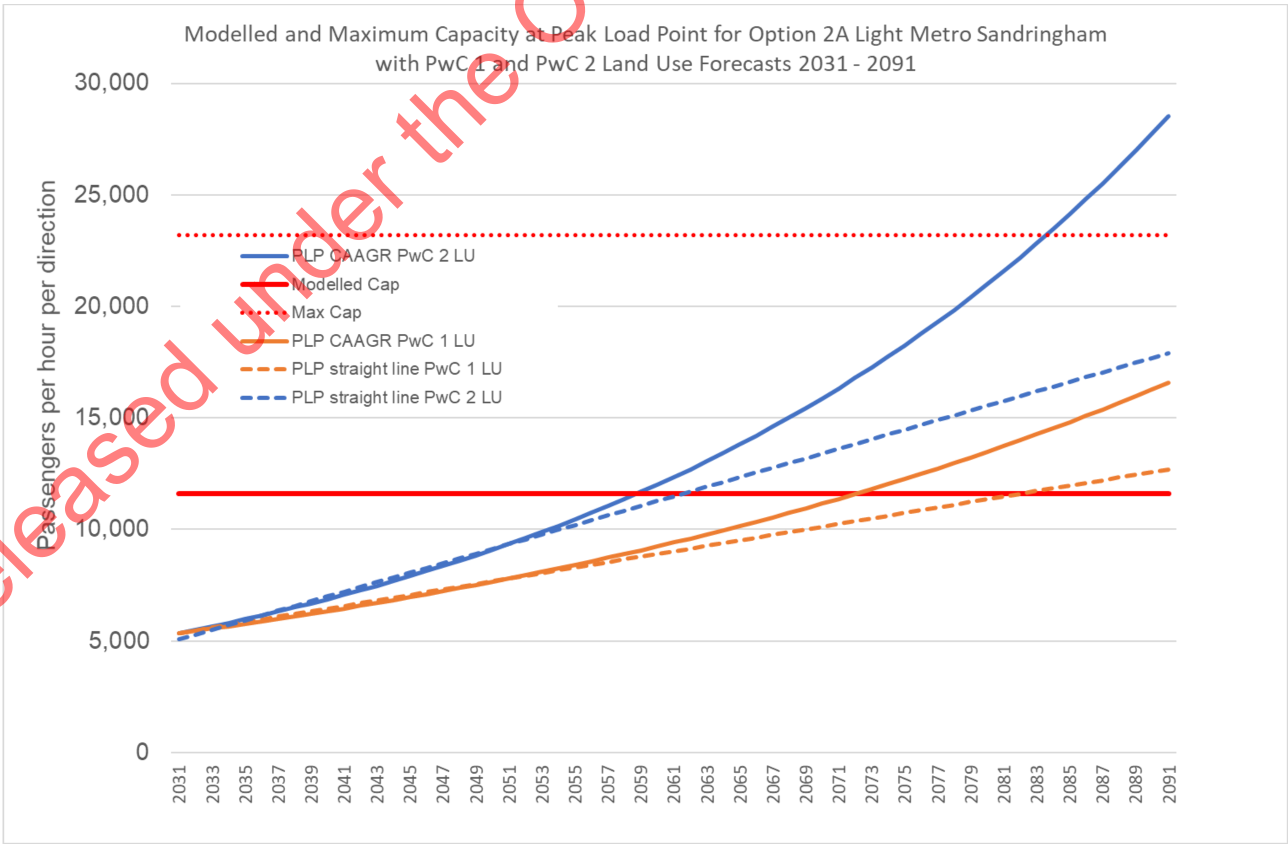
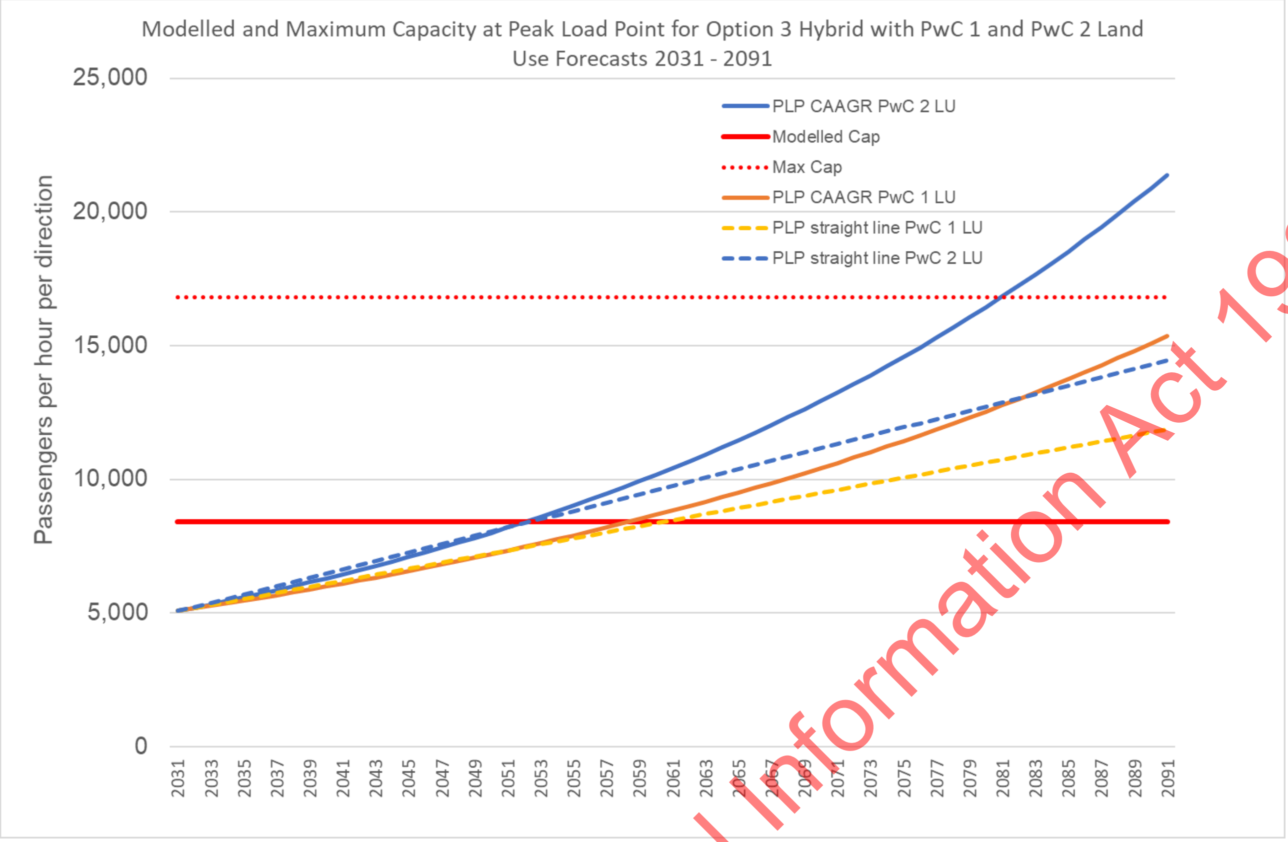


Figure 5-3: Hybrid Option demand and capacity



6 BENEFITS

Benefits of the ALR scheme have been evaluated using the Macro Strategic Model (MSM) – regional transport model. Four shortlist options have been compared to a do-minimum option with the different being used to calculate the benefits associated with each option.

Dynamic Land use has been assumed as a result of the project. I.e. land use patterns change as a result of the option.

Table 6-1: Benefits streams and source of data

Benefit stream	Data Source	Method
s 9(2)(i) [redacted]	[redacted]	[redacted]

s 9(2)(i)

Emissions benefits	MSM model results based on changes in future models based on the VEPM5.1 emissions model.	Model changes in emissions used converted to benefits using MBCM rates.

6.1 Application of the rule of a 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.

In the do-minimum, users experience benefits from their existing travel behaviour. If they choose to change their travel behaviour in response to a new or improved activity, then it must be the case that they experience a higher level of benefits as a result of the activity. However, upon changing their travel behaviour, the users must also forgo the benefits of their previous travel behaviour in the do minimum, which offsets the increase in benefits after the change. Therefore, the transport system users who change their travel behaviour receive only an incremental increase in benefits between the do-minimum and activity scenarios.

For the purposes of the ALR economic assessment, the rule of a half has been applied to new user public transport benefits only. What this means in practise is as follows:

- Public transport users on existing services (i.e., bus services on Sandringham Road) which change to using the ALR project experience the full benefits of the ALR project.
- Users who shift mode of travel (i.e. from a car trip to the ALR) to the ALR are considered to receive half the benefits (consistent with the rule of a half)
- Cars using the network which experience a change to VOC or travel time for any given trip are considered to receive the full benefit / disbenefit of the project.

The rule of the half has been applied to some of the benefits for PT user benefits and PT reliability benefits.

6.2 Traffic benefits

The traffic benefits are calculated within a MSM MACRO which compares each option against the do minimum scenario. The calculations are outlined as follows:

- Travel time: (do min car demand + option car demand) *(do min car travel time – option car travel time)
- Perceived VOC: (do min car demand + option car demand) *(do min car distance – option car distance)
- Resource cost correction: ((option car demand * option car distance) – (do min car demand * do min car distance)) * (1-1/1.15)
- Where car = car by purpose or HCV

Overall vehicle operating benefits are calculated with Perceived VOC added to the resource cost correction. The resource cost correction accounts for the proportion of the perceived VOC cost to users which is paid in GST. GST is not included in economic calculation as this is a transfer between an individual user and the government hence excluded from an economic perspective. Traffic benefits and VOC costs are converted to $ based on value of time in the MCBM for the various trip purposes extracted from the model.

6.3 PT benefits

PT benefits from the MSM models are based on generalised cost so include changes in travel time, allowance for transfers, and crowding. Benefits are expressed as minutes.

The PT benefits are calculated as:

- 0.5 * (do min PT demand + option PT demand) * (do min PT GC – option PT GC)
- Where PT = PT by purpose

The MACRO applies the rule of a half to all PT benefits. This is then corrected using the following formula:

$$Rule\ of\ a\ half\ Correction\ Factor = \frac{Reduction\ in\ bus\ KM\ travelled\ (Do\ Min - option)}{ALR\ km\ travelled\ (Option - do\ Min)}$$

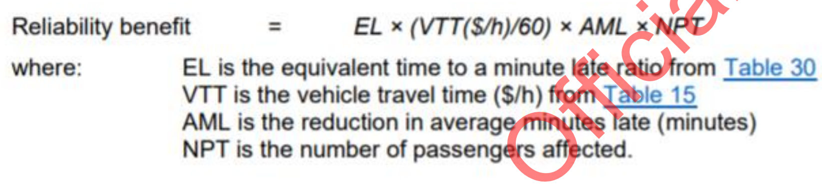
PT benefits are converted to $ based on value of time in the MCBM for the various trip purposes extracted from the model.

6.4 Reliability benefits

The ALR project will have a significant improvement to travel time reliability for people within its catchment. Some travel time benefits are likely for general vehicles due to a reduction in travel time and VKT on the surrounding network.

Reliability benefits have been calculated based on a factor of the PT benefits stream and traffic benefits stream. Traffic reliability benefits have been estimated at 8% of travel time benefits based on typical rates experienced on similar projects.

Public transport reliability benefits have been calculated based on a benchmarking exercise using the MCBM method for estimate reliability benefits and comparing this as a ratio to travel time benefits. The MCBM methodology is outlined below:



Reliability benefit = $EL \times (VTT(\$/h)/60) \times AML \times NPT$

where: EL is the equivalent time to a minute late ratio from Table 30
VTT is the vehicle travel time ($/h) from Table 15
AML is the reduction in average minutes late (minutes)
NPT is the number of passengers affected.

A series of scenarios have been developed to test the likely bounds that PT reliability benefits may account for. The scenarios have been developed based on some benchmarking of existing bus punctuality on key services within the study area as outlined in Table 6-2.

Table 6-2: Bus services assessed for punctuality

Region	Number	Type	Route
Central	243X	Peak only	New Lynn to City Centre via Richardson Rd and Sandringham Rd, express
Central	248X	Peak only	Blockhouse Bay to City Centre via Sandringham Rd, express
Central	**24B**	Frequent branch	New Lynn to City Centre via Blockhouse Bay and Sandingham Rd
Central	**24R**	Frequent branch	New Lynn to City Centre via Richardson Rd and Sandringham Rd
Central	**24W**	Peak only	Wesley to City Centre via Sandringham Rd
Central	**252**	Peak only	Lynfield to City Centre via Dominion Rd and Don Mckinnon Dr
Central	**253**	Peak only	Blockhouse Bay to City Centre via Dominion Rd and Don Mckinnon Dr
Central	**25B**	Frequent branch	Blockhouse Bay to City Centre via Dominion Rd and Mt Eden Station
Central	**25L**	Frequent branch	Lynfield to City Centre via Dominion Rd and Mt Eden Station
Central	**30**	Frequent	Onehunga to City Centre via Royal Oak and Manukau Rd
South	**309**	Connector	Mangere to City Centre via Onehunga and Pah Rd

South	309X	Peak only	Mangere to City Centre via Pah Rd, express
South	380	Frequent	Manukau to Onehunga via Papatoetoe, Airport, and Mangere

Future operation of the ALR project has been based on some international research given there is no operational light rail corridors in New Zealand.

Table 6-3: Reliability scenarios tested

	Base test	High range	Low range	Interpeak
	Test 1	Test 2	Test 3	Test 4
Corridor Length, km	5.6km	5.6km	5.6km	5.6km
DM Time, minutes	2.8	3.8	2.8	2.5
Opt Time, minutes	0.5	0.5	1	0.5
Ratio of Reliability benefit to Travel time benefit	76%	108%	59%	66%

Overall a public transport reliability benefits have been estimated at **75% of public transport user benefits** based on an average of the above scenarios. Given this is a direct factor of the PT benefits, this takes into account the rule of a half applied to new trips only.

6.5 Crash benefits

The ALR project will reduced the overall volume of VKT on the road network within the study area, and lead to an increase in PT usage. A trip on a PT service has an overall lower safety risk than a comparable trip by a vehicle.

The MSM model provides an estimate of crash reduction based on a reduction in VKT. Different crash rates are applied to VKT in the various road environments across the Auckland Region.

A reduction is provided for each option which is then converted to $ using the MBCM rates for injury accidents in various road environments. Values for each type of injury crash are outlined in Table 6-4.

Table 6-4: Cost per injury crash

Total crashes	$ per crash
Urban crash	$220,000
Rural crashes	$580,000
Motorway crashes	$290,000

6.6 Impact of Mode on Physical and mental health

As a result of the LRT project, more walking and cycling is likely to take place with people changing modes and connecting to the service.

Users of a public transport service generally walk to and from a service to a destination. A good level of literature exists outlining the average walking distance to a station or stop. In Auckland few studies have been carried out to understand the Auckland, or New Zealand, context. One study which did was conducted by the Council's Research, Investigations and Monitoring Unit[1] which looked at Rail and Busway stations. This study found that people were prepared to walk considerable distances to these services (over 4km in some cases) and while the median distance walked to these stations differed considerably between stations, a majority of the stations recorded a median walking distance of less than 800m.

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[1] Wilson, L (2013). Walkable catchments analysis at Auckland train and Northern Busway stations – 2013. Auckland Council technical report, TR2013/014

The benefits associated with the ALR project have been calculated based on the new user patronage of each option and using assumptions on likely walking and cycling to and from the service compared with typical trips using a car. The following assumptions are made in the assessment:

- 90% of new PT users are assumed to walk to stop or station. Each user is assumed to walk 800m on one end of the trip and 400m on the other end.
- 10% of new users are assumed to cycle to a station with an average trip length of 3km on one end and 1km on the other end.
- A typical vehicle trip involves a 200m walk

Benefits only apply to new users to the ALR service (I.e., people transferring from Bus services are excluded)

Standard MBCM rates for walking and cycling KM were applied to convert KM into benefits.

6.7 Emissions benefits

The ALR project enables a shift in travel between private vehicles and the Light rail service resulting in a reduction in Transport emissions. The MSM model outputs for greenhouse gas emissions have been extracted which take into account the changing nature of the vehicle fleet in NZ (As per the VEPM 6.1 emissions model).

6.8 PT user experience benefits

The ALR project will improve the user experience on public transport services. These benefits are generally related to the level of comfort and exclude the typical PT benefits such as fare change benefits, increased service frequency benefits and interchange reduction benefits.

Public transport users value infrastructure and vehicle features. Typical user valuations expressed in terms of in-vehicle time (IVT) are outlined in the MBCM for each attribute. PT user experience benefits have been calculated based on the MBCM methodology which consider the impacts on infrastructure and vehicle features / attributes. The IVT for each of these attributes were then converted to generalised costs by multiplying the value of time given in the MBCM. A weighted average of the value of time was used for this calculation, which was based on the total PT trip by trip purpose multiplied by value of time in the MBCM based on trip type.

Perceived benefits of multiple features are advised to be less than the sum of individual components, therefore the total value of benefits have been divided by two and thus adjusted for overestimation.

Table 6-5: Attributes assumed for ALR project

Vehicle feature values for public transport services - bus (Table 33 of MBCM)			
Attribute	**Sub-attribute**	**Valuation (IVT minutes)**	**Generalised costs ($)**
Boarding	No steps	0.1	$0.02
Driver	Attitude	0.4	$0.09
	Ride	0.6	$0.13
Cleanliness	Litter	0.4	$0.09
	Exterior	0.3	$0.07
	Interior	0.3	$0.07
Facilities	CCTV	0.7	$0.15
Information	External	0.2	$0.04
	Interior	0.2	$0.04
	Info of next stop	0.2	$0.04
Seating	Type / Layout	0.1	$0.02
Comfort	Legroom	0.2	$0.04

	Ventilation - air-conditioning	1	$0.22
Infrastructure features value for public transport - bus (Table 34 of MBCM)			
Attribute	**Sub-attribute**	**Valuation (IVT minutes)**	**Generalised costs ($)**
Stop / shelter	Condition	0.1	$0.02
	Size	0.1	$0.02
	Seating	0.1	$0.02
	Cleanliness	0.1	$0.02
	Graffiti	0.1	$0.02
Ticketing	Availability of machines	0.2	$0.04
Security	CCTV	0.3	$0.07
	Lighting	0.1	$0.02
Information	Terminals	0.1	$0.02
	Maps	0.2	$0.04
	Countdown signs / real-time information	0.8	$0.17
	Clock	0.1	$0.02
	Simple timetable	0.4	$0.09
Stations (up to 3)	Value for stations	1	$0.22
Total sum of benefits (adjusted for overestimation)			$0.91

The total equivalent in vehicle value is 4.2 minutes. Total benefits are calculated by application of this saving to all PT users on the corridor.

6.9 MCBM benefits summary

A summary of benefits by options is outlined in Table 6-1.

Table 6-1: Summary of MBCM benefits

	Long list option assessment					Short list assessment		
Option	LRT Sandringham	LRT Dominion	LM Sandringham	LM Dominion	Hybrid	LRT Dominion	LM Sandringham	Hybrid
Land Use	Low land use uptake	Low land use uptake	Low land use uptake	Low land use uptake	Low land use uptake	High land use uptake	High land use uptake	High land use uptake
	Option 1A	**Option 1B**	**Option 2A**	**Option 2B**	**Option 3**	**Option 1B**	**Option 2A**	**Option 3**
Traditional Benefits								
Vehicle benefits (TT)	$923M	$772M	$1917M	$1962M	$1365M	$584M	$1651M	$1184M
Vehicle operating cost	-$2M	-$2M	-$1M	-$1M	-$1M	-$2M	-$3M	-$3M
Public transport benefits	$1089M	$1011M	$1558M	$1520M	$1281M	$1099M	$1620M	$1422M
Crash cost reduction	$262M	$233M	$328M	$331M	$293M	$506M	$622M	$617M
Emissions	$27M	$24M	$40M	$40M	$34M	$47M	$63M	$59M
Walking and cycling	$250M	$219M	$425M	$415M	$354M	$672M	$1163M	$1027M
Car reliability	$74M	$62M	$153M	$157M	$109M	$47M	$132M	$95M
PT reliability	$818M	$760M	$1171M	$1142M	$963M	$826M	$1217M	$1069M
PT Experience	$253M	$254M	$419M	$405M	$364M	$284M	$489M	$446M
Noise								
Traditional Benefits total	$3695M	$3332M	$6011M	$5971M	$4762M	$4062M	$6954M	$5916M

7 WIDER ECONOMIC BENEFITS

7.1 OVERVIEW

This document describes the analysis performed to estimate the Wider Economic Benefits (WEBs) associated with the Project. The three WEBs that are covered are:

- agglomeration benefits which measure the productivity gains that arise when increased spatial concentration results in higher efficiency
- imperfect competition benefits which measure the impact of transport infrastructure induced increases in output in sectors with price cost margins
- increased labour supply benefits which measure the additional tax take that results when improved transport infrastructure increases the labour supply.

The WEBs are estimated for the five shortlisted options using the dynamic accessibility-based land use estimates. These land use estimates adjust the modified I11.6 do minimum (DM) land use scenario to account for the impacts of changes in accessibility on population and employment density associated with each option. WEBs are calculated as at the base year of 2021 (in 2021$). It is assumed that the first year in which benefits are accrued is 2032, corresponding to the year in which the ALR scheme is assumed to open.

For three of the shortlisted options (LRT Dominion Road, MRT Sandringham Road and Hybrid), the WEBs are also estimated for a 'higher intensification land use' scenario which assumes higher intensification within the corridor. These scenarios are described in more detail in the 'ALR Land Use Change & Development Capacity - Technical Paper' dated 17 September 2021.

The total present value of the WEBs using a 4% discount rate ranges between $3.7b (LRT Dominion Road) and $6.6b (MRT Sandringham Road) across the five shortlisted options. Agglomeration is by far the largest WEB, comprising about 90% of the total value of the WEBs. A breakdown of the estimated WEBs for each of the five shortlisted options is given in Table 7-1 below.

Table 7-1 WEBs summary (2021$, 4% discount rate, accessibility-based land use)

Option	Agglomeration ($m)	Labour supply ($m)	Imperfect competition ($m)	Total WEBs ($m)
LRT Sandringham Road (Option 1A)	s 9(2)(i) [redacted]	[redacted]	[redacted]	**4,287**
LRT Dominion Road (Option 1B)	[redacted]	[redacted]	[redacted]	**3,685**
MRT Sandringham Road (Option 2A)	[redacted]	[redacted]	[redacted]	**6,626**
MRT Dominion Road (Option 2B)	[redacted]	[redacted]	[redacted]	**6,475**
Light Rail Hybrid (Option 3)	[redacted]	[redacted]	[redacted]	**5,862**

Source: *AC rating database, MSM, PwC analysis*

A breakdown of the estimated WEBs using the higher intensification land use scenario is shown in Table 7-2. Under this scenario, the WEBs are slightly higher for the LRT Dominion Road and MRT Sandringham Road options (total of $4.0b and $7.0b respectively) and slightly lower for the Hybrid option (total of $5.8b) relative to the accessibility-based land use scenario.

Table 7-2 WEBs summary (2021$, 4% discount rate, higher intensification land use)

Option	Agglomeration ($m)	Labour supply ($m)	Imperfect competition ($m)	Total WEBs ($m)
LRT Dominion Road (Option 1B)	s 9(2)(i) [redacted]	[redacted]	[redacted]	**3,989**
MRT Sandringham Road (Option 2A)	[redacted]	[redacted]	[redacted]	**6,988**
Light Rail Hybrid (Option 3)	[redacted]	[redacted]	[redacted]	**5,760**

Source: *AC rating database, MSM, PwC analysis*

The rest of the document includes a detailed methodology following the steps described in the Waka Kotahi NZ Transport Agency (Waka Kotahi) Monetised Benefits and Costs Manual (MBCM) together with the results of the analysis.

7.2 METHODOLOGY

This section sets out the methodology applied to estimate the value of each of the three WEBs. The methodology follows the specifications set out in the MBCM.

The required data is taken from a range of sources. Transport-related metrics are derived from the Auckland Forecasting Centre's (AFC's) macro strategic model (MSM) for the forecast years 2031 and 2051. Economic and demographic data is generally taken from Statistics New Zealand and New Zealand government sources. The precise sources for each of the required inputs are described within the methodology for each WEB below.

The WEBs are estimated for the five shortlisted options using the dynamic accessibility-based land use estimates. These land use estimates adjust the modified I11.6 DM land use scenario to account for the impacts of changes in accessibility on population and employment density associated with each option. WEBs are calculated as at the base year of 2021 (in 2021$). It is assumed that the first year in which benefits are accrued is 2032, corresponding to the year that the ALR scheme is assumed to open.

For three of the shortlisted options (LRT Dominion Road, MRT Sandringham Road and Hybrid), the WEBs are also estimated for a 'higher intensification land use' scenario which assumes higher intensification within the corridor. These scenarios are described in more detail in the 'Land use change' technical paper.

7.2.1 Agglomeration (productivity) benefits

Improvements in transport infrastructure reduce travel costs between employees and firms and therefore increase the effective economic density of an area.[2] The resulting agglomeration economies lead to firms experiencing productivity gains. These productivity gains can occur through several processes including:

1. business network effects such as greater business interactions, networking opportunities and the sharing of knowledge
2. more efficient labour markets
3. more efficient input and output markets.

As stated in the MBCM, the realisation of agglomeration benefits can only realistically be achieved in the context of large and complex transport infrastructure investments in major urban and industrial centres. The Project satisfies these conditions as it:

- passes through key urban and industrial centres and connects these centres with each other as well as with residential areas
- significantly alters the structure of the overall transport network and the transport choices available to employees.

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[2] See Kernohan and Rognlien (2011).

The MBCM (Section 3.10) describes seven steps (A to G) which should be followed in deriving agglomeration benefits. These are discussed in turn below.

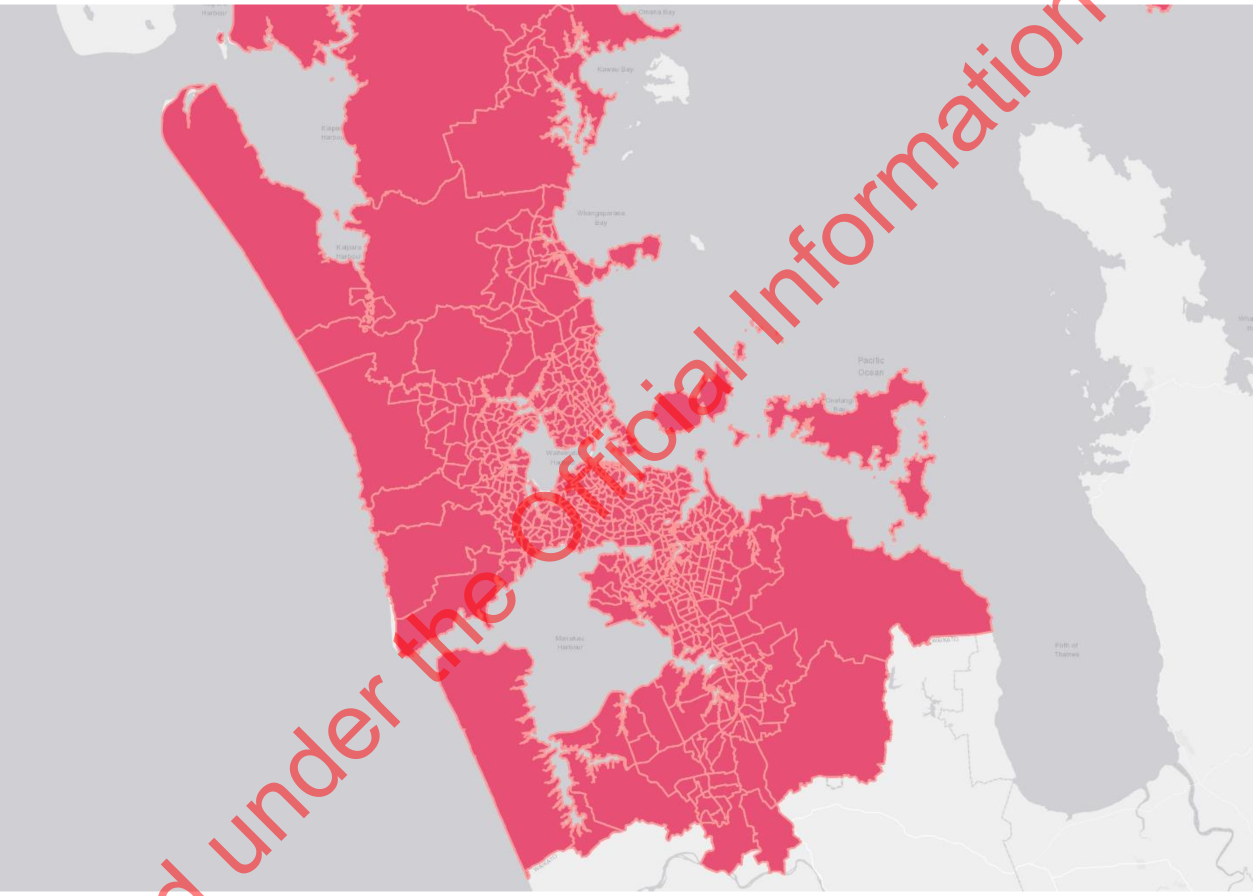
Step A: Define spatial zoning system

The spatial zoning system applied in the MSM separates the wider Auckland region into 596 zones. This satisfies the three criteria defined in the MBCM for a spatial zoning system:

1. the 596 MSM zones fully cover the Auckland region
2. with a total of 596 zones and an average of 2,796 residents (as at 2021) per zone, a high level of detail is achieved
3. detailed statistical data is available on employment at the zonal level, and output matrices can be extracted for each origin-destination (OD) zonal pairing.

Figure 7-1 displays the Auckland region broken down into MSM zones.

Figure 7-1: MSM zones



Source: *MSM*

Step B: Gather economic data

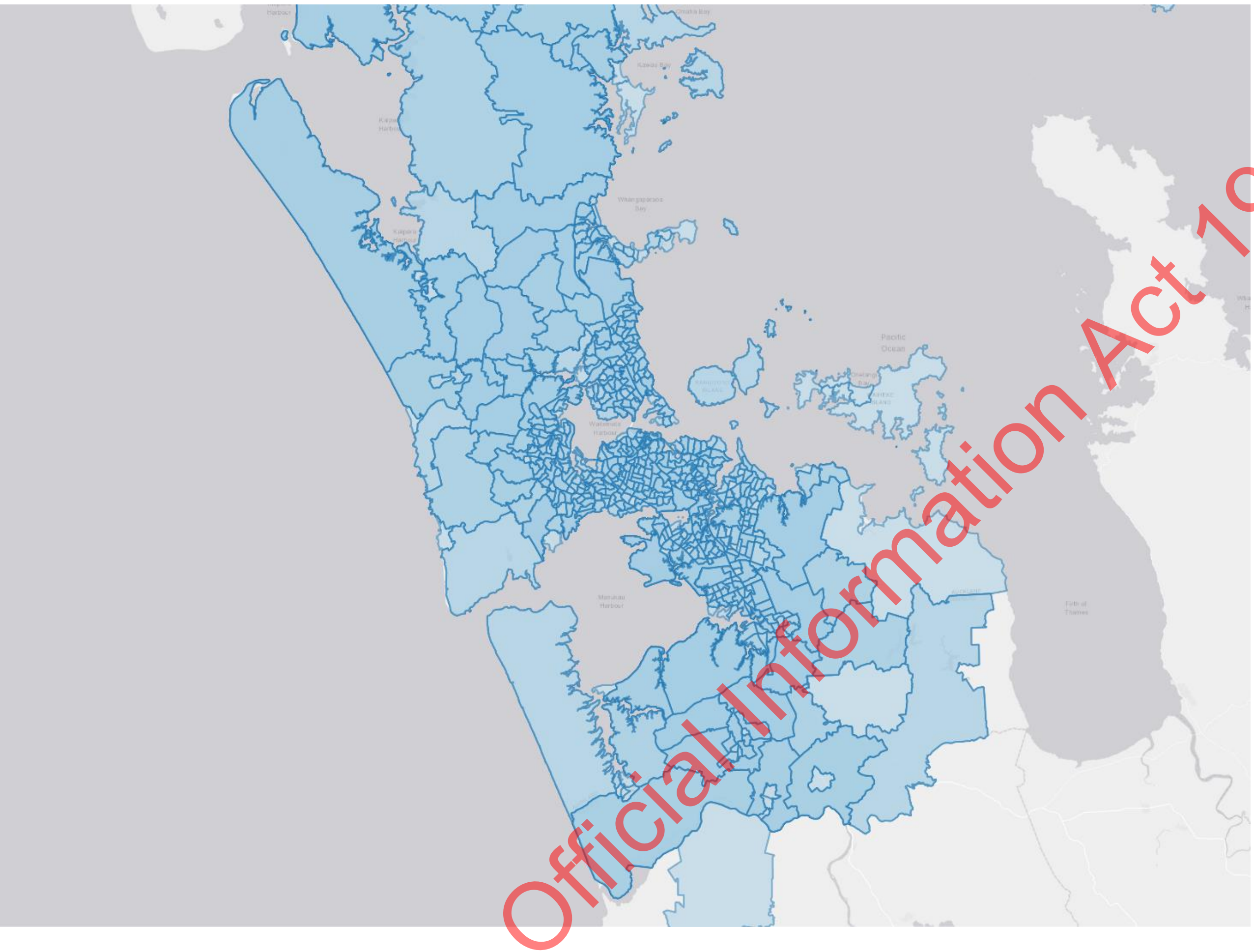
B1: Employment data

Employment data is available at the zonal level separately for the Do-Minimum (DM) and Do-Something (DS) scenarios for each of the forecast years (2031 and 2051). For the DM scenario, employment projections are based on the modified I11.6 scenario. For the DS scenario, adjusted employment projections are used as described in the technical paper on land use change.

B2: Economic output data

To derive the breakdown of employees by zone and sector, recent employment data is collected from Statistics New Zealand. Employment data is available by Australian and New Zealand Standard Industrial Classification (ANZSIC) sector and Statistical Area 2 (SA2) area unit level, using 2018 area boundaries. The geographic areas covered by the SA2 units are generally larger than the MSM zones. This is illustrated in Figure 7-2. There are 574 SA2 units that match to the 596 MSM zones.

Figure 7-2 SA2 zones



Source: *Statistics New Zealand*

Employment values at the SA2 unit level are therefore mapped to the relevant MSM zone using the proportion of overlap between areas as follows:

$$Emp_{i,x} = \sum_{SA2} \frac{AreaOverlap_{i,SA2}}{Area_{SA2}} \times Emp_{SA2,x}$$

Equation 1

where

- $Emp_{i,x}$ is the number of employees for MSM zone i and ANZSIC sector x
- $AreaOverlap_{i,SA2}$ is the amount of overlap (in metres squared) between MSM zone i and area $SA2$.
- $Area_{SA2}$ is the area (in metres squared) of area $SA2$
- $Emp_{SA2,x}$ is the number of employees for area $SA2$ and ANZSIC sector x.

B3: Agglomeration elasticities by zone

Agglomeration elasticities by ANZSIC sector are taken from Table 38 of the MBCM. A weighted agglomeration elasticity is estimated using the numbers of employees in each zone by ANZSIC sector x. This is calculated in Equation 2 as follows:

$$\varepsilon_i = \frac{\sum_x (\varepsilon_x \times Emp_{i,x})}{\sum_x Emp_{i,x}}$$

Equation 2

where

- ε_x is the agglomeration elasticity for ANZSIC sector x, sourced from Table 38 of the MBCM.

B4: Transport model outputs

Origin-destination (OD) matrices of demand and generalised cost (GC) are obtained from the MSM, which cover:

- two transport modes:
  1) public transport (PT)
  2) car
- two journey purposes:
  1) commute to/from work or “home-based work” (HBW)
  2) in-work or “employer business” (EB)
- the DM and the DS scenarios
- the 2031 and 2051 assessment years.

Consistent with the MBCM methodology, it is noted that:

- both of the main modes of transport (PT and car) are covered
- demand and cost matrices are estimated separately for each of the journey purposes.

There are a small number of OD pairs for which no valid GC is available. According to the AFC transport modelling team, this issue can arise, for example, when a GC for the PT mode is not available for an OD pair which is not served by PT. The GC in cases such as this is set to 9999.

However, the MSM may still generate a positive (albeit very small) demand for this OD pair. This is due to the logit formulation of the utility function used to estimate mode split. Including OD pairs such as this in the agglomeration benefits estimation may result in biased outputs because weight would be given to OD pairs with arbitrary cost values. In calculating effective job density (see step D), the AFC transport modelling team therefore exclude OD pairs with a GC greater than 4000. The same approach is applied when required throughout the WEB estimation methodology.

Step C: Calculate weighted average costs for in-work and travel to work across all modes

Average generalised cost (AGC) for each OD pair is calculated directly by the AFC modelling team according to the methodology set out in the MBCM:

$$AGC_{i,j}^{s,f} = \frac{\sum_{m,p} D_{i,j}^{*,m,p,f} \ GC_{i,j}^{s,m,p,f}}{\sum_{m,p} D_{i,j}^{*,m,p,f}}$$

Equation 3

where

- $AGC_{i,j}^{s,f}$ is the AGC for OD pair i, j and scenario s in forecast year f
- $D_{i,j}^{*,m,p,f}$ is the sum of the number of trips (demand) for OD pair i, j, scenario s, mode m and purpose p in forecast year f, sourced from MSM outputs
- $GC_{i,j}^{s,m,p,f}$ is the GC for OD pair i, j, scenario s, mode m and purpose p in forecast year f, sourced from MSM outputs.

The MSM produces separate demand and GC matrices for five time periods:

1. AM covering the period 7am to 9am
2. interpeak (IP) covering the period 9am to 3pm (for the PT mode, matrix values outputs are given on

a 2 hour basis)

3. school peak (SP) covering the period 3pm to 4pm
4. PM covering the period 4pm to 6pm
5. off peak (OP) covering the period 6pm to 7am.

The MBCM does not specify how the five time periods should be aggregated to derive an average GC that reflects an entire 24-hour period. The method applied by the AFC modelling team is to calculate AGC separately for each of the time periods, and then calculate a weighted average cost across all periods where the weights are based on the demand in each period. This approach helps ensure that the 24-hour AGC reflects the average travel time actually experienced by commuters. The calculation proceeds as follows:

$$24\ hour\ AGC = \frac{\mathrm{AGC}^{AM} \times \mathrm{D}^{AM} + \mathrm{AGC}^{IP} \times \mathrm{D}^{IP} + \mathrm{AGC}^{SP} \times \mathrm{D}^{SP} + \mathrm{AGC}^{PM} \times \mathrm{D}^{PM} + \mathrm{AGC}^{OP} \times \mathrm{D}^{OP}}{\mathrm{D}^{AM} + \mathrm{D}^{IP} + \mathrm{D}^{SP} + \mathrm{D}^{PM} + \mathrm{D}^{OP}}$$

Equation 4

Step D: Calculate effective job density by zones for each scenario

Effective job density (EJD) is calculated for each zone according to the methodology set out in the MBCM:

$$EJD_i^{s,f} = \sum_j \frac{Emp_j^{s,f}}{AGC_{i,j}^{s,f}}$$

Equation 5

where

- $EJD_i^{s,f}$ is the EJD for zone i and scenario s in forecast year f
- $Emp_j^{s,f}$ is number of employees for zone j and scenario s in forecast year f.

EJD is calculated directly by the AFC modelling team and provided as part of MSM outputs. Figure 7-5 displays the percentage changes in EJD over the DM by MSM transport zone, using the MRT Dominion Road option as an example.

Figure 7-3 **Percentage change in EJD for MRT Dominion Road option**

s 9(2)(i)

[redacted]

Step E: Calculate productivity gains by zone

Productivity gains are estimated by zone according to the methodology set out in the MBCM, and is given by Equation 6 below:

$$\delta PR_i^f = \left(\frac{ED_i^{DS,f}}{ED_i^{DM,f}}\right)^{\varepsilon_i} - 1$$

Equation 6

where:

- δPR_i^f is the relative increase in productivity between the DM and DS scenarios for zone i in forecast year f
- $ED_i^{DS,f}$ is the effective density of employment for zone i and the DS scenario in forecast year f
- $ED_i^{DM,f}$ is the effective density of employment for zone i and the DM scenario in forecast year f.

The absolute increase in productivity is then estimated at the zonal level by multiplying the relative increase in productivity by the gross domestic product (GDP) of that zone:

$$dPR_i^f = \delta PR_i^f \times GDP_i^f$$

Equation 7

where:

- dPR_i^f is the dollar increase in productivity for zone i in forecast year f
- GDP_i^f is the estimated GDP for zone i in forecast year f, as described below.

An estimate of GDP is obtained by disaggregating Auckland regional GDP in proportion to zonal employment as given in Equation 8:

$$GDP_i^{s,f} = \frac{Emp_i^{s,f}}{\sum_i Emp_i^{s,f}} \times GDP\ Auckland^f$$

Equation 8

where

- $GDP_i^{s,f}$ is the GDP for zone i, scenario s in forecast year f
- $Emp_i^{s,f}$ is the number of employees for zone i , scenario s and in forecast year f
- $GDP\ Auckland^f$ is Auckland regional GDP in forecast year f.

Annual GDP to 2021 for New Zealand and to 2020 for the Auckland region were sourced from Statistics New Zealand. Auckland GDP for 2021 is estimated by applying the actual New Zealand GDP growth rate for 2021 to Auckland's 2020 GDP.[3] For the years 2022 to 2025, Auckland GDP is projected using the real GDP growth rate forecast by the New Zealand Treasury (Treasury). After 2025, a constant real GDP growth rate of 2% is assumed. This is consistent with the base GDP growth rate generally assumed for developed countries in long-term economic models.

Step F: Sum output increases across all zones in the study area

The absolute increases in GDP are then summed across all zones (i) for forecast year (f) as follows:

$$Aggl^f = \sum_i dPR_i^f$$

Equation 9

The resulting output represents the dollar value resulting from agglomeration impacts for forecast year f.

Step G: Profiling and calculation of net present values

Interpolation of the agglomeration benefits between the base year and the assessment years (2031 and 2051) is done using linear interpolation. Agglomeration benefits are assumed to start in 2031. The benefits are extrapolated from the last assessment year (2051) until the last year of the evaluation period (2081) by assuming that all variables remain constant except GDP growth, which is assumed to increase at the annual real GDP growth rate described under Step B2 above. Total agglomeration benefits are derived by discounting the annual benefits to the base year (2021) and summing to obtain the NPV. The same approach is used to calculate net present value for the labour supply WEB.[4]

7.2.2 Increased labour supply

The wider economic impact of increased labour supply arises when reduced costs of travelling to and from work lead to an increase in total labour hours and a higher tax take. Individuals make work decisions by trading off the marginal costs and marginal benefits of working. A transport infrastructure project which reduces the commute time for workers is likely to reduce the perceived costs of working and therefore increase the labour supply. This is because:

1) more people are induced to join the labour force
2) workers already in the labour force work longer as they spend less time commuting.

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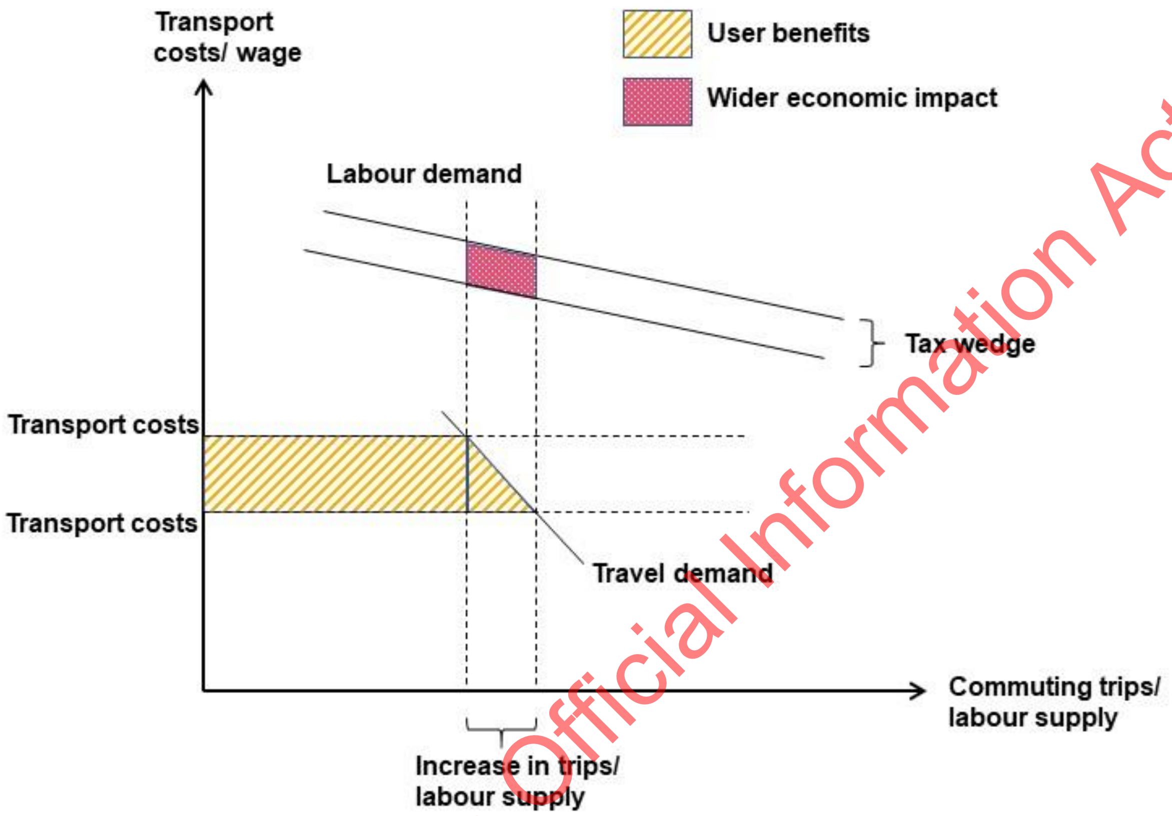
[3] Auckland GDP has been steady at about 38% of NZ GDP over the last 6 years so it is assumed this trend will continue.

[4] For consistency, for the labour supply WEB, earnings are also assumed to grow in real terms.

The direct welfare gains to workers from the above are already captured in conventional economic benefits. However, a wider economic benefit arises because the higher labour supply increases the tax take.

Figure 7-4 illustrates this. The pink shaded area represents the tax wedge resulting from increased labour supply, or the labour supply WEB.

Figure 7-4 Wider economic impacts from increases in labour supply



Source: *Adapted from Kernohan and Rognlien (2011)*

The methodology applied to estimate benefits resulting from increased labour supply follows that defined in the MBCM under Section 3.11.

Step 1: Calculate commuting costs

The first step estimates the change in the dollar value of round-trip commuting costs for workers living in each zone between the DM and DS scenarios.

The MSM produces matrices showing GC of travel by OD pair, mode of transport and trip purpose. These GCs are provided in minutes and incorporate travel-related costs including:

- travel time
- waiting time
- fares (for the PT mode)
- vehicle operating costs (for the car mode).

For the purposes of calculating increased labour supply benefits, only the HBW trip purpose is required, as this represents the trips between home and work. The relevant modes of transport are car and PT.

Because the commuting costs are required in dollar terms for the purposes of deriving the increased labour supply impact, the relevant time-based GCs are converted to dollar values by applying the values of time provided in Table 15 of the MBCM as follows:

$$g_{i,j}^{s,m,HBW,f,t} = GC_{i,j}^{s,m,HBW,f,t} \times TV$$

Equation 10

where:

- $g_{i,j}^{s,m,HBW,f,t}$ is the dollar cost per trip for OD pair i,j mode m, the HBW trip purpose and scenario s in forecast year f and time period t
- $GC_{i,j}^{s,m,HBW,f,t}$ is the GC (in minutes) for OD pair i,j mode m, the HBW purpose and scenario s in forecast year f and time period t, sourced from MSM outputs
- TV is the dollar value of time provided in Table 15 of the MBCM for the commute to/from work trip purpose. The $7.80/h July 2002 value is adjusted to 2020 using update factors provided in the MBCM and converted to $/min. This increased by a further 1.5% (representing the real GDP per capita growth rate) to obtain the value for 2021.[5]

The HBW purpose does not differentiate between trips from home to work and trips from work to home. The round-trip commuting cost for the average commuter in a given zone is determined by first assuming that home-to-work trips occur primarily during the AM peak and that work-to-home trips occur primarily during the PM peak. The round-trip "peak-time" GC from zone i to zone j is obtained by adding the AM dollar cost per trip from i to j to the PM dollar cost per trip from j to i:

$$gPeak_{i,j}^{s,m,HBW,f} = g_{i,j}^{s,f,m,HBW,AM} + g_{j,i}^{s,f,m,HBW,PM}$$

Equation 11

where:

- $gPeak_{i,j}^{s,m,HBW,f}$ is the round-trip "peak-time" dollar cost per trip between zone i and zone j for the HBW purpose and scenario s in forecast year f
- $g_{i,j}^{s,f,m,HBW,AM}$ is the dollar cost per trip from zone i to zone j for scenario s, mode m and the HBW purpose in forecast year f during the AM period sourced from MSM outputs
- $g_{j,i}^{s,f,m,HBW,PM}$ is the dollar cost per trip from zone j to zone i for scenario s, mode m and the HBW purpose in forecast year f during the PM period sourced from MSM outputs.

Consistent with the methodology followed to estimate agglomeration benefits, OD pairs with a GC greater than 4000 are excluded.

The above peak period commuting cost is likely to overestimate the actual cost for the average commuter, because not all commuters travel during the peak period. The peak period cost is adjusted to take into account the lower cost in non-peak periods and the number of commuters commuting in the non-peak periods as follows:

$$G_{i,j}^{s,m,HBW,f} = gPeak_{i,j}^{s,m,HBW,f} \times \sum_{t} (CF_{i,j}^{s,m,HBW,f,t} \times Prop^{s,m,HBW,f,t})$$

Equation 12

where:

- $G_{i,j}^{s,m,HBW,f}$ is the average dollar round-trip commuting cost for a commuter living in zone i and working in zone j for scenario s, model m and the HBW purpose in forecast year f
- $CF_{i,j}^{s,m,HBW,f,t}$ is a cost factor which measures the average commuting cost from i to j in each of the non-peak periods relative to the peak period for scenario s, mode m and the HBW purpose in forecast year f
- $Prop^{s,m,HBW,f,t}$ is the proportion of total HBW trips that are assumed to occur in time period t for scenario s, model m and the HBW purpose in forecast year f.

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[5] The Benefit update factor of 1.57 is obtained from https://www.nzta.govt.nz/assets/resources/monetised-benefits-and-costs-manual/update-factors.pdf.

For the AM and PM periods, the cost factor is set equal to 1. For the IP, SP and OP periods, the cost factor is calculated by dividing the GC of travelling from zone i to zone j during that time period by the peak-time cost:

$$CF_{i,j}^{s,m,HBW,f,t} = \frac{2 \times GC_{i,j}^{s,m,HBW,f,t}}{gPeak_{i,j}^{s,m,HBW,f}}$$

Equation 13

The proportion of commuters in each time period is calculated at the global level as follows:

$$Prop^{s,m,HBW,f,t} = \frac{D^{s,m,HBW,f,t}}{\sum_t D^{s,m,HBW,f,t}}$$

Equation 14

where:

- $D^{s,m,HBW,f,t}$ is the demand (number of trips) for scenario s, mode m and the HBW purpose in forecast year f and time period t.

This then allows the total annual commuting cost savings to be calculated by multiplying the change in the average round-trip cost by the number of commuters in each origin zone and taking the sum across both modes and all destination zones:

$$dG_i^f = \sum_{j,m} W_{i,j}^{DS,m,HBW,f} \times \left(G_{i,j}^{DM,m,HBW,f} - G_{i,j}^{DS,m,HBW,f}\right) \times Annualisation\ factor$$

Equation 15

where:

- dG_i^f is the total annual commuting cost savings between the DS and DM scenarios in forecast year f for commuters living in zone i
- $W_{i,j}^{DS,m,HBW,f}$ is the number of commuters living in zone i and working in zone j for the DS scenario, mode m and the HBW purpose in forecast year f, calculated as described below
- The annualisation factor is set equal to 250.

To determine the number of commuters living in zone i and working in zone j, the number of commuters during the peak AM and PM period is first derived. Similar to the calculation for the peak-time round-trip commuting cost (above), this assumes that home-to-work trips occur primarily during the AM peak and that work-to-home trips occur primarily during the PM peak:

$$WPeak_{i,j}^{DS,m,HBW,f} = \frac{D_{i,j}^{DS,m,HBW,f,AM} + D_{j,i}^{DS,m,HBW,f,PM}}{2}$$

Equation 16

where:

- $D_{i,j}^{DS,m,HBW,f,AM}$ is the demand (number of person trips) from zone i to zone j for the DS scenario, mode m and the HBW purpose in forecast year f during the AM period sourced from MSM outputs
- $D_{j,i}^{DS,m,HBW,f,PM}$ is the demand (number of person trips) from zone j to zone i for the DS scenario, mode m and the HBW purpose in forecast year f during the PM period sourced from MSM outputs.

Finally, the total number of commuters living in zone i and working in zone j is determined by scaling the peak-time commuters up to take into account the non-peak commuters. To do this, the sum of the non-peak proportions obtained in Equation 14 are used as follows:

$$W_{i,j}^{DS,m,HBW,f} = \frac{WPeak_{i,j}^{DS,m,HBW,f}}{1 - \left(Prop^{DS,m,HBW,f,IP} + Prop^{DS,m,HBW,f,SP} + Prop^{DS,m,HBW,f,OP}\right)}$$

Equation 17

Step 2: Labour supply response

Following the specifications set out in the MBCM, the labour supply response is calculated as follows:

$$dE_i^f = \varepsilon^{ls} \frac{1}{y_i^f(1-\tau_i)} dG_i^f$$

Equation 18

where:

- dE_i^f is the estimated labour response (in dollars) in forecast year f
- ε^{ls} is the elasticity of labour supply with respect to effective (real) wages
- y_i^f is the gross median residence-based earnings for zone i in forecast year f
- τ_i is the tax parameter to convert gross earnings to net.

To derive gross earnings by zone, earnings data disaggregated at the SA2 level is collected from Statistics New Zealand for 2018. This is then converted to the MSM zone level by calculating the weighted average median earnings using the spatial overlap between each MSM zone and SA2 as the weights:

$$y_i = \sum_{SA2} \frac{AreaOverlap_{i,SA2}}{Area_i} \times y_{SA2}$$

Equation 19

where:

- y_i is the gross median residence-based earnings for MSM zone i
- y_{SA2} is the gross median residence-based earnings for area $SA2$
- $AreaOverlap_{i,SA2}$ is the amount of overlap (in metres squared) between MSM zone i and area $SA2$
- $Area_i$ is the area (in metres squared) of MSM zone i.

The gross median earnings are adjusted to 2021 using the growth rate in wages for Auckland sourced from Stats NZ. From 2021 onwards, earnings are assumed to grow at the average real wage growth rate between 2018 and 2021.

A value of 0.4 is applied for the elasticity of labour supply with respect to effective wages. This reflects the value that is recommended for this parameter by Kernohan and Rognlien (2011). An estimate of 32% for the tax parameter to convert gross earnings to net is obtained from the same report.

Step 3: Gross Labour supply impact

The labour supply response is calculated as follows:

$$Labour\ supply\ impact^f = \sum_i dE_i^f \eta m_i^f$$

Equation 20

where:

- η is the productivity of marginal labour market entrants relative to the average
- m_i^f is the gross mean GDP per worker in zone i in forecast year f.

A value of 81% is applied for the productivity of marginal labour market entrants relative to the average. This is based on the 19% productivity differential for new employees which is recommended by Kernohan and Rognlien (2011). GDP per worker at the zonal level is obtained by dividing total GDP for a given zone by the number of employees in that zone.

Step 4: Net labour supply impact

The dollar value for the impact of increased labour supply is then derived by estimating the proportion of the labour supply response taken in taxation as follows:

$$WEB\ from\ increased\ labour\ supply^{f} = Labour\ supply\ impact^{f} \times t^{ls}$$

Equation 21

where:

- t^{ls} is the tax take on the increased labour supply.

A value of 26% is adopted for the value of this parameter, as recommended by Kernohan and Rognlien (2011). Table 7-3 summarises the values of the parameters that are applied.

Table 7-3 Labour supply input parameter values

Input parameter	Value*
Tax parameter to convert gross earnings to net ($\boldsymbol{\tau_i}$)	32%
The elasticity of labour participation with respect to wages ($\boldsymbol{\varepsilon^{ls}}$)	0.4
The tax takes on increased labour supply ($\boldsymbol{t^{ls}}$)	26%
Productivity of marginal labour market entrants relative to the average (η)	81%

* as recommended by Kernohan and Rognlien (2011)

Source: *Kernohan and Rognlien (2011)*

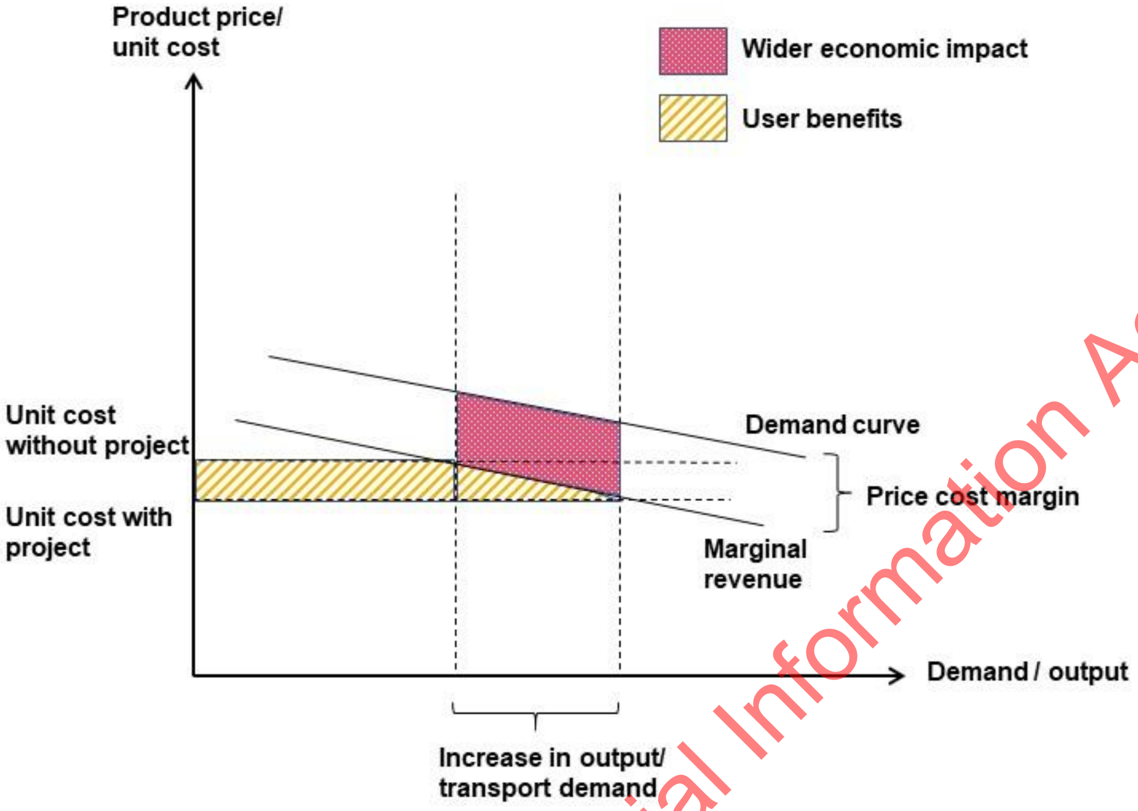
7.2.3 Imperfect competition

If an investment in transport infrastructure causes output to rise in industries with price cost margins, then this gives rise to a wider economic impact from imperfect competition.

Conventional economic cost-benefit-analysis assumes that industries operate under perfect competition. This means that if transport infrastructure investments reduce transport costs, then the value of these travel time savings are treated as a saving in gross labour cost. However, if there is imperfect competition, travel time savings result in an additional benefit proportional to the margin between output prices and the costs to produce the output.

Figure 7-5 illustrates this. The pink shaded area on the diagram represents the additional benefit from transport cost savings when price cost margins exist in an industry. This represents the imperfect competition WEB.

Figure 7-5 Wider economic impacts from imperfect competition



Source: *Adapted from Kernohan and Rognlien (2011)*

The methodology applied to estimate benefits resulting from the impact of imperfect competition follows the specifications defined in the MBCM under section 3.12.

The imperfect competition impact is calculated as follows:

$$Imperfect\ competition\ impact_f = \tau \times Business\ user\ benefits_f$$

Equation 22

and:

$$Imperfect\ competition\ impact = \sum_f Imperfect\ competition\ impact_f$$

Equation 23

where:

- $Business\ user\ benefits_f$ are total conventional business user benefits from travel time and vehicle operating cost savings in forecast year f
- τ is the imperfect competition uplift factor, specified as having a value of 10.7% in the MBCM.

To ensure consistency, annual user benefits from travel time and vehicle operating cost savings are taken directly from the conventional economic benefits analysis. Total benefits from imperfect competition are derived by discounting the annual benefits to the base year and summing to obtain the NPV. In deriving the benefits, only EB (employer business) trips are included.

7.3 Results

7.3.1 Accessibility-based land use scenario

Table 7-4 and Table 7-5 display the total discounted value of the WEBs for each of the options, using the accessibility-based land use scenario and discount rates of 4% and 6% respectively. The total present value of the WEBs using a 4% discount rate ranges between $3.7b (LRT Dominion Road) and $6.6b (MRT Sandringham Road) across the five shortlisted options. Using a 6% discount rate, the value ranges between $2.0b and $3.7b.

The WEBs are substantially higher for the light metro options relative to the light rail options, driven by the much higher agglomeration benefit. Agglomeration is by far the largest WEB, comprising about 90% of the total value of the WEBs.

Table 7-4 WEBs summary (2021$, 4% discount rate, accessibility-based land use)

Option	Agglomeration ($m)	Labour supply ($m)	Imperfect competition ($m)	Total WEBs ($m)
LRT Sandringham Road (Option 1A)	s 9(2)(i) [redacted]	[redacted]	[redacted]	**4,287**
LRT Dominion Road (Option 1B)	[redacted]	[redacted]	[redacted]	**3,685**
MRT Sandringham Road (Option 2A)	[redacted]	[redacted]	[redacted]	**6,626**
MRT Dominion Road (Option 2B)	[redacted]	[redacted]	[redacted]	**6,475**
Light Rail Hybrid (Option 3)	[redacted]	[redacted]	[redacted]	**5,862**

Source: *AC rating database, MSM, PwC analysis*

Table 7-5 WEBs summary (2021$, 6% discount rate, accessibility-based land use

Option	Agglomeration ($m)	Labour supply ($m)	Imperfect competition ($m)	Total WEBs ($m)
LRT Sandringham Road (Option 1A)	s 9(2)(i) [redacted]	[redacted]	[redacted]	**2,345**
LRT Dominion Road (Option 1B)	[redacted]	[redacted]	[redacted]	**2,018**
MRT Sandringham Road (Option 2A)	[redacted]	[redacted]	[redacted]	**3,656**
MRT Dominion Road (Option 2B)	[redacted]	[redacted]	[redacted]	**3,576**
Light Rail Hybrid (Option 3)	[redacted]	[redacted]	[redacted]	**3,226**

Source: *AC rating database, MSM, PwC analysis*

Figure 7-6 and Figure 7-7 display the annual undiscounted and discounted value of the WEBs respectively over time in real dollars. As shown in

Figure 7-6, the annual value increases strongly from 2032 as the project is operational (per the modelling assumptions) and the response in land use is realised. After 2051, the rate of increase slows as all factors except GDP are assumed to remain at their 2051 levels.

Figure 7-6 Undiscounted annual total WEBs in real dollars (2021$, accessibility-based land use)

s 9(2)(i)

[redacted]

Source: AC rating database, MSM, PwC analysis

Figure 7-7 Discounted annual total WEBs in real dollars (2021$, 4% discount rate, accessibility-based land use)

s 9(2)(i)

[redacted]

Source: AC rating database, MSM, PwC analysis

7.3.2 Higher intensification land use scenario

This section repeats the WEBs analysis for three of the shortlisted options but applies the higher intensification land use scenario. This scenario assumes substantially higher intensification in the corridor. A breakdown of the estimated WEBs using the higher intensification land use scenario is shown in Table 7-6 and Table 7-7 (using a 4% and a 6% discount rate respectively).

Under this scenario, the total WEBs are slightly higher for the LRT Dominion Road and MRT Sandringham Road options relative to the accessibility-based land use scenario. They are slightly lower for the Hybrid option.

Table 7-6 WEBs summary (2021$, 4% discount rate, higher intensification land use)

Option	Agglomeration ($m)	Labour supply ($m)	Imperfect competition ($m)	Total WEBs ($m)
LRT Dominion Road (Option 1B)	s 9(2)(i) [redacted]	[redacted]	[redacted]	**3,989**
MRT Sandringham Road (Option 2A)	[redacted]	[redacted]	[redacted]	**6,988**
Light Rail Hybrid (Option 3)	[redacted]	[redacted]	[redacted]	**5,760**

Source: *AC rating database, MSM, PwC analysis*

Table 7-7 WEBs summary (2021$, 6% discount rate, higher intensification land use)

Option	Agglomeration ($m)	Labour supply ($m)	Imperfect competition ($m)	Total WEBs ($m)
LRT Dominion Road (Option 1B)	s 9(2)(i) [redacted]	[redacted]	[redacted]	**2,176**
MRT Sandringham Road (Option 2A)	[redacted]	[redacted]	[redacted]	**3,848**
Light Rail Hybrid (Option 3)	[redacted]	[redacted]	[redacted]	**3,176**

Source: *AC rating database, MSM, PwC analysis*

7.4 REFERENCES

Kernohan, D and L Rognlien (2011) Wider economic impacts of transport investments in New Zealand. NZ Transport Agency research report 448. 128pp.

Waka Kotahi NZ Transport Agency. (2020, August 13). Monetised benefits and costs manual. Retrieved from https://www.nzta.govt.nz/resources/monetised-benefits-and-costs-manual/

8 COSTS

8.1 Capital cost

Costs have been provided by the Turner and Townsend team for each option. Estimates have been carried out by option based on activity / components of the project.

Table 8-1: Costed elements

Project Life	
DLR_1025	Total Client and Delivery Entity Costs
Pre Construction	
DLR_2830	Total Core Professional Services Costs (60%)
DLR_2840	Total Peripheral Professional Services Costs (60%)
Property	
DLR_2730	Total Core Property Costs
DLR_2740	Total Peripheral Property Costs
Construction	
DLR_2790	Total Core Professional Services Costs (40%)
DLR_2800	Total Core Construction Costs
DLR_2810	Total Peripheral Construction Costs
DLR_2820	Total Peripheral Professional Services Costs (40%)
Rollingstock	
DLR_2780	Rollingstock - Cost Distribution

Table 8-2 sets out the capital send by option for each year.

Table 8-2: Capital spend by option

s 9(2)(i)

[redacted]

8.2 Operational costs

Opex and maintenance cost has been estimated by Mode on a per annum basis. OPEX cashflow by option is provided below. The OPEX includes operations & maintenance, lifecycle costs, rolling Stock Fleet - end of Life Replacement, rolling Stock Fleet - fleet expansion and bus operations costs. Table 8-3 sets out OPEX cashflows.

Table 8-3: Operational costs

s 9(2)(i)

[redacted]

s 9(2)(i)

9 BENEFIT COST RATIO

Benefit cost ratios for each long list option have been included in the Table 9-1. Benefit cost ratios for the short list options are outlined in Table 9-2. BCRs are shown to 2 decimal places to provide comparison between options.

Table 9-1: Long list options assessed

Option	LRT Sandringham	LRT Dominion	LM Sandringham	LM Dominion	Hybrid
Land Use	Low land use uptake	Low land use uptake	Low land use uptake	Low land use uptake	Low land use uptake
	Option 1A	**Option 1B**	**Option 2A**	**Option 2B**	**Option 3**
Traditional Benefits total	$3695M	$3332M	$6011M	$5971M	$4762M
Wider Economic Total	$4287M	$3685M	$6626M	$6474M	$5861M
NPV costs	$7197M	$7141M	$11196M	$12001M	$10362M
BCR without WEBS	0.51	0.47	0.54	0.50	0.46
BCR with WEBS	1.11	0.98	1.13	1.04	1.03

Table 9-2: Short list option assessment

Option	LRT Dominion	LM Sandringham	Hybrid
Land Use	High land use uptake	High land use uptake	High land use uptake
	Option 1B	**Option 2A**	**Option 3**
Traditional Benefits total	$4062M	$6954M	$5916M
Wider Economic Total	$3989M	$6988M	$5760M
NPV costs	$7141M	$11196M	$10362M
BCR without WEBS	0.57	0.62	0.57
BCR with WEBS	1.13	1.25	1.13

10 CHANGES TO DEVELOPMENT COSTS - URBAN DEVELOPMENT

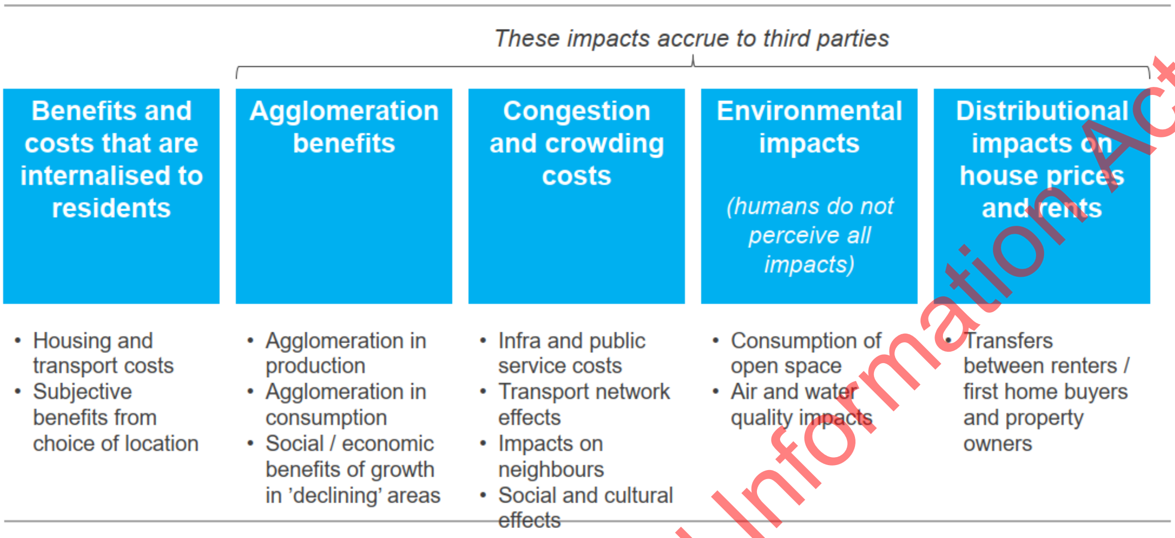
The ALR project will enable an increase in Urban Development along the corridor, focused around stations. This increase in development potential has a series of impacts (costs and benefits) which can be considered.

Figure 10-1 sets out a framework for the assessment of benefits and costs. From an economic standpoint, third party benefits are relevant from an economic perspective. Many of the identified benefits are captured through the traditional MCBM methods. One particular area which is not captured by MCBM methods is the relative reduced cost of development in this study area compared with development in an alternative location.

This project provides additional development potential in the Mangere and central isthmus brownfield areas. It is likely increased development potential in these areas will prolong/remove the need for new development areas to be provided to cater for housing demand. There is evidence suggesting development in a brownfield area such as Mangere and the central isthmus is significantly cheaper in infrastructure service costs compared with development of a greenfield area.

From an economic perspective this efficiency in infrastructure is an important benefit of the ALR project.

Figure 10-1: A Framework for urban development beneifts and costs (Source: Peter Nunns: Costs and benefits of urban development)



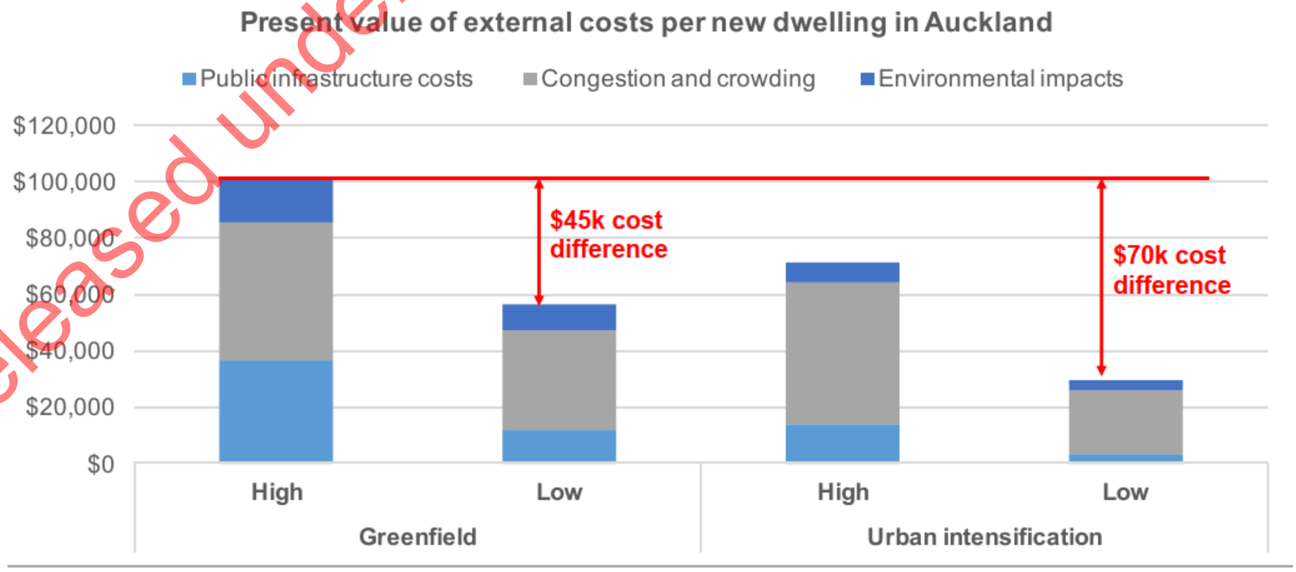
These impacts accrue to third parties

Benefits and costs that are internalised to residents	Agglomeration benefits	Congestion and crowding costs	Environmental impacts *(humans do not perceive all impacts)*	Distributional impacts on house prices and rents
• Housing and transport costs • Subjective benefits from choice of location	• Agglomeration in production • Agglomeration in consumption • Social / economic benefits of growth in 'declining' areas	• Infra and public service costs • Transport network effects • Impacts on neighbours • Social and cultural effects	• Consumption of open space • Air and water quality impacts	• Transfers between renters / first home buyers and property owners

While infrastructure costs tend to have high levels of variation depending on site specific conditions, there is body evidence which suggests development in Greenfield areas is more costly than within already built-up areas such as the brownfield areas around the ALR project. This difference in infrastructure cost is not captured through traditional transport economics but is considered a key benefit to the ALR project.

In 2016, Nunns and Deane found that external costs of development tend to be lower for urban intensification than for greenfield development, but there are likely to be exceptions to this pattern. The graph below shows the estimated ranges of cost for development of Greenfield areas vs brownfields. The cost presented in the graph are in present value.

Figure 10-2: Estimated range of cost of development per household



Source: Nunns and Denne (2016). External cost estimates have been derived using a mix of methods.

From a purely transport perspective, the cost of transport infrastructure to support growth is available in recent assessments undertaken by Auckland Transport and Waka Kotahi as summarised in the table below:

Study	Details of assessment	Change in Households 2018 – 2048+	Cost of upgrades	$ per additional house
Brownfield's growth areas	The AT Brownfields Business case (2021) considers 5 growth areas within the existing urban area and identifies the transport network required to cater for growth	30,000	$1.3 (includes some projects from other programmes within each area)	+-$43k per household
South area – Greenfield's development	The supporting growth Indicative Business (2019) case calculated the cost of the transport network required to cater for the expected growth of the Future Urban area in south Auckland.	52,000	$7.0B	+- $134k per household

Recent work suggests a large difference in transport infrastructure cost exists between growth in the Brownfield areas vs greenfield development. It is likely other infrastructure costs follow a similar trend. The Auckland Council FULSS document provides an indication as to the proportion of total development cost related to transport. Transport is assumed to contribute around 55% of total development cost for greenfield areas. Other costs include water infrastructure, parks and community facilities. While the dust has not settled as to how much of this difference will cost the economy, the difference is likely to remain significant.

The ALR project enables more development to occur in Brownfields sites, and as such is considered to reduce future infrastructure costs. The PWC land use tests consider induced land use of between 5,000 – 35,000 additional dwellings within the catchment of the ALR project. If savings as per the table above were applied to this range for all infrastructure, it is expected this could lead to a reduction / deferral in infrastructure costs as set out in the table below.

Table 10-1: Changes in infrastructure cost between Brownfields and Greenfields

Change in households as a result of ALR	Transport infrastructure cost saving
5,000 dwellings	$0.5B
20,000 dwelling	$1.8B
35,000 dwellings	$3.2B

The costs outlined in the table above have been considered within the sensitivity testing for the recommended option. A reduction in cost has been assumed according to the table above in the 2051 year with the cost then incurred 20 years later in 2071. This effectively assumes a 20-year deferral of cost as a result of deferring greenfield growth in favour of increase Brownfield Growth as a result of this project. A reduction in overall NPV cost is credited to the project as a result of this deferral.

11 SENSITIVITY TESTING

Sensitivity testing has been undertaken on Option 3 only. The following tests have been assessed:

- Low land use test – assumed uplift in density does not occur
- Different do min – The assumed land use change occurs regardless of the project
- 3 % discount rate – both benefits and costs are discounted with a 3% discount rate
- 5 % discount rate - both benefits and costs are discounted with a 5% discount rate
- Increased cost by 20% - Capital cost and opex increases by 20%
- Benefits increase by 20%
- Slower benefits ramp up – 2031 benefits are achieved over a 5 year ramp up period instead of 2 years as assumed in the base
- Reduced cost of urban development – Savings are achieved through deferral of Greenfield growth costs as a result of the project.
- An increase in the value of CO2 reduction as per high value as outlined in UK valuing gas emissions in policy appraisal paper[6]
- A test applying the rule of a half to all of the PT user benefits and traffic benefits

The results of sensitivity testing are set out in Table 11-1. The sensitivity testing shows a variance in BCR between 0.9 - 1.2 including WEBS and 0.5 - 0.7 excluding WEBS.

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[6] https://www.gov.uk/government/publications/valuing-greenhouse-gas-emissions-in-policy-appraisal

Table 11-1: Sensitivity testing

Option	Recommended option - Hybrid	Test - Low land use	Test - Different do min	Test - 3 % discount rate	Test - 5 % discount rate	Test - increased cost by 20%	Test - increase benefits by 20%	Slower benefits ramp up (5 years instead of 2)	Reduction in wider costs	Increase in Value of CO2 reductions	Rule of a half on all PT / Traffic benefits
Traditional Benefits total	$5916M	$4762M	$5409M	$8305M	$4301M	$5916M	$7099M	$5916M	$5916M	$6182M	$4927M
Wider Economic Total	$5760M	$5760M	$5760M	$5760M	$5760M	$5760M	$5760M	$5760M	$5760M	$5760M	$5760M
Benefits TOTAL	$11676M	$10522M	$11169M	$14065M	$10061M	$11676M	$12859M	$11676M	$11676M	$11942M	$10687M
NPV costs	$10362M	$10362M	$10362M	$11429M	$9488M	$12434M	$10362M	$10362M	$9826M	$10362M	$10362M
BCR without WEBS	0.6	0.5	0.5	0.7	0.5	0.5	0.7	0.6	0.6	0.6	0.5
BCR with WEBS	1.1	1.0	1.1	1.2	1.0	0.9	1.2	1.1	1.2	1.1	1.0