Benefits from Auckland road decongestion

NZIER report to the Employers and Manufacturers Association, Infrastructure New Zealand, Auckland International Airport Ltd, Ports of Auckland Ltd, National Road Carriers Association

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Key points

The benefits of decongestion to current capacity in Auckland would be between $0.9 billion and $1.3 billion (1% to 1.4% of Auckland's GDP)

These estimates represent the economic and social benefits to Auckland if the road transport network was operating **at its capacity** Monday to Friday i.e. as it is designed to. The estimates do not include the benefits of decongestion in the weekends. This level of decongestion could be achieved through investment in policy initiatives such as better traffic management technologies and smart pricing.

The range of estimates reflects different assumptions about how an easier commute would affect Auckland's labour supply. Research to date on the impact of congestion on labour supply is not definitive so we use lower and upper bounds to reflect this uncertainty. The literature suggests that there is a greater likelihood that the total benefits from decongestion are closer to the lower bound than the upper bound estimate. However, applying the New Zealand Treasury estimate of labour supply elasticity, the benefits of decongestion would be closer to $1.3 billion.

The benefits of decongestion to free-flow conditions are higher

If the average speed across the Auckland network was close or equal to the speed limit, which is also known as **free-flow**, we estimate the benefits of decongestion during weekdays at between $1.4 and $1.9 billion (between 1.5% and 2% of Auckland's GDP)[1].

This suggests the cost of congestion, relative to a network at free-flow, is up to double that calculated by previous studies (a figure of $1 billion is often quoted), although methodological differences mean direct comparisons should be treated with care.

Achieving this level of benefits from a free-flow situation would require further significant investment into expanding the Auckland road network beyond what is already planned.

Targeting free-flow speeds (i.e. the speed limit) would not be an optimal use of the Auckland network as it would mean an under-utilised network.

Our approach includes economic benefits, both direct and indirect through Auckland supply chains, as well as social benefits

The benefits of decongestion go well beyond their direct time-savings impact on freight and commuters. They also accrue to all businesses that use transport and employ workers who commute, and to households who waste their scarce time in traffic jams.

Our estimate of the benefits of decongestion includes these flow-on impacts across the economy, plus social benefits such as reduced carbon emissions. We thus extend previous research which estimated only the direct benefits from decongestion. However, we have not attempted to quantify the overall liveability benefits of decongestion in Auckland, or wider economic benefits including improved accessibility allowing more choice for business locations, and better skill matching for workers. Our modelling shows a boost to tourism-related activities through the benefits to tourists, but does not capture any increase in tourists from decongestion. To the extent one believes decongestion will lead

[1] Estimate of the costs of congestion are based on average speed differences across the network. The average speed at the morning (AM) peak was 41.2 km/hour in 2016. Estimated average speed if the network was operating at capacity and at free-flow are respectively 50.5 km/hour and 56.8 km/hour. Note that network average speeds cover the entire Auckland network including motorways, arterial and rural roads.

to an increase in tourist numbers, the benefits of decongestion to the tourism sector could be under-estimated. We have yet to uncover empirical evidence that explores this.

Congestion is a side-effect of success but past a certain threshold it impedes economic growth

The relationship between economic development and congestion is complex. An increase in economic activity generally leads to more congestion given increased transport needs. However, past a certain point the reduced accessibility that arises from congestion starts to impede growth.

Auckland's congestion is the flipside of its economic success, largely resulting from population growth. But economic growth from a rising population needs to be accommodated for, otherwise externality costs like congestion begin to hold the economy back.

Congestion in Auckland is well above comparable cities…

The latest annual Traffic Index from GPS navigation company TomTom shows Auckland is now the 47th worst city in the world in terms of traffic congestion. Auckland's congestion is above most cities with a similar population size (Perth, Brisbane, Adelaide) and is now comparable to much larger cities such as Melbourne and Sydney.

Auckland's recent rapid population growth has stretched the capacity of the network. For example, it now takes 67 minutes to drive from Papakura to the CBD in the morning, up from 46 minutes in 2013 (AA, 2016).

Congestion in Auckland has increased both at different times of the day and across more of the network, particularly during the Interpeak (the middle of the day between the morning and late afternoon peak) when most freight trips are made. This is spreading congestion across the day.

…and projected to get worse as the population keeps growing

Congestion is expected to worsen. Auckland Transport projects that more than a quarter of the arterial network will be congested by the end of this year – an increase from 18 percent at the end of 2014. And population growth will continue, meaning more vehicles will be on the road every day.

As congestion worsens over time, the benefits from decongestion identified in this report will obviously rise accordingly.

Auckland businesses are suffering from congestion

Congestion results in increased travel times for businesses, lifting their labour, fuel and insurance costs. Most firms do not believe they pass these higher costs onto customers.

Besides the financial costs, congestion also means a lower quality of service offered by businesses. This is often an implicit cost borne by customers. For example, congestion has seen businesses reduce the number of locations they deliver to, or pick up from.

Congestion is also contributing to a mismatch between the demand and the supply for labour. Some firms specifically choose to only hire staff in the areas they operate in, given the need for staff to respond to callouts quickly.

Decongestion would have economic and social benefits

The benefits from decongestion for Auckland can be broken down into economic benefits, which would raise GDP and living standards, and social benefits, which are not measured through GDP but some of which can be valued nonetheless e.g. a reduction in carbon emissions, the opportunity cost of time spent commuting. We estimate these benefits for the capacity and free-flow scenarios.

Each scenario has lower and upper bounds that relate to the labour supply assumptions used, given the uncertainty over how much labour supply would increase in response to lower commuting times.

The lower bound represents no labour supply expansion from shorter commuting times. The upper bound represents an expansion in the labour supply from shorter commuting times based on Treasury's labour supply elasticity estimate.[2]

Table 1 Summary of the benefits of decongestion

$ millions; 2016; Economic benefits are in real terms

Benefits	Capacity		Free-flow	
	Lower bound	Upper bound	Lower bound	Upper bound
Economic	$488	$842	$735	$1,266
Social	$439	$439	$658	$658
Total	**$927**	**$1,281**	**$1,392**	**$1,924**
% of Auckland GDP				
Economic	0.52%	0.90%	0.79%	1.35%
Social	0.47%	0.47%	0.70%	0.70%
Total	**0.99%**	**1.37%**	**1.49%**	**2.06%**

Source: NZIER

Decongestion would generate more jobs and higher incomes

We estimate that decongestion would create between 1,500 and 2,300 jobs for the 'at capacity' scenario. This is a result of the Auckland economy growing faster.

Workers would also become more productive. These productivity gains lead to an increase in 2016 GDP per capita of between $307 and $528 in real terms in the network at capacity scenario. Household consumption, a proxy for living standards, would increase by between $233 million and $382 million in the network at capacity scenario.

Decongestion would also improve Aucklanders' quality of life

Past a certain congestion threshold, overall liveability tends to decrease. Based on TomTom data, congestion in Auckland is about to reach that threshold.

Aucklanders are adjusting their behaviour to cope with increased congestion. But this comes at a cost. Congestion has reduced firms' and households' ability and willingness to travel within the Auckland region. An AA survey taken last year found:

2 Treasury estimates the labour supply elasticity to be 0.31 (Creedy and Mok, 2017).

- 87% of its Auckland members rated congestion as extremely heavy to heavy
- 80% consider that traffic congestion has worsened over the last five years
- Almost half of its Auckland members considered either moving house or changing jobs because of congestion
- 72% will be frustrated or extremely frustrated if congestion remains the same in five years' time.

And improve the growth prospects for many industries

Table 2 shows, the 'at capacity' scenario, and the value of potential output gains for selected industries.

Table 2 Headline economic benefits of decongestion by industry

2016; Nominal; Network at capacity; $ millions; selected industries

Industry	Lower bound	Upper bound
Manufacturing	$112	$206
Electricity, gas, water and waste services	$19	$31
Construction	$152	$210
Wholesale trade	$22	$37
Retail trade	$17	$25
Accommodation and food services	$12	$27
Transport, postal and warehousing	$7	$33
Information media and telecommunications	$26	$46
Financial and insurance services	$44	$76
Rental, hiring and real estate services	$55	$91
Professional, scientific and technical services	$67	$140

Source: NZIER

To the extent that decongestion improves the productivity of the construction industry, we would expect it to make a modest contribution to improving housing affordability as an additional downstream impact.

Furthermore, the impact of decongestion in Auckland would flow through the wider New Zealand economy, given many regions (particularly in the North Island) depend on the Auckland transport network to operate effectively.

There may be additional benefits from decongestion that we have not been able to estimate

Our range of estimates may be conservative due to:

- Data limitations on the spread of different travel types across the day and the value of time saved by different groups of Aucklanders
- Not including any potential benefits from decongestion at weekends
- Not modelling agglomeration and labour market matching benefits that might reasonably be expected to occur

- Leaving capital productivity unchanged in our model.

Future research may address these issues, but at this stage we suggest they represent upsides to the benefits we estimate here.

Achieving greater precision on the labour supply impacts of decongestion (both in terms of participation and productivity) will also be important for refining our estimates in the future. The existing literature is not definitive because different groups respond differently to congestion. Throwing greater light on this would require an analysis of income distribution in Auckland, travel to work times, location choice (where to live, where to buy a house), occupation and other factors to better understand how much labour supply would increase due to decongestion.

Cost-benefit analysis is now required to examine how to cost-effectively unlock the potential gains from decongestion

The state of congestion in Auckland, New Zealand's centre of economic gravity, is now well above that of comparable cities. Furthermore, congestion is projected to worsen.

The benefits estimated in this study should form the basis of investigating policy opportunities to reduce the burden of congestion on Auckland's economy. The opportunity cost, or the forgone opportunities, to the development of the city in a context of rising economic activity will continue to rise as congestion worsens.

The key question left unanswered – and beyond the scope of our report – is:

> *Are the benefits of decongestion in Auckland greater than the costs required to achieve it?*

We have modelled the benefits of a decongested Auckland road network, but it was out of scope to specify how this might be achieved or how much it would cost. A comprehensive cost-benefit analysis of specific policy options would be required to establish the *net* impact of decongestion on Auckland's economy and overall liveability.

Until then, Auckland – and New Zealand – continues to potentially forego the benefits from decongestion that we have estimated here.

Case study – Construction

The experience of a major construction company highlights the substantial impact of congestion on key sectors of the Auckland economy. The productivity factor on a route which traverses a key route along the Southern Motorway from Drury to the Ports of Auckland has dropped from 4.22 loads per day in 2014 to 3.56 loads per day in 2016. This reduction in productivity reflects the increased time required to travel the route.

Lower productivity has led the company to increase its transport fleet – at substantial cost – to maintain the same level of service to customers. A 21 percent reduction in average speed per trip over the past three years has led it to add 27 percent more trucks to its fleet. It plans to further expand its fleet to maintain the same level of service in anticipation of a further deterioration in congestion in the coming years.

Greater difficulty travelling across Auckland means the company has imposed restrictions on which areas it will operate in, with deliveries to Devonport ceasing three years ago while deliveries to the Auckland CBD were stopped more recently. The company has also imposed "out of area" charges to reflect the increased travelling times to some other areas. These charges act to push up construction prices in Auckland.

The restrictions on its operations and increased costs has had a negative impact on the company.

Case study – Commercial trade

A flooring company has seen the deterioration in congestion impact its staff. With around 20 contractors on the road on a typical day, its contractors now refuse to take any job 20km away from the city given the time it takes to travel there. Its in-house installers have seen an increase in working hours because of the extra time travelling, with a typical day now stretching from 5am to 4pm, compared to 7:30am to 3:30pm around five years ago.

The increased time travelling leads to extra labour, fuel and insurance costs, which they believe cannot pass onto customers because of the competitive environment in the sector. Although the firm's vehicles have GPS systems which makes it easier to track their workers which in turn makes it easier to update customers on the estimated time of arrival of their staff, explanations to customers that its staff is delayed by traffic often come across as clichéd.

Increased congestion has made the operating environment harder for the company in terms of increased costs and the reduced level of service it can offer customers, given the increased difficulty in travelling through Auckland.

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1. Introduction

Auckland's roads are increasingly congested. The latest annual Traffic Index from GPS navigation company TomTom shows Auckland now ranks 47th in the world in terms of traffic congestion. This data shows that when it comes to the extra time Auckland commuters are stuck in traffic, we are doing worse than Hong Kong (NZ Herald, 2017).

1.1. Scope of this report

This report estimates the benefits of reducing congestion in Auckland which should be weighed against the cost of reducing congestion depending on the policy or policies implemented, such as packages as identified by Auckland Transport Alignment Project (ATAP).

Our approach to estimating the benefits of decongestion goes beyond travel time savings, to one that accounts for wider benefits of decongestion. The true cost of congestion touches many sectors and areas of society. Congestion affects the competitiveness and liveability of Auckland, which in turn affects how New Zealand as a country can compete on the world stage.

We show how Auckland traffic congestion has far-reaching implications given the importance of roading transport in the supply chain, as well as the broad-based impacts of congestion on Auckland households.

1.2. Quantifying the downstream benefits of reducing congestion

Understanding the economic, social and environmental benefits of decongestion in Auckland involves looking at the downstream impacts of decongestion across the different sectors of the Auckland economy, based on productivity improvements to businesses and households.

ATAP (2016) has acknowledged that congestion in Auckland negatively impacts freight but that there is no estimate of this cost:

> *Congestion is an increasingly serious problem for freight movements in Auckland. Along with increasing travel time, travel unpredictability is also creating significant supply chain cost. There is currently limited understanding of the extent of this cost.*

Our work helps to address that gap.

Reducing congestion would provide productivity gains for businesses and households, starting directly with the transport sector. Freight movements have become increasingly compromised, both through delays in deliveries as well as unreliability over delivery times.

A more efficient freight sector will have positive flow-on effects for sectors that rely on freight to move goods and provide services. These sectors will also benefit from workers having more time available to work when roads are less congested. More workers may become available in the labour force as the costs of travelling to work fall.

Households will benefit through increased wages as the Auckland economy grows faster, and workers will be able to choose to spend at least a portion of their newly-found spare time with their families or on leisure activities.

Finally, other regions in New Zealand will benefit from a more efficient Auckland economy, as most regions have supply chain links to the Auckland economy in some shape or form.

We estimate these direct and downstream benefits of a decongested Auckland transport network using our regional Computable General Equilibrium (CGE) model. Our model is highly detailed, incorporating 106 industries and 201 commodities, as well as being able to examine the impacts of decongestion on households, the government and export sectors in Auckland and across New Zealand. We use our CGE model to show in detail how decongestion will affect different industries and households within Auckland and the ripple effects across the Auckland and New Zealand economies.

In addition to businesses and households working more effectively, there are also social benefits from decongestion such as environmental and liveability benefits.

1.3. Overall approach

Our approach has two main steps:

- Update to 2016 the only estimate of the direct cost (i.e. travel time savings) of congestion in Auckland for 2010 from Wallis and Lupton (2013)
- Apply this updated direct cost of congestion to our CGE model (which now become benefits to the economy if they are avoided) to estimate the downstream impact of congestion on the wider economy. This cost forms the estimate for the benefits of decongestion.

Our estimate of the benefits of decongestion captures the effects of productivity gains from a traffic network that is operating as intended, for the following groups of road users:

- Freight (heavy vehicles)
- Trades and postal services (light commercial vehicles)
- Commuters (light private vehicles)
- Business trips (light private vehicles)

These groups each have their own growth and demand drivers. Therefore, each group will be affected by congestion differently. Personal commuters make up the largest group of road users of the four, and freight the smallest in terms of numbers, but the effects of congestion on freight are far-reaching along supply chains.

This is particularly important given road's dominance in moving freight around New Zealand, with 91% of total tonnage and 70% of tonne-kilometres of freight moved on roads in 2012 (Ministry of Transport, 2014).

Finally, our estimates of the total benefits from decongestion consider the uncertainty around the response from Auckland commuters to shorter commute times. We explore two options:

- Lower bound – we assume no expansion in the labour supply from shorter commute times
- Upper bound – we use Treasury's labour supply elasticity estimate as an upper bound estimate of the labour force expansion from shorter commute times.

1.3.1. Comparison with previous studies

Our approach builds directly on Wallis and Lupton's approach and extends it by modelling the downstream impacts of congestion on Auckland's supply chains.

The costs of congestion in Auckland have been widely quoted as around $1 billion per annum. Wallis and Lupton (2013) explain that:

> *This figure is based primarily on a 1997 (Ernst & Young) study, which drew on analyses of the situation in 1991, with the figures adjusted and broadly updated for traffic growth and inflation.*

Further, they provide a detailed review of the approach taken by Ernst & Young (EY) and conclude that the study:

- *"is inadequately documented – the major component of the cost estimate, i.e. the $570 million pa figure derived from the ART model, is not accompanied by any information on the basis of its derivation making it difficult to form any judgement as to its validity and merits.*
- *is of dubious validity – the secondary component of the cost estimate, i.e. the $185 million pa relating to delays affecting the Auckland manufacturing and distribution sectors is based on 'rubbery' assumptions based survey results*
- *provides an estimate of the costs of congestion relative to free-flow conditions, which is of limited merits in policy terms*
- *is based on assessments relating to conditions some 20 years ago (e.g. ART model runs for the 1991 situation), and thus are increasingly outdated."*

Nonetheless, public opinion around the cost of congestion to Auckland (and hence the benefits of decongestion) is that it lies in the vicinity of $1 billion, based on the EY study. In comparing the $1 billion EY estimate to our estimate, a few important considerations need to be made:

- Our headline estimate of the benefits of decongestion is based on the Auckland network operating at capacity. Despite this significant methodological difference with the EY study, we find that the cost of congestion is close to $1 billion
- Our approach is similar to that of EY, but more robust. The EY study also incorporates downstream benefits rather than focusing solely on the direct cost of congestion (the value of travel time saved)

- However, as explained by Wallis and Lupton, EY's approach to estimating wider economic benefits is largely based on survey results. We take a CGE modelling approach which is widely recognised as a more comprehensive and robust approach (a full description of our CGE modelling approach is provided in Appendix D)
- The EY study does not account for the labour supply response to decongestion, emissions and scheduling costs.

We therefore believe our estimates of the benefits of decongestion in Auckland are the most robust, transparent and up-to-date available.

1.4. Defining congestion

One of the key challenges in quantifying the effects of congestion is defining what congestion is in the first place, as it means different things to different people.

We adopt the engineering measure of congestion in estimating the benefits of decongestion. This engineering measure defines congestion as the state at which demand for the road exceeds its capacity (Wallis and Lupton, 2013). An extensive discussion on the different ways congestion is defined is provided in Appendix B.

Wallis and Lupton (2013) explain that

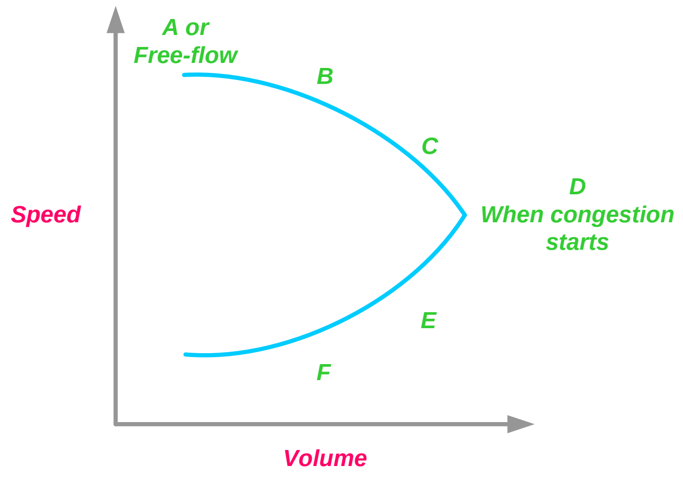
> *Although […] roads are not at 'capacity' until LoS E, in practice the maximum flow is at LoS D (Wallis and Lupton, 2013).*

Based on Wallis and Lupton (2013) we consider the Auckland network at capacity at LOS D because at LOS D the Auckland network is working at maximum sustainable flow (i.e. the relationship between speed and volume is optimised to achieve maximum throughput on the network). We define Level of Service D as the point at which congestion starts.

Figure 1 summarises the speed-flow curve and the different network levels of service.

Figure 1 Stylised speed-flow curve and network level of service

LOS levels are in green



Source: NZIER

From LOS A (free-flow) to LOS D, speed decreases but flow increases (as more vehicles are using the network, the volume to capacity ratio increases). At LOS D, the relationship between speed and flow is optimal (where the trade-off between speed and volume allows for the highest flow of vehicles), and this is the point where congestion starts in the Auckland network.

Beyond LOS D up to LOS F, additional vehicles on the network reduce speed enough so that the total flow of vehicles (for a given period) is less than LOS D (despite there being more vehicles on the road).

Hence beyond LOS D, congestion generates a cost that could be avoided if the network was operating at capacity (LOS D). The cost of congestion is the difference between the observed travel time and the travel time when the road is operating at this threshold, along with schedule delay costs, reliability of travel costs and other social and environmental costs.

The average speed[3] at the morning (AM) peak was 41.2 km/hour in 2016 (BECA, 2016). Estimated average speed if the network was operating at capacity (LOS D) and at free-flow (LOS A) are respectively, 50.5 km/hour and 56.8 km/hour.

3 Network average speeds cover the entire network including motorways, arterial and rural roads.

2. Congestion a side-effect of Auckland's success

The Auckland economy has grown by over a third since 2010 – from $68.5 billion to $93.5 billion in 2016 (Statistics New Zealand, 2017).

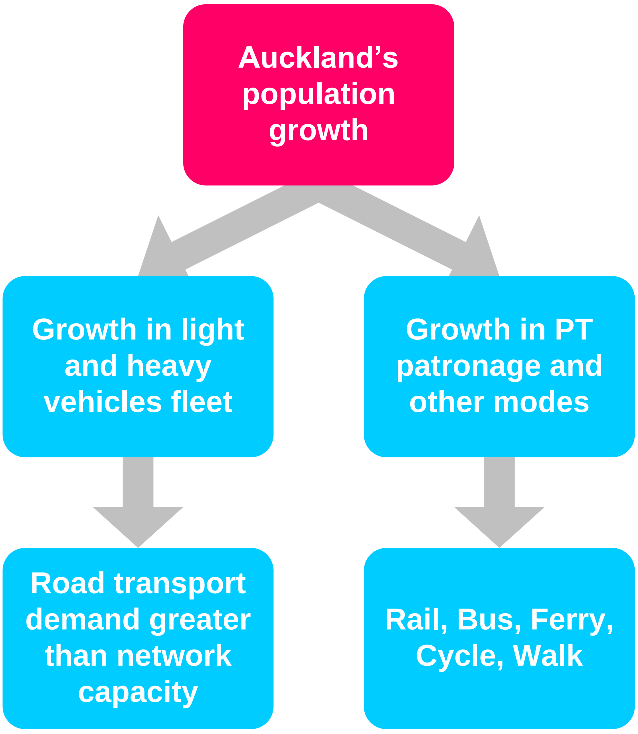
This growth has been supported by strong population growth. Over that time, the region's population surged by 160,000 people from 1.43 million to 1.59 million (Statistics New Zealand, 2017a).

The effects of this surge in population have been felt widely in the Auckland economy. Besides the boost to economic activity, it has also increased demand in many sectors, including transport.

Increased transport needs have seen:

- An increase in the light and heavy vehicle fleets in Auckland
- A rise in the use of public transport (PT) and other modes of transport, particularly rail.

Figure 2 Auckland's population growth and transport demand

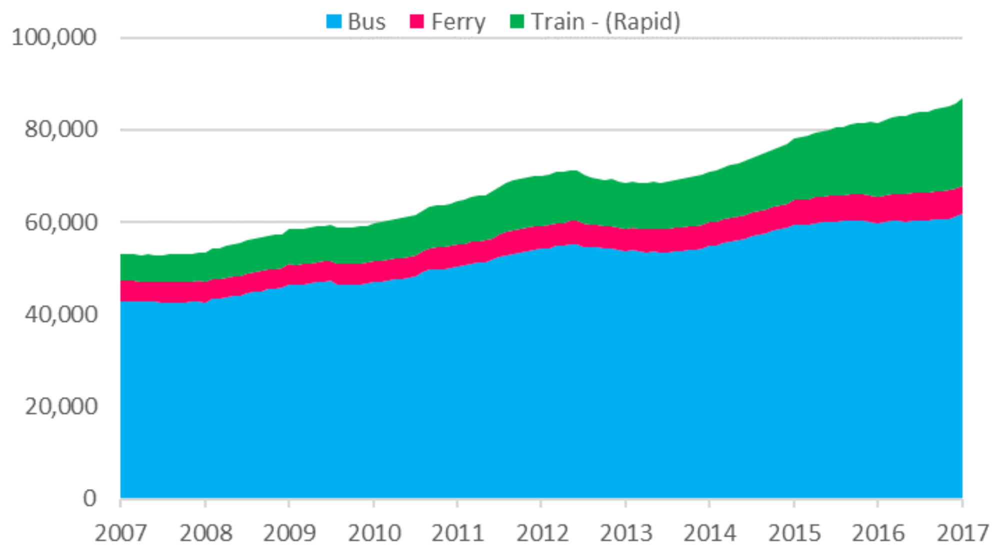


Source: NZIER

Public transport usage has grown strongly since 2014, underpinned by a surge in rail patronage. Over the past year, rail patronage has increased by 20% and on an annual average basis is well above the circa-7% growth in overall public transport patronage.

Figure 3 Patronage of public transport

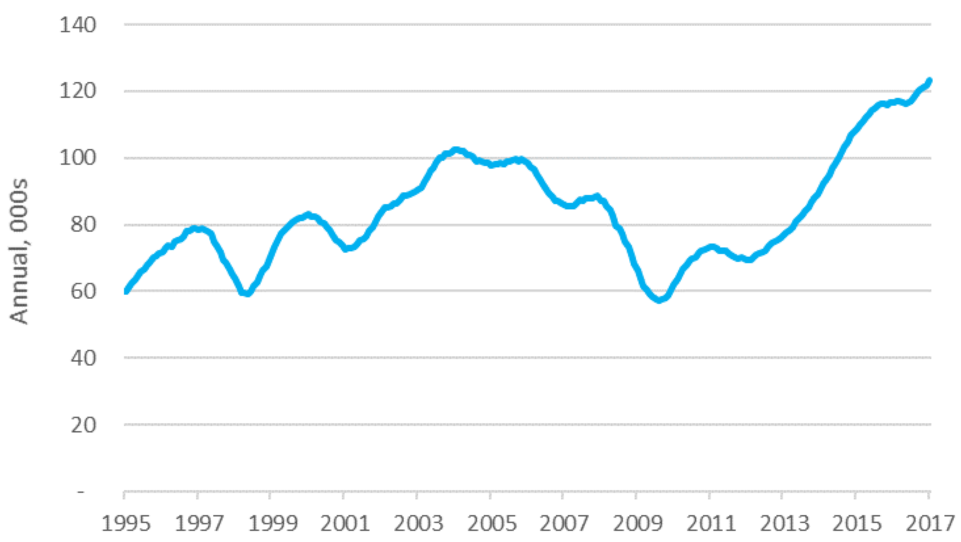
Annual patronage



Source: Auckland Transport, 2017a

Besides the increase in public transport patronage, the large increase in the Auckland population has led to a significant increase in the Auckland light vehicle fleet. Light vehicle registrations provide an indication of the increase in demand for road transport. Auckland light vehicle registrations have surged from around 70,000 in 2012 to 123,000 for the year to March 2017.

Figure 4 Auckland's new car registrations

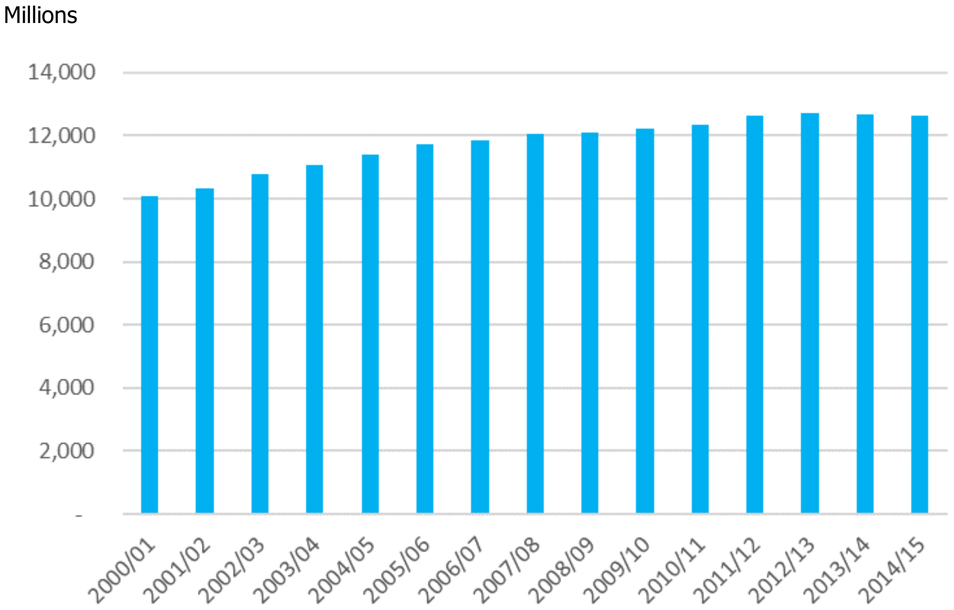


Source: Statistics NZ

Despite the surge in light vehicle registrations since 2012, the total number of vehicle kilometres travelled (VKT) in Auckland has been relatively stagnant over this period (Figure 5). Combined with strong population growth, VKT per capita is falling. This decline in VKT per capita can be explained by several factors:

- A shift towards other modes of transport, particularly rail
- Demographic changes which are reducing residents' willingness to drive. Research conducted by Roy Morgan showed a decrease in the number of 25- to 34-year olds owning cars in line with an increase in this age group travelling by bus from 2003 to 2013 (NZ Herald, 2014)
- Shorter trip distances because of congestion.

Figure 5 Auckland total vehicle kilometres travelled



Source: Ministry of Transport, 2017a

Congestion reduces the ability and willingness of households and businesses to travel long distances. For example, businesses we interviewed for this report have increased the number of vehicles they use given the reduced number of deliveries they can now make in a day.

Households and businesses have modified their behaviour to some extent in response to congestion, but these changes have not been enough to offset the increased demand on the Auckland road network.

3. The state of congestion in Auckland

Auckland has historically had a high dependence on its roads as a means of transport. The 2013 Census showed only 8.3% of journeys to work in Auckland were made by public transport, while 82.7% were made by private vehicle (Statistics New Zealand, 2017).

As a comparison, public transport patronage in Sydney at peak times is 20% (Deloitte Touche Tohmatsu Ltd (DTT), 2016). Cities with the highest populations tend to have the highest shares of public transport patronage at peak times.

A dependence on roading is a common feature of relatively young and fast-growing cities. Auckland's roading network has become more congested as its population has swelled (DTT, 2016). For example, the time taken to travel:

- from Papakura to the CBD in the morning has increased from 46 minutes in 2013 to 67 minutes in 2016
- along the Northwestern Motorway from Royal Road to the CBD has increased from 25 mins to 37.5 minutes over this period (AA, 2016).

3.1. Auckland congestion is above comparable cities

The latest annual Traffic Index from GPS navigation company TomTom shows Auckland now ranks 47th in the world in terms of traffic congestion, based on traffic conditions at peak hours relative to a free-flow situation. The surge in the number of vehicles on Auckland roads has seen congestion in the region deteriorate to higher levels than cities of a similar population size internationally.

The deterioration in travel time reliability in Auckland means that drivers need to budget an additional 45% travel time to arrive on time nine times out of ten during the afternoon.[4]

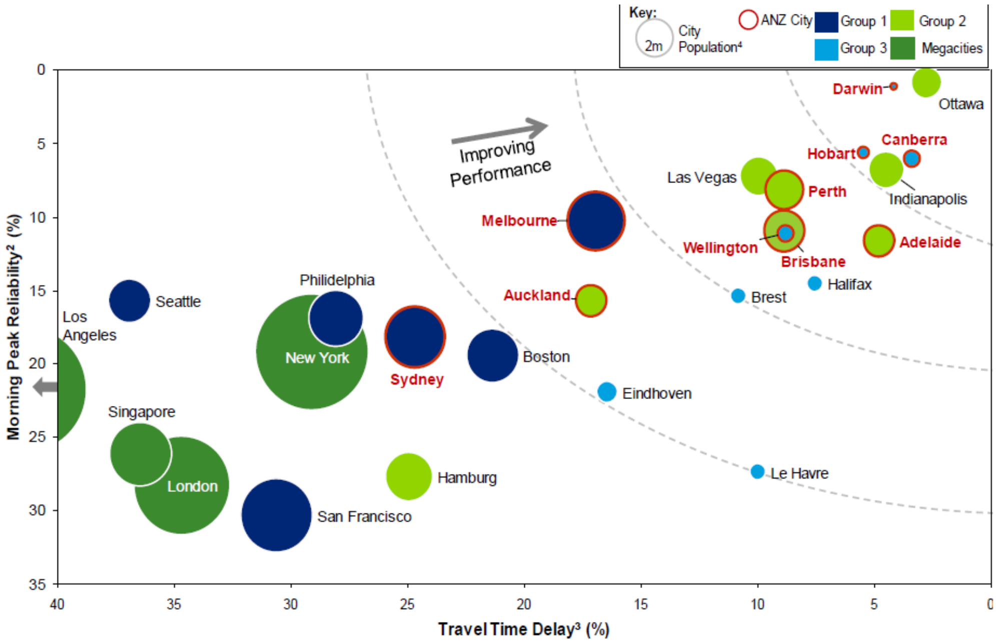
Congestion in Auckland is significantly worse than that of Australian cities of a similar population size, including Perth, Brisbane and Adelaide (DTT, 2016).

Figure 5 shows how selected cities fare on congestion, based on reliability of travel times in the morning peak and travel time delays relative to free-flow. The colours of the cities are grouped according to population size.

A move from the bottom left of the chart to the top right shows an improvement in travel time reliability and reduced travel time delays.

4 Congestion and Reliability Review (DTT, 2016).

Figure 6 Auckland is one of the most congested cities in the world amongst its peers

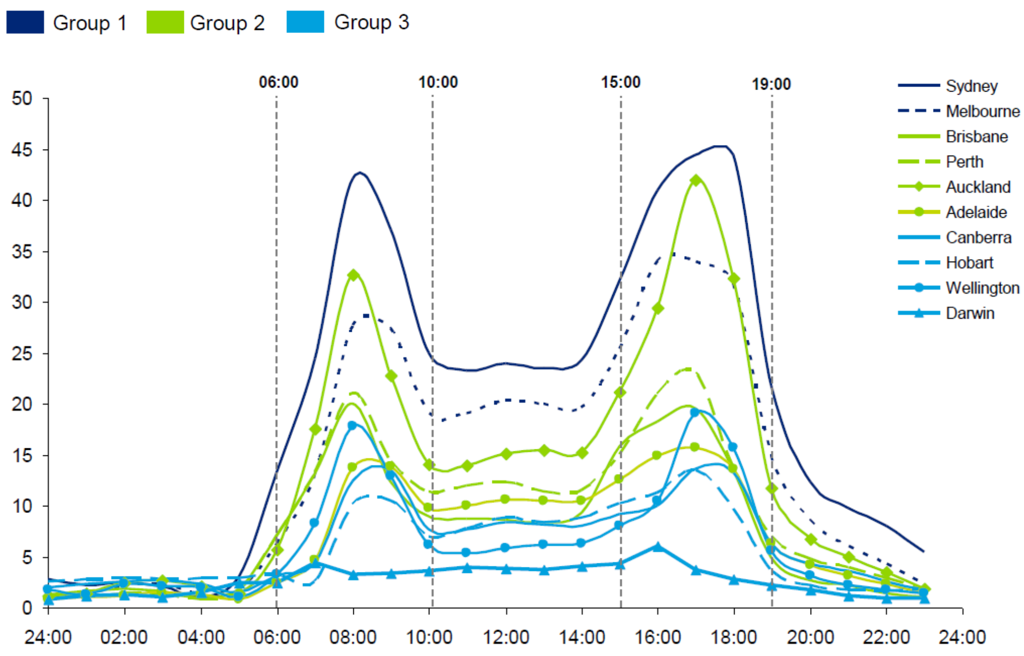


Source: Deloitte Touche Tohmatsu, 2016

Travel time delays (as measured relative to free-flow conditions) in Auckland are similar to Melbourne – a region with a population of almost three times the size of Auckland. During the evening peak delays, relative to free-flow conditions are almost as bad as Sydney (DTT, 2016).

Figure 7 Time delay by time of the day

By city, weekdays



Source: DTT, 2016

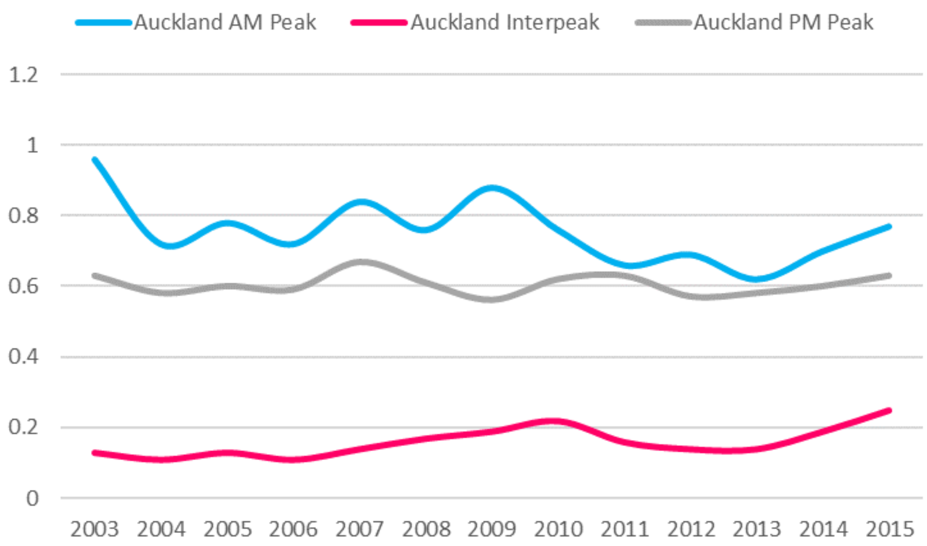
3.2. The increase in congestion is spreading across the day

Due to increased demand on the road network and drivers adjusting their time of travel in response to congestion, Auckland's congestion is spreading across the day. Travel time delays during the morning and evening peaks have been relatively steady over the past decade, but travel time delays have increased during the interpeak periods (DTT, 2016).

Households are choosing to leave for work earlier and leave work later to avoid peak congestion. And businesses are modifying their operations where possible to mitigate delays associated with congestion. According to businesses we interviewed for this research, this includes doing deliveries earlier in the morning or later at night to avoid peak hour traffic.

Figure 8 Auckland morning and afternoon delays have been relatively constant but interpeak delays are increasing

Minute delay per km



Source: Ministry of Transport, 2017a

3.3. Congestion is also spreading across the network

Traffic congestion has also worsened across the networks in recent years.

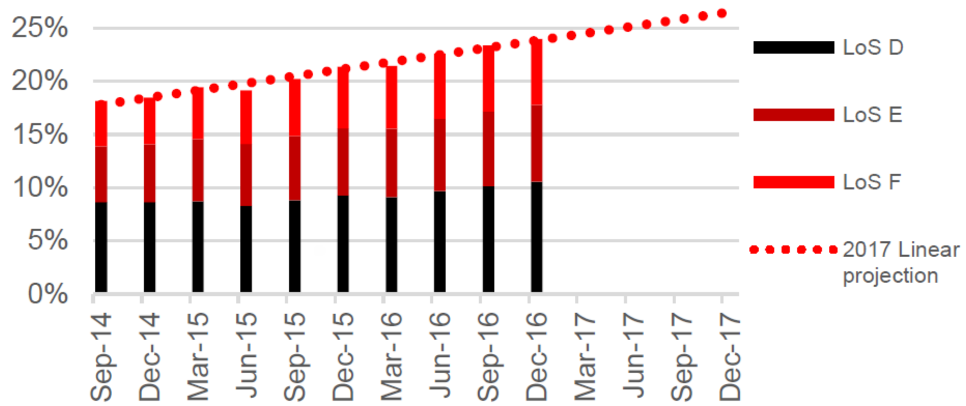
The spreading of traffic flows across the networks has led to a deterioration in the level of service (defined in Figure 9) for Auckland's key arterial roads. The average speed at which vehicles travel on these arterial roads has been steadily declining in recent years, reflecting a greater proportion of the arterial road network becoming congested.

3.4. Congestion is projected to worsen

Twenty-four percent of the arterial network was congested during the morning peak in the December 2016 quarter, a lift from the 18% for the same period two years ago. Auckland Transport projects that more than quarter of the arterial network will be congested by the end of this year (Auckland Transport (AT), 2017b).

Figure 9 Congestion and unreliability projected to worsen

Morning peak congestion on the arterial network; Based on the rolling 12-month average for the quarter[5]



Source: Auckland Transport, 2017b

Longer term, Statistics New Zealand projects that the Auckland population will grow to 1.89 million in 2028, and 2.23 million in 2043 (Statistics New Zealand, 2017c).

Auckland Transport, based on ART model projections, expects the average AM trip time to increase from 14.6 minutes to 15.3 minutes over the next 10 years.

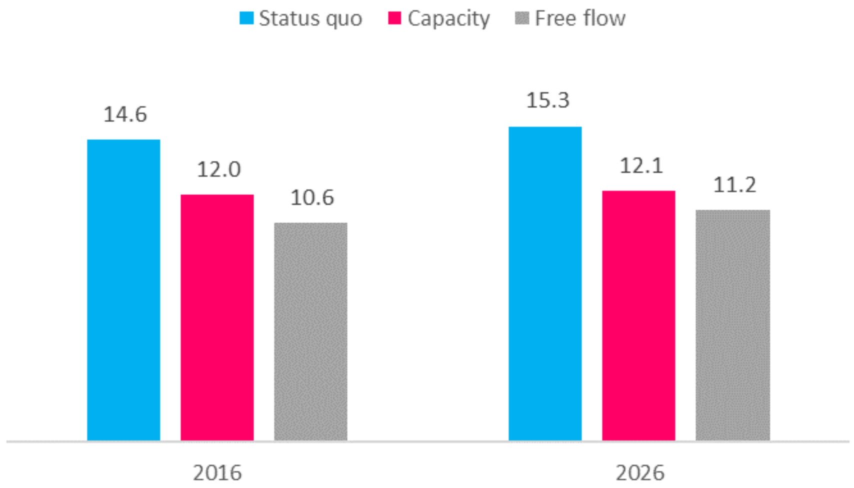
The ART model incorporates planned ATAP transport infrastructure investments. Hence despite these planned investments to expand Auckland's network capacity, travel times are still projected to increase over time.

[5] LoS (Level of service) shows the arterial road Level of Service as measured by average speed as a % of the posted speed limit:

- LoS D: 40-50%
- LoS E: 30-40%
- LoS F: less than 30%.

Figure 10 Average AM travel time projection

Average trip minutes, ART model



Source: Auckland Transport

Without improvement in vehicle technology, and absent any policy changes to contain congestion, further increases in road transport demand because of this forecast of population growth will put further strain on the Auckland transport network and increase the costs of congestion.

3.5. Reliability for Auckland's key freight routes

With congestion spreading both across the day and throughout the roading networks, travel time reliability has declined. Businesses are less certain about the time it takes to travel across Auckland.

Reliability costs associated with traffic congestion negatively affects freight productivity. Increasing congestion and a reduction in reliability is leading to fewer deliveries and pickups per truck given the increased uncertainty over the time it takes to reach pick-up and delivery points along the key freight routes. Businesses have responded by increasing their truck fleets to maintain the total quantity of deliveries.

Auckland Transport's indicators show a marked increase in delays for freight in recent months, with only three of the ten key freight routes maintaining their target baseline travel times in December 2016 (AT, 2017b). Increased congestion has reduced average speeds which trucks can travel at along its key freight routes. Whilst freight makes up a relatively small proportion of road users, the reliance of many other sectors on transport means that travel time delays have implications across the supply chain.

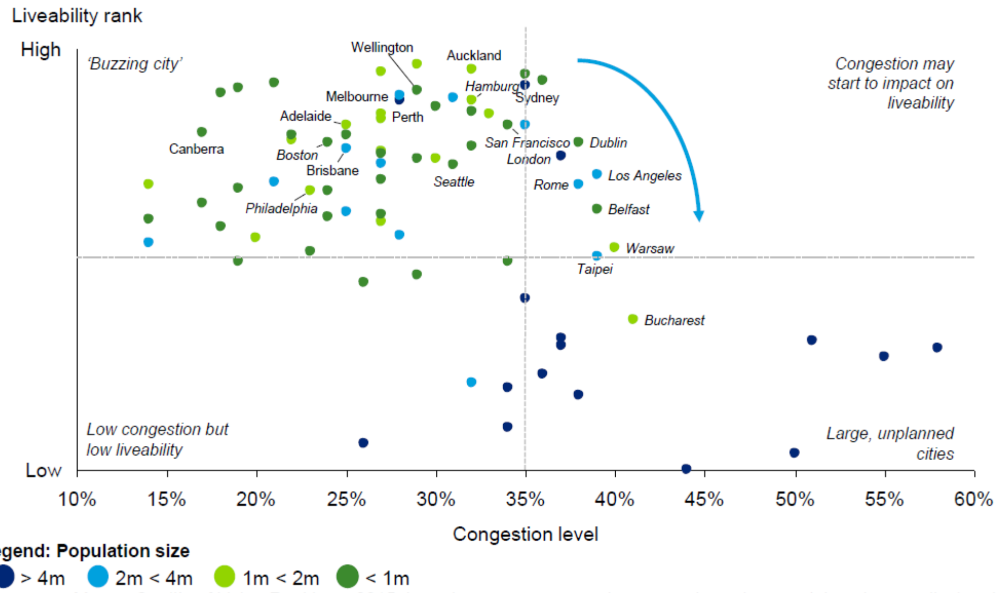
4. Auckland congestion and deteriorating liveability

The liveability of a city depends on, amongst other things, the accessibility of workplaces and key amenities. Congestion reduces the distances households are able and willing to travel on the road, making communities more siloed.

Congestion appears to partly explain cities' liveability. The figure below shows a correlation between a higher level of congestion and lower liveability, as measured by Mercer's Quality of Living Rankings. Quality of ranking dropped sharply when congestion reached 40% – this is the extra time required during peak hour relative to free-flow, as measured by TomTom data (DTT, 2016).

Congestion in Auckland is increasing to 35% on this measure, which is nearing the point beyond which cities see their overall liveability score deteriorate.

Figure 11 City congestion and quality of living rankings



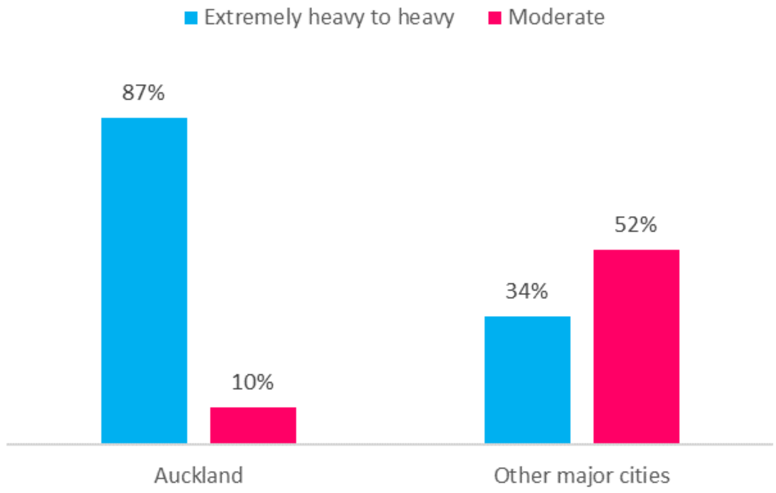
Source: Mercer Quality of Living Rankings, 2015, based on consumer goods, economic environment, housing, medical and health considerations, natural environment, political and social environment, public services and transport, recreation, schools and education, socio-cultural environment; TomTom congestion data

Source: Deloitte Touche Tohmatsu, 2016

A recent survey conducted by the Automobile Association (AA) finds 87% of its Auckland members rated congestion as extremely heavy to heavy – much higher than the average of 34% for its members in the other major cities.

Figure 12 How would you rate the congestion where you live?

Auckland



Source: Automobile Association, 2017

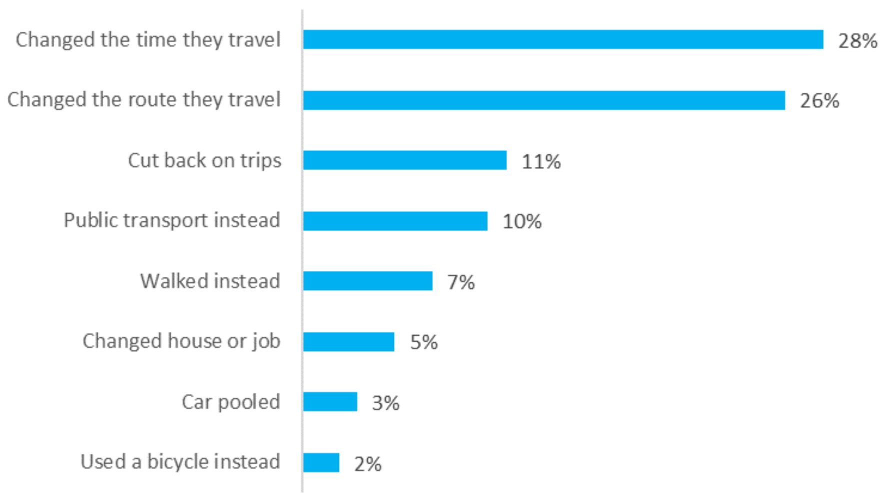
Across the main centres of Auckland, Wellington and Christchurch, the AA survey finds:

- 80% consider that traffic congestion has worsened over the last five years
- 72% will be frustrated or extremely frustrated if congestion remains the same in five years' time.

Like businesses, households have modified their behaviour where possible to mitigate or avoid the effects of congestion. More than half of the respondents have either changed the time or the route travelled in response to congestion. 22% changed their mode of transport, either to public transport, walking, carpooling or cycling.

Figure 13 Responses to increasing congestion

All city centres



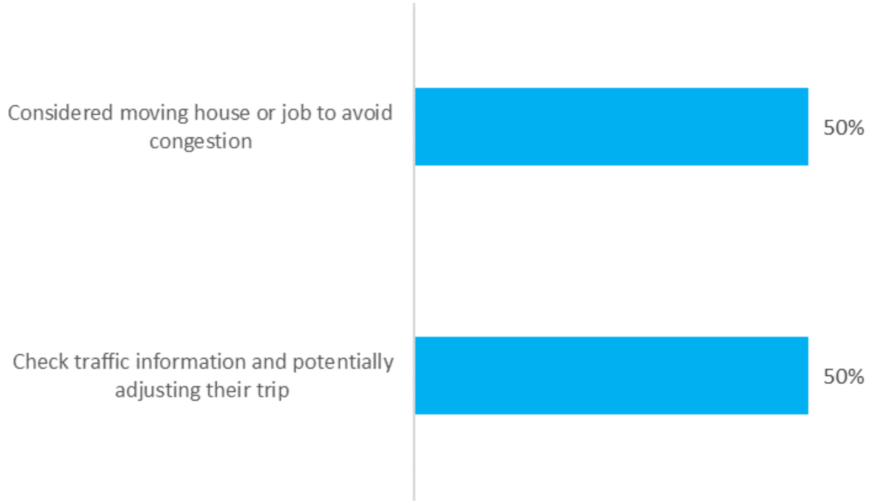
Source: Automobile Association, 2017

A significant proportion of residents are willing to make major changes to avoid or minimise the effects of congestion on their everyday activities.

Fifty percent of its Auckland members have considered moving house or changing jobs due to congestion, and some are leaving Auckland because of it. Congestion affects where households choose to work and live. This highlights how influential congestion is on residents' satisfaction with their city.

Figure 14 Aucklanders' response to congestion

Auckland

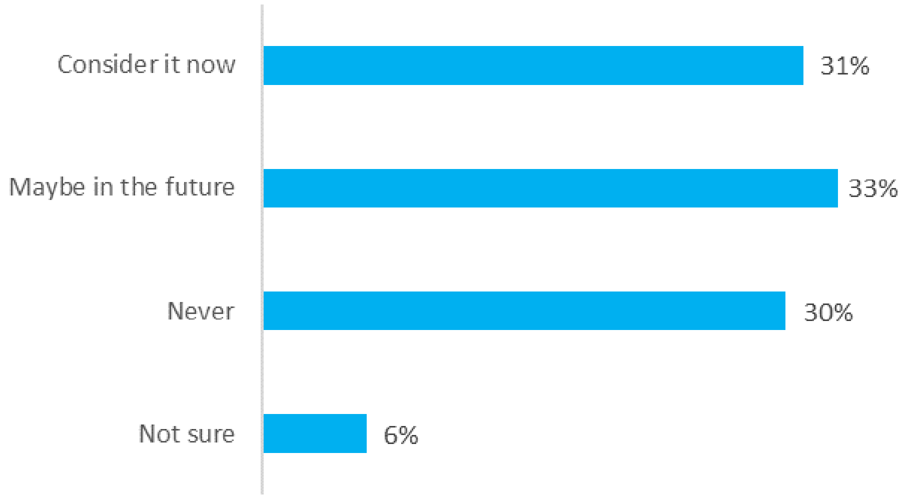


Source: Automobile Association, 2017

Households place a higher priority on the Auckland Council addressing traffic congestion than on housing affordability. Almost 75% of AA members feel that addressing congestion should be a very high or high priority – greater than the 50% of members which consider housing affordability as important. High levels of congestion reduce the liveability of a city, given time spent stuck in traffic is time that could be spent more productively, either through work or leisure (AA, 2016).

To address traffic congestion, about two-thirds of AA members think central government should either consider charging a toll on congested roads now or in the future.

Figure 15 Should the government consider charging tolls on congested roads to encourage people to avoid them at busy times?



Source: Automobile Association, 2017

These survey results highlight the importance households place on a road network operating effectively. If there was to be no change to the current congestion situation, this will likely make it harder to attract talent to Auckland in the future.

5. How transport affects the Auckland and New Zealand economies

A more efficient Auckland transport network will have widespread benefits. This extends not just across the sectors of the Auckland and New Zealand economies, but also on how residents live. Time not spent sitting in traffic is time that residents can spend on more enjoyable activities. A transport network that is more efficient would allow both businesses and households to operate more effectively.

5.1. Relationship between economic growth and congestion

The literature on the cost of congestion is extensive and outlines the various ways in which congestion reduces the competitiveness of cities through its impact on the choice of employment and location for businesses and households. We summarise the key aspects of the literature below.

The cause and effect between economic development and congestion is complex. Although an increase in economic activity tends to lead to more congestion, this congestion in turn hinders further growth through reducing accessibility. This issue of feedback effect highlights the challenges of disentangling the competing forces of big city development and dense travel patterns from the effects of congestion on travel costs and unreliability (Zhang and Kockelman, 2013).

Although congestion reduces the competitiveness of a region (Boarnet, 1997; Hymel, 2009), businesses and households tend to adapt through location decisions – for example, households choosing to work closer to where they live. It is not clear at what point these adaptations can no longer offset the costs of congestion (Sweet, 2011).

Congestion also induces employers and employees to locate close to one another (Crane and Chatman, 2003; Levinson and Kumar, 1994).

But research also finds that while road users modify their behaviour to mitigate the effects of congestion, it still slows the growth of a city and hinders agglomeration (Sweet, 2011).

One study finds that above a certain threshold, congestion has a negative impact on employment growth. Across 88 US metropolitan areas, congestion resulting in an average of 4.5 minutes or more of delay per commute reduces employment growth (Sweet, 2013). Hymel (2009) finds that high levels of congestion has a lagged negative effect on employment growth.

Finally, the effects of congestion across each sector depends on the sector's mix of production inputs, including skilled labour and access to a large transportation-based market area. Congestion reduces the "agglomeration economies" of businesses in large urban areas (Weisbrod et al, 2003).

Weisbrod and Fitzroy (2011) find that the effects of congestion go beyond changes in work shift schedules, delivery volumes and locations as modelled by supply chain simulation models. Congestion can also affect the size and nature of businesses, their production processes and customer markets served.

5.2. Relationship between labour supply and congestion

5.2.1. Evidence that congestion hinders job matching and reduces labour force participation

A number of studies review the relationship between commuting costs and labour supply and find evidence that congestion reduces labour supply (Bovenberg and Goulder, 1996; Mayeres and Proost, 2001; Parry and Bento, 2001).

Kernohan and Rognlien (2011) state in a report for NZTA that reduced time and cost of commuting can enable easier access to work. It states that:

> *It is natural to assume a reduction in the perceived cost of working can induce more people to work than would otherwise be the case. This could either be by encouraging previously inactive individuals to join the labour market or by reducing the likelihood that workers leave the labour market, for instance to retire or to take up familiar responsibilities.*
>
> *Similarly, it is conceivable a proportion of a commuting time saving will be allocated to productive activities, more work and higher pay (this is part of the basis for the value of time benefits in a standard appraisal).*

Anderstig et al (2015) argue that congestion may reduce matching and labour force participation. Importantly they point out the complex set of responses which is driven by groups having different:

- Values of time, so the sign of the change in generalised travel costs may be different for different groups (including between genders)
- Wages, and hence weigh the trade-offs between accessibility and income differently.

They estimate the impact of the Stockholm congestion charges on labour market outcomes and concluded that the labour market effects of decongestion were significant and positive, estimated at 60 M€/year (Anderstig et al, 2015).

5.2.2. Congestion may increase daily hours worked

The literature on the relationship between commuting times and labour supply was extended over time to allow differentiating between the number of workdays and number of hours work per day (Cogan, 1981; Black et al., 2008; Ehrenberg and Smith, 2003). This research provides evidence that the impact of congestion on labour supply is not definitive.

Gutiérrez-i-Puigarnau & Ommeren (2010) analyse the relationship between labour supply and commuting distances and time for Germany between 1997 and 2007. Their labour supply model distinguishes the impact of commuting time on daily work time and number of days worked.

They find that commuting distance increased daily hours worked and do not find a negative relationship with total labour supply. They also show that commuting time increases daily work hours, whereas the number of workdays decreases.

They conclude the net effect on total labour supply of greater commuting distance and time is not definitive (Gutiérrez-i-Puigarnau & Ommeren, 2010).

Gimenez-Nadal & Molina (2011) undertake a similar analysis for Spain and find a positive impact of commuting time on the time devoted to working. They estimate that one hour of commuting increases daily time worked by 35 minutes – the more time a worker has to spend commuting the longer they tend to work.

Arnott et al (1993) argue that as result of congestion workers may work longer hours to avoid congestion.

5.2.3. Decongestion is likely to mean greater choice for commuters of where to live, rather than shorter commuting times

Metz (2008) argues that there is little empirical evidence to support the view that transport infrastructure improvements reduce travel time, as in the long run average travel time is maintained at around 1 hour per day.

Commuters, he argues, tend to bank the benefit of transport investment in gaining access to greater amenities. That is, travel time savings allows a commuter to travel further in the same amount of time, so commuters can choose to live further away from their work as a result of transport investment (Metz, 2008; Gubits, 2004). Similarly, Laird (2006) associates an increased length of commuting journeys with workers either moving house or changing jobs, such that the effects of congestion manifest itself in workers choosing a job closer to home.

Vickrey (1969) and Arnott (2005) make a similar case by arguing that a positive effect of reduced travel time on labour supply is only possible if workers have flexibility around the time at which start and end their workday.

5.2.4. Labours supply impacts literature review: implications for Auckland

The literature on the relationship between congestion and labour supply is not definitive, largely concluding that this impact of congestion depends on a range of factors.

Studies have looked at this relationship from different angles and find different answers. The only conclusion that can be confidently made is that the sign and magnitude of the impact of congestion on labour supply depends on many factors, such as wage distribution, how road tolls are implemented, the structure of a city (density as opposed to sprawl), availability of public transport, the reliability of the network (how congested it is) and others.

While the literature findings are relevant for Auckland, without more detailed analysis it is not clear how much decongestion would expand the Auckland labour supply.

At worst, it could have absolutely no impact at all. This is the assumption we use in our lower bound estimates.

For our higher bound estimates, we take the approach recommended by NZTA and use Treasury's most recent labour supply elasticity of 0.31 to estimate the total increase in labour supply resulting from shorter travel times.

The literature suggests that there is a greater likelihood that the total benefits from decongestion are closer to the lower bound than the upper bound estimate. However, applying the New Zealand Treasury estimate of labour supply elasticity, the benefits of decongestion would be closer to $1.3 billion.[6]

5.3. Importance of the freight industry

Within the transport, logistics, and distribution sector, road transport employs the largest share of workers. The largest share of road transport value is added in Auckland, accounting for around 28% of the national total (Westpac, 2015).

Although the transport, postal and warehousing sectors only account for just over 5% of the Auckland economy, the use of their services by many other sectors means that congestion has broad-based effects across the Auckland economy (Statistics New Zealand, 2017a).

A study conducted in 2012 showed around 16.2% of all freight movements around New Zealand were within Auckland (ATAP, 2016).

5.4. Users of the freight industry

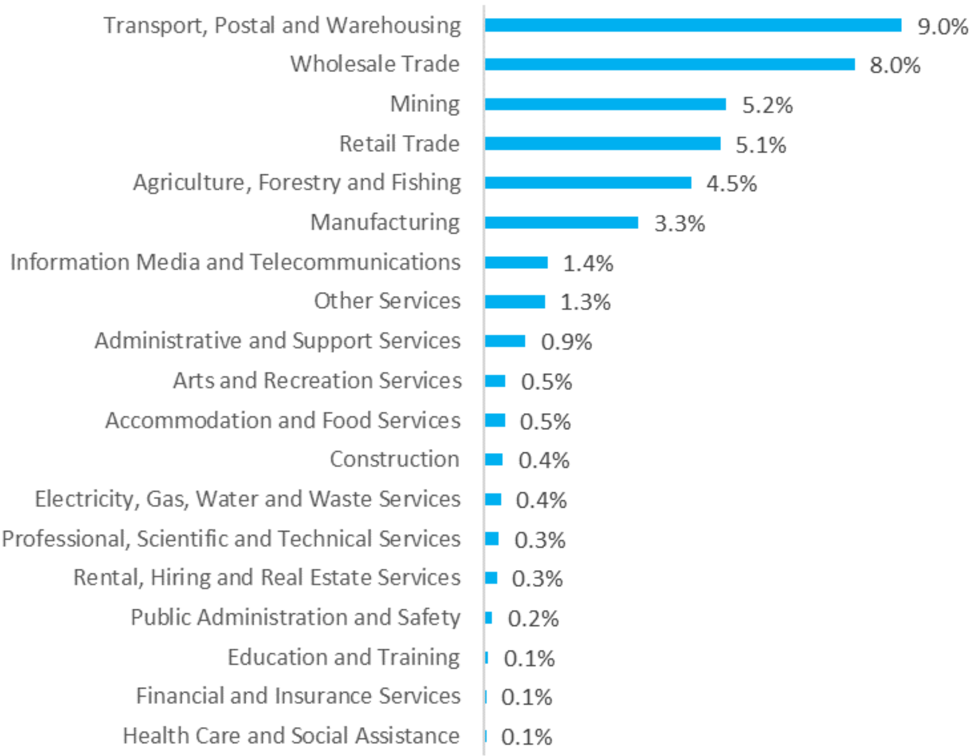
A well-functioning Auckland transport network is important for the New Zealand economy. Delays in deliveries will have ripple effects on many supply chains, impacting on the timely provision of goods and services to other sectors and regions.

Aside from the transport and logistics sector, the wholesale trade, retail, primary and manufacturing sectors are relatively intensive in their use of freight. These sectors are particularly reliant on freight as an input into their production, and hence are likely to be more affected by traffic congestion.

[6] KPMG estimated an increased labour supply in New South Wales due to reduced travel by applying a labour supply elasticity of between 0.05 and 0.1 (KPMG, 2015), and expected the lower end of this range to be more realistic. This is a sixth to a third of Treasury's elasticity. However, there is no documentation of KMPG's recommended elasticities and therefore we do not use them.

Figure 16 Spending on freight by industry as a % of total inputs

Selected sectors, Input-Output table, 2013



Source: Statistics New Zealand, NZIER

5.5. Auckland commuters

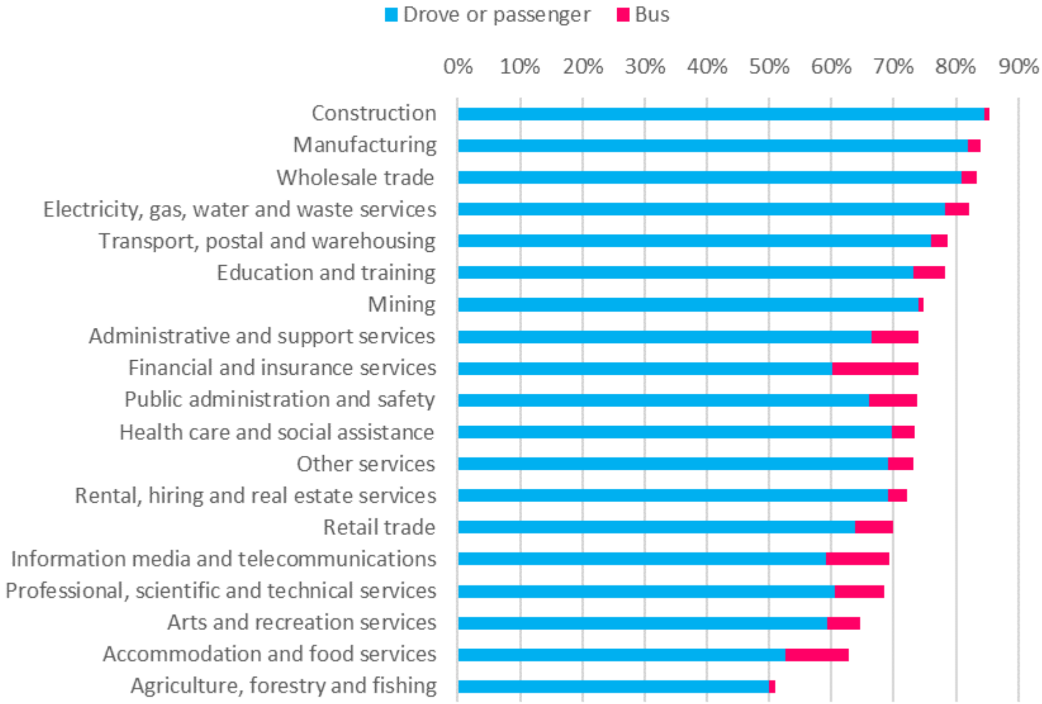
Commuters make up the largest group of road users. We estimate 79% of road users are in light private vehicles (NZIER calculations based on Auckland Transport and NZTA data).

Census 2013 indicates that Auckland workers in the construction, manufacturing, wholesale trade, utilities, transport and logistics and education sectors are particularly reliant on using a vehicle to get to work (Statistics New Zealand, 2017).

These sectors are likely to be more affected by traffic congestion when it comes to staffing requirements such as hiring. Increased congestion has seen workers choose to work closer to where they live to avoid long commutes, thus reducing the catchment areas of applicants for businesses when they are looking to hire.

Figure 17 Share of Auckland workers who either drove, were a passenger or took the bus to work, by industry

Proportion of workers in the Auckland region; Census 2013



Source: Statistics New Zealand, 2017

5.6. Auckland transport and the New Zealand economy

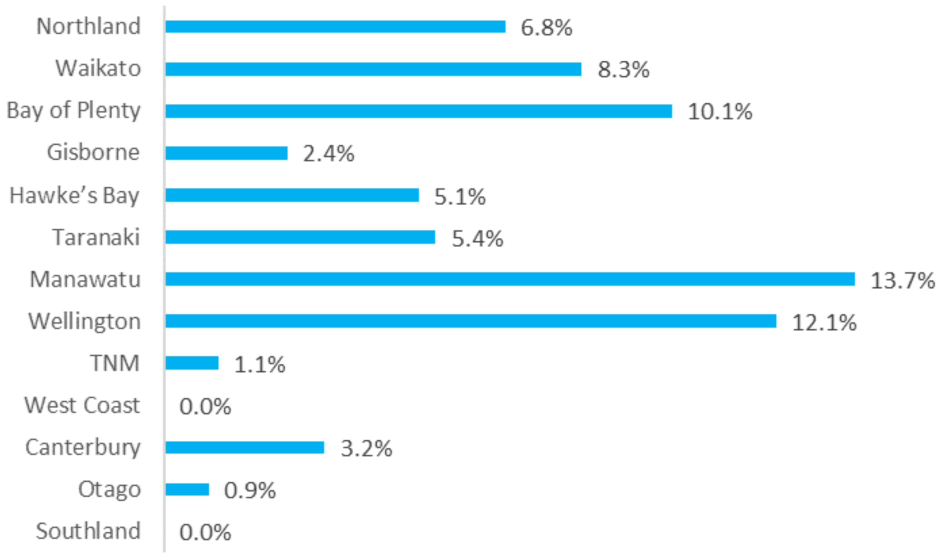
Congestion in Auckland has ripple effects across the rest of New Zealand, given the importance of Auckland to the economy (Auckland accounts for 37% of New Zealand's GDP).

Overall, around 25% of New Zealand's freight has an origin or destination in Auckland (ATAP, 2016).

Many regions in the North Island depend on the Auckland transport network to operate effectively. Any delivery delays in Auckland will flow through to operations in these other regions. The following figure summarises the share of freight to each region which originated from Auckland.

Figure 18 Freight from Auckland feeds other New Zealand regions

2012; Share of regional freight with origins from Auckland



Source: Ministry of Transport, 2014

6. Industry insights

We conducted a business focus group and interviews so we could better understand the effects of congestion on Auckland businesses (see Appendix A for the full list of participants).

These discussions indicate that the effects of congestion reach across a wide range of industries. Many businesses note congestion picked up noticeably five years ago, and with it an increase in costs and/or decline in the level of service that can be offered. Many talk of having to employ more resources to maintain the same level of production or service.

The key themes that we took away from these discussions are explained below.

6.1. Costs

Using more resources to maintain the same level of production or service means increased costs for businesses. This is often in the form of increased wage costs or increased investment on additional sites or vehicles.

Having to hire more staff or paying staff for the extra hours worked because of delays from traffic congestion increases wage costs. Rearranging staffing hours to take stock of later deliveries also mean an increase in staffing costs in the form of overtime paid.

Businesses find it hard to pass on these costs to customers in a competitive market, especially as many of these costs cannot be directly attributable to the provision of a good or service. Sometimes, the costs are absorbed by businesses keen to maintain key strategic relationships with certain customers. Instead, these costs reduce businesses' operating margins and weigh on profitability.

6.2. Adaptation in travel times

Businesses have changed operations to avoid peak travel times where possible, but there are constraints to how much peak travel times can be avoided, due to:

- Flow-on effects to the rest of the operations
- Demand
- Regulations
- Additional costs.

6.2.1. Flow-on effects to the rest of the operations

There is a limit to how much businesses can bring forward or push back delivery times to avoid travelling in peak traffic, given the effects on the rest of their operations. For example, a later delivery into a store would mean having to reorganise staffing hours at the store to take the stock after the delivery.

6.2.2. Demand

Changing the hours of operations affects demand. For example, long-haul buses bringing forward departure times to beat rush hour traffic face demand resistance from passengers unwilling to travel early in the morning.

6.2.3. Regulations

Some regulations also mean any changes will affect operations for the day before or after. For example, mandatory ten-hour rest breaks for drivers mean that arrival times also need to be brought forward in line with earlier departure times, so that drivers can take their allotted rest break before setting off the next day.

Other regulations such as noise restrictions before 7am and after 9pm in residential areas also limit the ability for businesses to operate outside of peak times to avoid congestion.

6.2.4. Additional costs

Sometimes extra costs associated with operating outside of peak times do not outweigh the costs of having a delivery truck stuck in traffic during peak times. For example, later deliveries mean having to employ a security guard at night to watch over stock. These extra costs limit the extent to which businesses are willing to change their behaviour to avoid peak traffic congestion.

6.3. Productivity loss

Businesses often take steps to avoid congestion which involves a duplication of resources employed.

6.3.1. Capital

Businesses make investments such as building concrete plants close to construction sites to avoid trucks travelling too far. The increased difficulty in staff returning to the main depot after each job has seen one business establish satellite storage systems in various Auckland areas to reduce travelling time.

Other forms of investment include adding vehicles to fleets given the reduced number of deliveries each vehicle can now make in a day due to increased travel times. For example, the high productivity heavy vehicle fleet is growing strongly (AT, 2017b). Other changes include increasing truck load volumes and changing loading configurations so that fewer trips need to be made.

6.3.2. Labour

Congestion is also affecting labour productivity. That is because the catchments from which businesses can attract labour are reducing as travel times increase between work and home.

Congestion is therefore contributing to a mismatch between the demand and the supply for skills. Sometimes, businesses may specifically choose to only hire staff in the areas they operate in, given the need for staff to respond to callouts quickly. South Auckland businesses report instances where it is easier to hire workers who lived in Hamilton as the commute for these workers would be easier than for someone living in central Auckland.

Some sectors are already facing skills shortages. Besides the reduced catchment area of applicants for businesses looking to hire, some sectors such as transport and logistics businesses are finding it hard to attract workers. The ageing workforce of truck drivers will further constrain the growth of transport activity.

6.4. Quality of service

Besides the financial costs, congestion also means a lower quality of service offered by businesses. This is often an implicit cost borne by the customers. For example, the difficulty in travelling around Auckland has seen businesses reduce the number of locations they deliver to, or pick up from.

Congestion also means decreased reliability of promised job times, given vehicles are held up in traffic and unable to get to the next job on time.

The customer experience for Auckland tourists is also affected by congestion. Tourism operators can no longer pick up all of their customers individually by bus and hence employ taxis and shuttles to assemble to main meeting points before sightseeing tours commence. This reduces the quality of the service offering to customers.

6.5. Regulations and planning

Businesses we spoke to highlighted how regulations and poor planning can contribute to and exacerbate the effects of congestion. For example, noise restrictions in residential areas limit the extent to which businesses can bring forward and push back operations to avoid peak hour traffic.

There has also been increased sprawl with new residential developments consented in the outer regions of Auckland with few infrastructure and employment opportunities nearby. This sprawl means a further increase in the use of motorways as workers travel from these outer regions.

6.6. Other modes of transport

Some businesses have used other modes of transport to work around congestion. The inland port in Wiri is used to bring goods to distribution centres in South Auckland by rail. However, rail is only viable for long-haul deliveries, and requires full containers for it to be a better alternative to roading.

Businesses note the importance of encouraging private commuters off the road. Public transport usage is more likely to increase if there are more options for the “last mile” trip to rail and bus stations, such as increasing the number of carparks at train stations.

However, the development of other modes of transports can add to congestion on the roads. For example, the development of cycleways has seen the removal of bus stops, including main stops which pick up passengers at key tourism operations such as the ferry terminal where cruise ship passengers alight.

6.7. Technology

Technology is helping some of the businesses we interviewed to work smarter in the face of greater traffic congestion. More extensive information about traffic flows from GPS mean businesses can better plan travel times and routes, and has increased productivity in road transport. Nonetheless, there is limited scope for operations to move to after hours, due to staff availability, driver fatigue and other costs of operating around the clock.

Businesses are also considering an investment in electric vehicles to enable faster travel times should special lanes be opened for these types of vehicles.

6.8. Businesses outside Auckland

Congestion in the Auckland road network does not affect just Auckland businesses. Businesses outside of Auckland have found it more cost effective to outsource their manufacturing and then ship directly to Auckland, than to manufacture locally and transport it by freight to Auckland.

6.9. Summary

Congestion has increased costs for businesses, which can only partly be passed onto customers. Nonetheless, the reduced quality of the service offering because of congestion is a cost implicitly borne by customers. Although businesses have tried to adapt by changing operations, investing in additional capital and technology or hiring more staff, there is a limit to how much operations can change to work around congestion.

7. Framing the benefits of decongestion

7.1. Economic and social benefits

We estimate the impact of decongestion in lifting the living standards of Aucklanders and New Zealanders. A rise in living standards can be broken down into economic (measured through GDP) and social (not measured through GDP) measures.

Based on the discussion in Chapter 5, we want to examine the total impacts of decongestion for:

- **Businesses** – the impacts of decongestion on the performance of supply chains in Auckland and, since Auckland is at the centre of many national supply chains, in turn the performance of New Zealand's supply chains
- **Households** – the impacts of decongestion on the lives and productivity of Aucklanders themselves from changes in public and private transport costs.

Table 3 summarises the economic and social benefits of decongestion.

Table 3 Summary of benefits from decongestion

Assessment of benefits	Businesses (freight, trades and postal)	Commuters (public and private transport)
Economic	Increased productivity in freight labour and capital Improved reliability of deliveries Greater margins Fewer delays Fewer trucks and drivers required Downstream productivity impacts on other industries using transport as an input Improved access to international markets via access to ports and airports Fewer multiple depots and depot employment; release of land for other uses	Labour supply increases Tighter single labour market area, i.e. greater choice in work location (better skill matching around the Auckland region) Increase in consumption (from reduction in vehicle operating costs)
	Reduced vehicle operating costs	
Social		Greater benefits from urban sprawl Auckland's liveability will improve which will attract talent and investment
	Environmental Schedule delay	

Source: NZIER

We explain these channels of benefits in more detail below.

Economic benefits

- **Labour market response** – a reduction in commuting travel times on balance raises the supply of labour for Auckland industries both through time savings for employed workers and rising employment (NZTA, 2016)
- **Labour and capital productivity** – fewer delays to Auckland freight as well as the trades and postal industries raises the labour and capital productivity of those industries. Businesses can produce goods and services with fewer resources
- **Vehicle operating costs** – a reduction in congestion lowers the cost to operate vehicles which includes fuel, maintenance and depreciation (Wallis and Lupton, 2013).

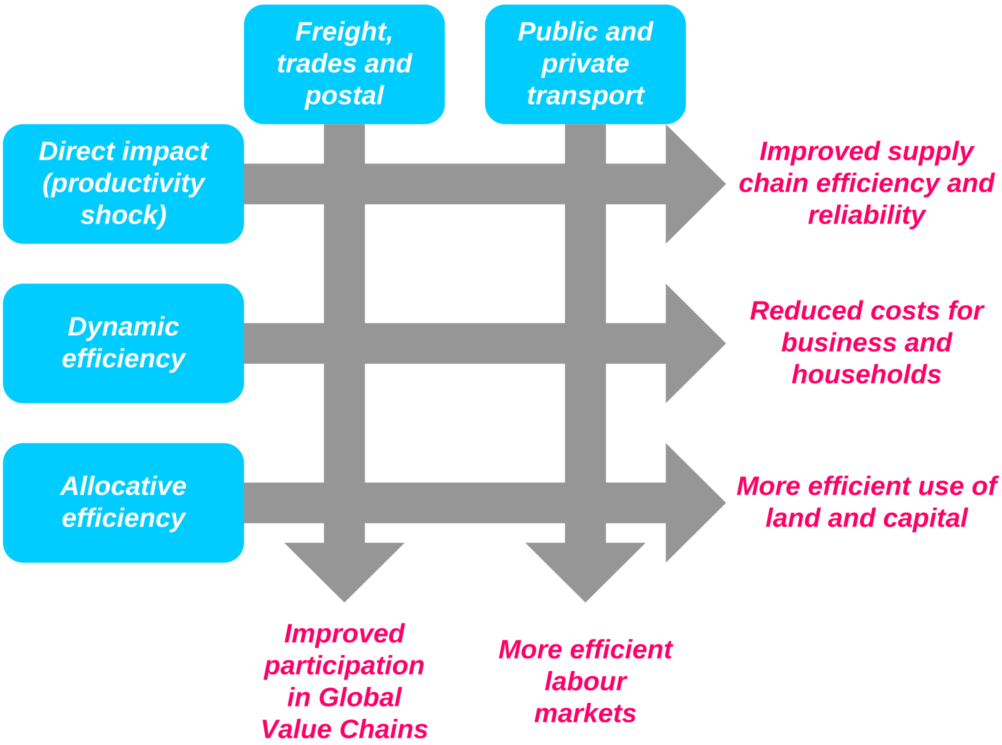
Social benefits

- **Shorter commuting times** – the value that Auckland commuters put on travel time savings (what Aucklanders are willing to pay for shorter travel times to work) (NZTA, 2016)
- **Environmental benefits** – decongestion reduces harmful carbon emissions given reduced travel times (Wallis and Lupton, 2013)
- **Reduced schedule delays** – decongestion prevents Aucklanders from having to change their travel times to avoid congestion. It is a cost to bear if Aucklanders decide to not travel at the times they desire. Decongestion would allow for better use of time as desired (Wallis and Lupton, 2013).

We not only estimate the direct but also indirect (or downstream) impacts of decongestion. The benefits manifest themselves over and above the direct impact of decongestion itself:

- **Direct productivity shock** itself, i.e. the travel time savings for the *freight* industry, *other industries using light commercial vehicles* such as trades and postal, as well as *commuters*
- **Dynamic efficiency** gains from an improved process for *other industries* because of the direct productivity gains
- **Allocative efficiency** gains through *resources being reallocated* to their highest-value uses.

Figure 19 Producitivity gains from decongestion



Source: NZIER

7.2. Benefits not quantified

There are several other potential benefits from decongestion that we did not attempt to quantify given data, time and resource constraints. The following benefits were not quantified:

- Tighter single labour market area, i.e. greater choice in work location (better skill matching around the Auckland region)
- Auckland's overall liveability
- Greater freedom for business to locate around Auckland (trading off labour market access and rental costs)
- Greater benefits from urban sprawl – improved accessibility from decongestion will allow households to locate further from their workplace. The transport costs to locate further from work or city centres will be lower thereby increasing the benefits residents enjoy by living at the city fringe.
- Increased tourism spending through attracting more visitors given improved ease of travelling.

As such, our quantitative estimates will be conservative. The potential gains from these benefits will be over and above the dollar figures we present here.

8. Total benefits of decongestion

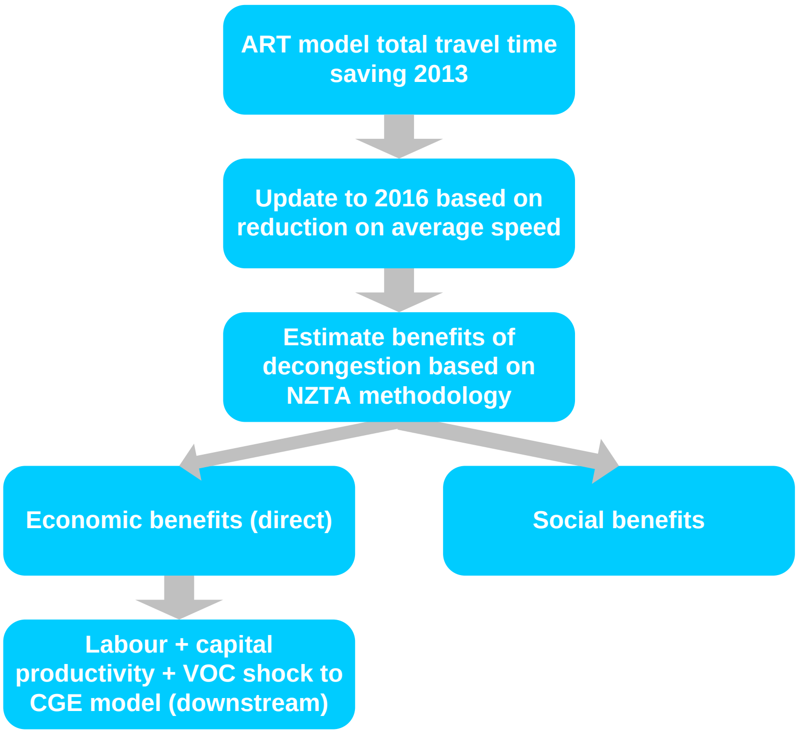
Our estimate of the benefits of decongestion begins with the Auckland Transport's ART model which estimates total travel times savings in Auckland if the network was operating at capacity and at free-flow. The ART model is calibrated for the year 2013. The update of the ART model from 2013 to 2016 is based on Auckland average speed data provided by BECA and the Ministry of Transport.

Using these ART model results updated for 2016, we replicate the Wallis and Lupton (2013) approach to the estimate the benefits of decongestion, which is consistent with the NZTA's economic evaluation manual (EEM).

The economic benefits to commuters as well as freight, trades and postal industries in the form of productivity gains (or rising labour supply for commuters) are then used as input to our CGE model. The economic benefits, estimated based on the Wallis and Lupton (2013) approach, effectively become shocks to the Auckland economy which then leads to further downstream benefits to the remaining Auckland industries.

For a detailed explanation of our approach to estimating the benefits from decongestion refer to Appendix F.

Figure 20 A summary of the approach to estimating the benefits of decongestion to Auckland

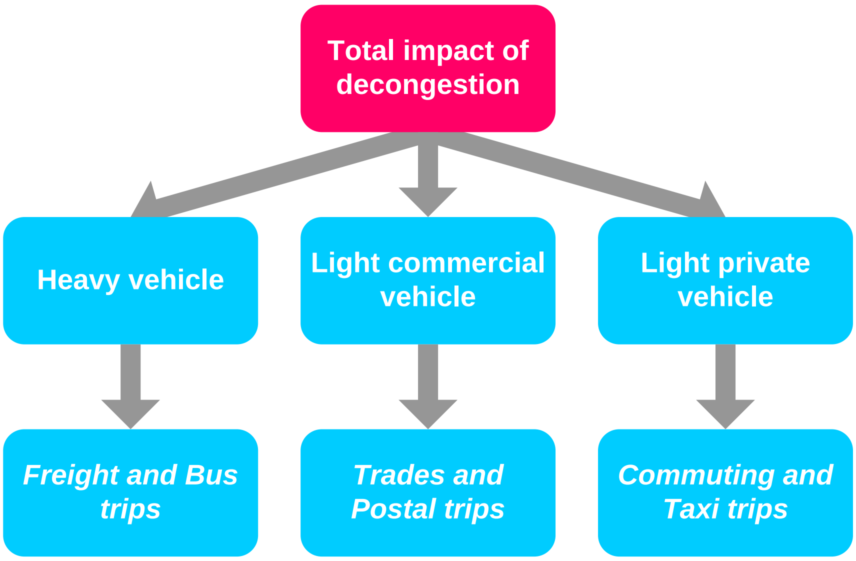


Source: NZIER

Estimating the benefits of decongestion requires a robust decomposition of the different value of time that Aucklanders place on time lost due to congestion. The most important distinction being trips which are for work and trips which are for non-work purposes (as the value of time is much for higher for those working in their vehicle).

We decompose Auckland traffic volumes into three vehicle types which act as a proxy for different trip purposes which is summarised in the following figure.

Figure 21 Decomposing the Auckland traffic volume into vehicle type



Source: NZIER

8.1. Total benefits for the Auckland economy

We estimate the total benefits (economic and social) of decongestion to the Auckland economy between:

- $0.9 billion and $1.3 billion (1% to 1.4% of Auckland's GDP) – these estimates represent the economic and social benefits to Auckland if the road transport network was operating at its capacity i.e. as it is designed to
- $1.4 billion and $1.9 billion (between 1.5% and 2% of Auckland's GDP) – these estimates represent the benefits if traffic flowed freely, i.e. the average speed across the Auckland network was close or equal to the speed limit, which is also known as free-flow.

We estimate Auckland's real GDP would increase by between $488 million (0.52%) and $842 million (0.90%) if Auckland traffic reduced to the capacity of its network.[7]

[7] These benefits would increase as congestion worsens over time as expected (see Figure 9).

8.1.1. Our range of estimates of the benefits of decongestion

The range of estimates reflect different assumptions about how an easier commute would affect Auckland's labour supply. Research to date on the impact of congestion on labour supply is not definitive, hence we use lower and upper bounds to reflect this uncertainty.

Not all Aucklanders will choose to work more (or join the labour force) as a result of decongestion. Some will choose to increase their leisure time, others may change their job to one that better matches their skill or experience or move houses. It is difficult to ascertain what will be the total impact on Auckland's labour supply.

The NZTA's EEM defines labour supply changes as Wider Economic Benefits (WEBs) to transport investments. The EEM provides procedures outlining how to quantify labour supply changes. The EEM recommends estimating the productivity (and therefore income) benefit from lower commuting times and using an elasticity of labour supply to estimate the labour supply response from decongestion.

We follow this methodology but the NZTA EEM does not provide a recommended elasticity of labour estimate to estimate the labour supply response from shorter commuting times.

Kernohan and Rognlien in a comprehensive review of the estimation methodology of Wider Economic Benefits (WEB) for NZTA recommend the following

> *Based on our analysis of tax, income and spending data in New Zealand and research into labour market impacts and commuting times we find the labour market impacts of transport are most likely to take effect through higher rates of labour participation rather than through a direct increase in the labour supply of existing employees.* ***From academic research we recommend an elasticity of labour participation with respect to wages of 0.4*** *(Kernohan and Rognlien, 2011).*

Kernohan and Rognlien's recommended labour supply elasticity of 0.4 is however outdated. We use the more recent Treasury recommended labour supply elasticity of 0.31 (Creedy and Mok, 2017). This labour supply elasticity of 0.31 is a more updated and robust estimate of NZTA's recommended elasticity of 0.4.

The elasticity of labour both from Kernohan and Rognlien, and Creedy and Mok was not estimated to represent the labour supply response as a result of decongestion. As the literature suggests, not all travel time savings are translated into an increase in labour supply.

Based on our review of the literature, we conclude that solely assuming a 0.31 elasticity of labour as result of decongestion is likely to overestimate the benefits of decongestion. We therefore use the 0.31 elasticity as an upper bound with the lower bound estimate of total benefits being no labour supply increase from shorter commuting times.

To our knowledge there is no estimate of labour supply elasticity *as a result of decongestion* for New Zealand. We have not uncovered estimates from the international literature either and while such an estimate would be informative it could not be directly used to estimate the labour supply impact of decongestion in Auckland. As explained in our review of the literature, there are many factors to account for and applying an elasticity of labour estimate as a result of decongestion from another urban area to Auckland would require that all those other factors to be controlled for.

It is important to note that:

- This does not mean that the lower bound estimate assumes no labour supply response from the *productivity benefits to Freight, Trades and Postal*, it negates the labour supply response from shorter commuting times only
- While a single elasticity of labour estimate is used indiscriminately for all commuters (without differentiating between income, occupation, and other factors) we do however account for the different average hourly earnings across Auckland industries.

The literature suggests that there is a greater likelihood that the total benefits from decongestion are closer to the lower bound than the upper bound estimate. However, applying the New Zealand Treasury estimate of labour supply elasticity, the benefits of decongestion would be closer to $1.3 billion.

8.1.2. Summary of benefits of decongestion

Tables 4, 5 and 6 summarise the benefits to the Auckland economy.

Table 4 Summary of the benefits of decongestion

$ millions; 2016; Economic benefits are in real terms

Benefits	Capacity		Free-flow	
	Lower bound	Higher bound	Lower bound	Higher bound
Economic	$488	$842	$735	$1,266
Social	$439	$439	$658	$658
Total	**$927**	**$1,281**	**$1,392**	**$1,924**
% of Auckland GDP				
Economic	0.52%	0.90%	0.79%	1.35%
Social	0.47%	0.47%	0.70%	0.70%
Total	**0.99%**	**1.37%**	**1.49%**	**2.06%**

Source: NZIER

Table 5 Headline lower bound economic benefits of decongestion for the Auckland economy

2016; Real terms; Network at capacity

Headline measure	Capacity		Free-flow	
	Increase in $ millions	Percentage change	Increase in $ millions	Percentage change
GDP	$488	0.52%	$735	0.79%
Consumption	$233	0.47%	$350	0.70%
Exports	$147	0.36%	$223	0.54%
Wages		0.31%		0.47%

Source: NZIER

Table 6 Headline upper bound economic benefits of decongestion for the Auckland economy

2016; Real terms; Network at capacity

Headline measure	Capacity		Free-flow	
	Increase in $ millions	Percentage change	Increase in $ millions	Percentage change
GDP	$842	0.90%	$1,266	1.36%
Consumption	$382	0.76%	$575	1.15%
Exports	$261	0.77%	$393	1.16%
Wages		0.48%		0.72%

Source: NZIER

8.2. Economic benefits

8.2.1. Direct productivity benefits

The direct impacts of the productivity improvement on businesses as result of shorter commuting times are initially felt by three industries: Freight, construction services (or trades) and postal services.

Output volumes for these three industries grow because of decongestion but prices fall as firms' transaction costs fall.

For freight, the price falls by more than the volume expansion meaning that the total value of its output falls marginally. That is because the demand for freight is less elastic (price responsive) to the reduction in price than the postal service and construction service which benefit more from decongestion overall.

Table 7 Direct benefit of decongestion to industries with high use of the Auckland network

2016; $ million

Industry	Capacity		Free-flow	
	Lower bound	Upper bound	Lower bound	Upper bound
Freight	-$12	-$5	-$15	-$6
Construction services (trades)	$84	$107	$119	$152
Postal services	$10	$14	$15	$20

Source: NZIER

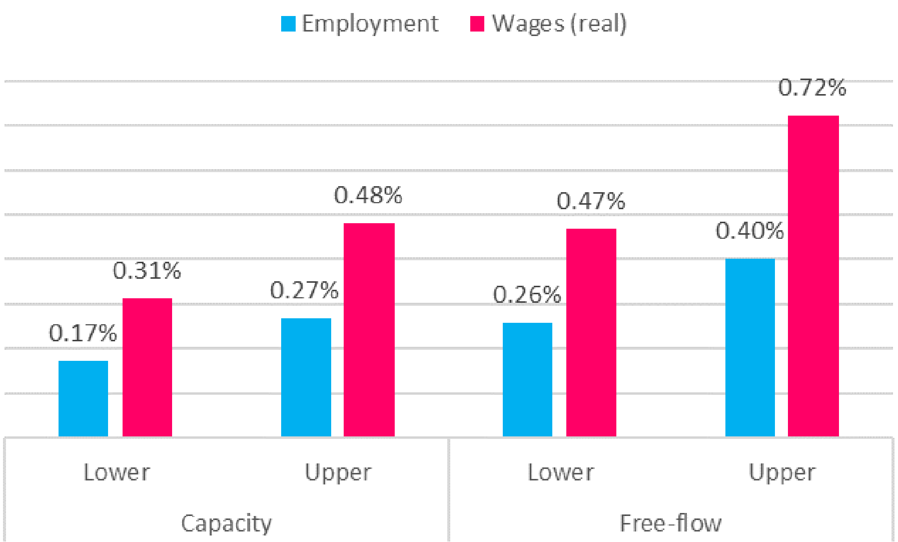
8.2.2. Labour market response

The benefit to Auckland's labour market (with network at capacity) is an increase of between 0.17% (lower bound) and 0.27% (upper bound) in employment and 0.31% and 0.48% in real wages resulting from all the benefits of decongestion. These benefits are not solely due to reduced travel times for commuters, but also to the downstream impact of freight, trades and postal productivity gains. Due to the increase in productivity, wages go up which attract workers and lifts employment.

Employment does not increase as much as real wages due to a fall in prices (CPI) as a result of productivity gains from decongestion. The increase in employment represents the creation of between 1,500 and 2,300 jobs in Auckland for the network at capacity scenario.

Figure 22 Auckland labour market response from decongestion

2016



Source: NZIER

8.2.3. Downstream benefits from greater freight productivity and labour supply

Downstream industries that use freight, construction services and postal services benefit from the productivity improvement in those sectors, and also from the productivity benefits for the commuting workforce. This allows them to produce more with less. Industries use the savings from decongestion to demand more of all other inputs to production and expand output.

This expansion of output also requires more capital investment and labour, which these growing industries draw from other parts of the economy.

The flow-on impacts manifest in a variety of ways. The productivity improvement raises real wages. Higher wages boost households' incomes leading to increased spending in industries such as supermarkets and food retailing, and more discretionary spending. Supermarkets and food retailers benefit additionally from lower freight prices.

Table 8 Key drivers of downstream benefits

$ millions; Nominal; Selection of industries – full impact by industry provided in Appendix D

Industry	Key driver of downstream benefits	Network at capacity		Network at free-flow	
		Lower	Upper	Lower	Upper
Residential building construction	Lower input costs	$34	$47	$48	$65
Specialised food retailing	Household spending	$0	$4	$0	$5
Accommodation	Household spending	$3	$6	$5	$8
Heavy and civil engineering construction	Lower input costs	$26	$40	$36	$56
Food and beverage services	Combination	$9	$21	$12	$29
Banking and financing; financial asset investing	Combination	$27	$45	$40	$65
Supermarket and grocery stores	Combination	$3	$8	$5	$11
Air and space transport	Combination	$9	$19	$13	$27
Motion picture and sound recording activities	Household spending	$5	$10	$8	$15
Non-metallic mineral product manufacturing	Lower input costs	$10	$15	$14	$21
Fabricated metal product manufacturing	Lower input costs	$15	$25	$22	$35
Pulp, paper, and converted paper product manufacturing	Lower input costs	$7	$12	$10	$16
Beverage and tobacco product manufacturing	Combination	$5	$10	$7	$14

Source: NZIER

8.3. Social benefits

Table 9 summarises the total impact of the social benefits of decongestion for Auckland. We estimate that the total social benefits of decongestion range from $439 million for the network at capacity to $658 million at free-flow for 2016.

We replicate Wallis and Lupton's approach to estimating social benefits, which was based on the NZTA EEM approach.

The value of time from shorter commuting times, which is not an activity that can be directly valued (as it is a non-market activity) is quantified based on NZTA's EEM. They are the benefits of decongestion, or travel times savings, that commuters are willing to pay for. Willingness to pay estimates are provided by the NZTA EEM.

Emission costs are valued at 8% of the vehicle operating costs (VOC) while scheduling benefits are equal to 67.5% of the total value of time saved by commuters, freight, trades and postal combined ($199 million is the sum of scheduling benefits to each commuter and the freight, trades and postal industries) (Wallis and Lupton, 2013).

Note that there isn't a lower and upper bound estimate for social benefits as those are not dependant on the labour supply response.

Table 9 Summary of the social benefits of decongestion

$ millions

Benefit	Network at capacity	Free-flow
Travel time savings	$209	$313
Emissions	$2	$3
Scheduling	$228	$342
Total	$439	$658

Source: NZIER

8.4. Limitations

There are important limitations to the estimation of the benefits of decongestion. These limitations reflect benefits which we did not estimate due to a lack of detailed datasets.

These limitations are not specific to our estimation methodology and apply to most estimates of the impact on congestion on the Auckland economy.

Nevertheless, these limitations mean our approach potentially underestimates the total benefit of decongestion. Both lower and upper bounds are potentially higher than those presented in this report.

8.4.1. Limitations induced by the ART model

The ART model offers the most precise and detailed travel time estimates available for the whole Auckland traffic network. It has a significant amount of detail on the traffic flows and road types (motorway, arterial and rural roads) as shown in Appendix F. But there are a few limitations to our analysis as a result of the structure of the ART model.

Morning (AM) estimates

The ART model only produces travel time savings estimates for the morning (AM) period. The total benefits of decongestion from the AM period are then scaled to account for the benefits of decongestion at the Interpeak and afternoon (PM) period. We use MOT's delay estimates at different times of the day as the basis for the scaling of the AM benefits to estimate the Interpeak and PM benefits.

This implicitly carries over assumptions made on the AM peak to the Interpeak and PM peak. One important assumption is that the distribution of trips by purpose across the day for light vehicles is constant across the day.

We estimate over the AM period that 2.4% of light private trips are work trips, with the remaining being commuting trips. Work and commuting trips have different values of time, with work trips having a higher value than commuting trips (Appendix F).

It is conceivable that the Interpeak period has a higher proportion of work trips than AM and PM periods which increases the average value of time for light private vehicle trips. This would result in decongestion delivering greater benefits than those we have estimated.

Finally, the MOT delay statistics are a year out of date. The statistics state that delays in the PM peak are slightly below those of the AM peak. There is the potential that delays at the PM peak may have worsened relative to the AM peak, which would raise the estimate of benefits of decongestion. A similar argument can be made for the Interpeak period.

Weekends

The ART model produces travel time savings at different levels of service over the AM period of a work day. There are no such estimates for weekend travel, so we do not consider the potential gains from decongestion at the weekend.

To the extent that decongestion also improves over the weekend, our estimate is likely to be underestimated.

8.4.2. Limitations relating to the NZTA EEM methodology

Value of time

The NZTA EEM provides different values of time for different trip purposes. The EEM's average values of time are derived from willingness to pay surveys which do not allow for differentiation across occupations, income, distance travelled, household composition and other important factors. They are also national averages, rather than Auckland-specific.

Willingness to pay estimates are based on survey data undertaken in 2002 and adjusted for inflation. It is possible that willingness to pay has increased over the last 15 years as congestion worsened and frustration increased. However, there is no current data on willingness to pay.

A detailed disaggregation of the value of time across relevant dimensions (including income and distance travelled) might increase or reduce the value of time for different Aucklanders. As a result, Aucklanders in aggregate could have a higher or lower willingness to pay to avoid congestion than the national average (the EEM value of time).

Agglomeration and skill matching benefits

We do not estimate the agglomeration and skill matching benefits of decongestion. While the NZTA EEM provides some indicative approaches to estimating those benefits at a localised level (in response to the construction of a new motorway, for example), estimating those benefits for an entire urban area like Auckland in a robust fashion is extremely challenging and demanding.

These benefits have not been estimated by any study that has investigated the cost of congestion to the Auckland economy, but represent an upside to the benefits of decongestion we present in this report.

8.4.3. Limitation on capital productivity benefit estimates

The direct benefits of decongestion through travel time savings are largely labour supply and productivity benefits. We estimate those economic benefits to the Auckland economy in this report.

There are downstream impacts on capital and land productivity from decongestion such as the greater productivity of a depot, which has higher utilisation if the frequency of deliveries is increased as congestion is reduced.

Our estimation methodology does not estimate the direct impact of decongestion on capital productivity. We do not build a ‘capital productivity shock’ to the Freight, Trades and Postal industries. Estimating the capital productivity benefits to those industries, i.e. developing a robust ‘capital productivity shock’, would require detailed information throughout Auckland of individual businesses in those three industries.

9. Conclusion and recommendations

Decongestion would benefit the Auckland economy…

Congestion has a significant negative effect on the Auckland economy and its liveability.

We estimate the benefits of decongestion to the current network capacity in Auckland would be between $0.9 billion to $1.3 billion (1% to 1.4% of Auckland’s GDP). This range reflects the uncertainty around the effect of lower commuting times on Auckland’s labour supply.

Research to date on the impact of decongestion on labour supply is not definitive, but overall suggests lower commuting times have a small positive effect on labour supply. This leads us to believe the benefits of decongestion are more likely to be towards the lower bound of this range. However, the literature findings are from a range of cities with different levels of congestion, which limits the comparability with Auckland’s situation.

These benefits from bringing traffic flows to the current network capacity could be achieved through investment in policy initiatives such as better traffic management technologies and smart pricing.

Achieving benefits beyond this would require further investment into expanding the Auckland road network beyond what is already planned. If the average speed across the Auckland network was close or equal to the speed limit, which is considered free-flow, we estimate the benefit of decongestion at between $1.4 and $1.9 billion (1.5% to 2% of Auckland’s GDP).

Achieving free-flow speeds across the network would likely be very expensive which is why we have not chosen it as our main scenario. Our key focus is on the benefits from managing traffic flows so that the Auckland road network operates as intended.

The impact of decongestion in Auckland would flow through the wider New Zealand economy, given many regions (particularly in the North Island) depend on the Auckland transport network to operate effectively.

… and improve Auckland’s liveability

Auckland residents have been adjusting their behaviour to cope with increased congestion. Beyond the economic effects we explore here, congestion has reduced firms’ and households’ ability and willingness to travel within the Auckland region.

Decongestion would make Auckland more accessible and less polluted, thereby improving the city’s liveability. In addition to the increase in wages as a result of the Auckland economy growing faster, workers will be able to choose to spend at least a portion of their newly-found spare time with their families or on leisure activities.

There may be additional benefits from decongestion that we have not been able to estimate

Our range of estimates may be conservative due to:

- Data limitations on the spread of different travel types across the day and the value of time saved by different groups of Aucklanders
- Not including any potential benefits from decongestion at weekends
- Not modelling agglomeration and labour market matching benefits that might reasonably be expected to occur
- Leaving capital productivity unchanged in our model.

Future research may address these issues, but at this stage we suggest they represent upsides to the benefits we estimate here.

Achieving greater precision on the labour supply impacts of decongestion (both in terms of participation and productivity) will also be important for refining our estimates in the future. The existing literature is not definitive because different groups respond differently to congestion.

Throwing greater light on this would require an analysis of income distribution in Auckland, travel to work times, location choice (where to live, where to buy a house), occupation and other factors to better understand how much labour supply would increase due to decongestion.

Without investment, congestion costs will continue to rise

Congestion in Auckland, New Zealand's centre of economic gravity, is now well above that of comparable cities. This study shows that the opportunity cost of congestion is high, between 1% and 1.4% of Auckland's GDP.

And it will get worse.

Auckland Transport expects the average AM trip time to increase over the next 10 years. Hence despite planned investments to expand Auckland's network capacity, travel times are still projected to worsen over time.

The next step involves exploring how these decongestion benefits could be unlocked, and what it would cost

Investment will be required to unlock the benefits from decongestion in Auckland that we have identified, and to prevent congestion getting worse over time. Such investment decisions should be based on comprehensive cost-benefit analysis.

If the goal is robust cost-benefit analysis, future research will need to consider several questions:

- What policies or packages would reduce congestion to the capacity of the Auckland network?[8]
- What is the total cost of those policies/packages?
- Are the costs above the benefits estimated in this report?

We have estimated the benefits of decongestion to the current network capacity in Auckland. The next step would be in estimating the costs of the policies required to achieve this outcome.

8 ATAP proposes several policies, including long-term investments, to address the growing transport needs for Auckland over the coming decades. These policy options are discussed in detail in Appendix H.

While empirical challenges remain for carrying out cost-benefit analysis of policies to reduce congestion, this should not be a reason for inaction. We hope that our estimates of the potential benefits of decongestion in Auckland can act as a clarion call to lift research and policy efforts in this area.

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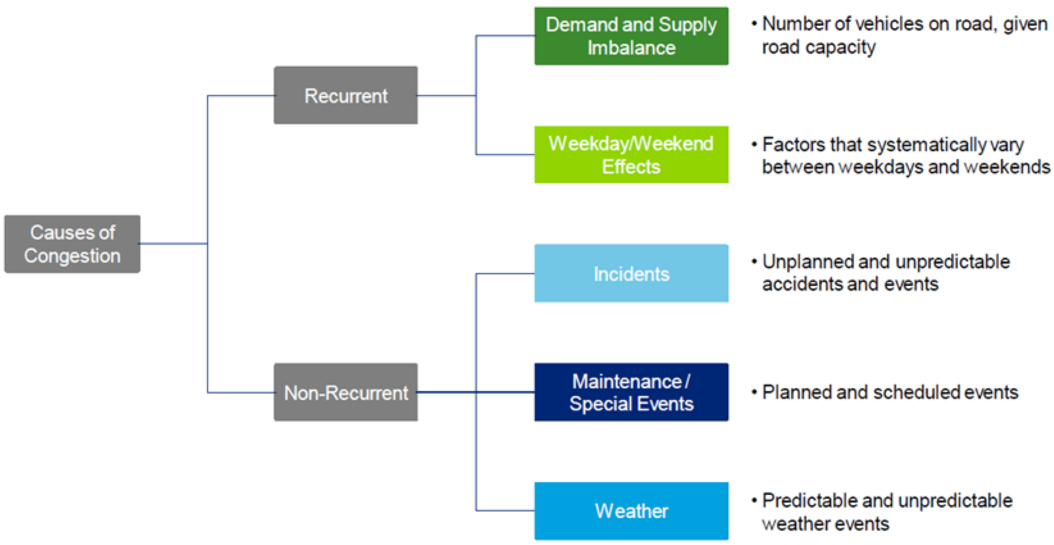
Appendix B Definition of congestion

Causes of congestion

Congestion is caused by recurrent and non-recurrent effects.

Figure 23 Causes of congestion



Source: Deloitte Touche Tohmatsu, 2016

Recurrent causes of congestion include:

- Demand and supply imbalance – number of vehicles on a road relative to the road design capacity
- Weekday effects – factors that systematically vary between weekdays and weekends that are not captured by the number of road users. This can include traffic management tools and driver behaviour which can be significantly different between weekdays and weekends (DTT, 2016).

Non-recurrent causes of congestion include:

- Traffic incidents – incidents, such as traffic accidents or signal failures, are unplanned and therefore unpredictable
- Maintenance and special events – planned events such as road closures due to roadworks or other scheduled maintenance
- Weather – rain can impact the speed of traffic, as drivers manage the risks of low visibility and road traction by reducing their speed. The secondary effect can increase the likelihood of road accidents which can further compound congestion (DTT, 2016).

Across New Zealand cities, recurrent causes of congestion have the largest impact on travel time, explaining an average of 91% of variations for the September and October

2015 data sample. Unplanned incidents explained an average of 7% of travel time variations, while rainfall and planned events each explained 1% of variations (DTT, 2016).

Our estimates of the benefits of decongestion only capture the effects of recurrent congestion. Hence our estimate is likely to be conservative in that it underestimates the impact of removing all forms of congestion from the Auckland roading network.

Definition of congestion

Engineering measures

At its most technical level, engineers use factors including speed, travel time, manoeuvrability, delay and safety to define how far away a transport network is from its optimal performance (Wallis and Lupton, 2013).

Levels of service (LoS) are defined by engineers as the range of operating conditions of the roading networks based on these factors, with A representing the best operating conditions and F the worst (see Figure 1). Each level of service corresponds to a range of traffic volume to capacity ratios, such that it shows the maximum traffic that the road can take to provide that level of service (Wallis and Lupton, 2013).

Volume to capacity (V/C) ratios are expressed in terms of vehicle per hour. If the capacity of the road is 1000 and the demand volume is 1200 vehicle, the V/C is 1200 / 1000 = 1.2.

Hence congestion is defined as the state of the current traffic situation relative to one where the roading network is operating at capacity i.e. as it was designed for (Wallis and Lupton, 2013). We use the ATAP classification of congestion described below.

Table 10 ATAP Level of service definitions

Volume to capacity ratio in terms of vehicle per hour, as stated in ranges

LoS	Description	Motorway /Express way	Local/ Arterial	Rural (flat, near speed limit)	Rural (other, lower than speed limit)
A	Free-flow conditions with unimpeded manoeuvrability. Stopped delay at signalised intersection is minimal.	<0.30	<0.26	<0.05	<0.05
B	Reasonably unimpeded operations with slightly restricted manoeuvrability. Stopped delays are not bothersome.	0.30 < 0.48	0.26 < 0.43	0.05 < 0.15	0.05 < 0.17
C	Stable operations with somewhat more restrictions in making mid-block lane changes less than LoS B. Motorists will experience appreciable tension while driving.	0.48 < 0.70	0.43 < 0.62	0.15 < 0.30	0.17 < 0.33
D	Approaching unstable operations where small increases in volume produce substantial increases in delay and decreases in speed.	0.70 < 0.90	0.62 < 0.82	0.30 < 0.46	0.33 < 0.58

LoS	Description	Motorway /Express way	Local/ Arterial	Rural (flat, near speed limit)	Rural (other, lower than speed limit)
E	Operations with significant intersection approach delays and low average speeds.	0.90 < 1	0.82 < 1	0.46 < 0.9	0.58 < 1
F	Extremely low speeds caused by intersection congestion, high delay and adverse signal progression.	> =1	> =1	>= 0.9	> =1

Source: NZTA

We adopt the engineering measure of congestion in estimating the benefits of decongestion which defines congestion as the state at which demand for the road exceeds its capacity, consistent with the approach of Wallis and Lupton (2013).

Economic measures

In contrast to engineers' focus on the capacity of the roading network, economists define congestion based on what the optimal level of traffic should be. This could either be free-flow or a level of traffic at which people can travel at their desired speeds i.e. perceived congestion (Wallis and Lupton, 2013).

The most common measure of the cost of congestion estimates the cost of travel relative to a free-flow, which is equivalent to making the trip early in the morning (Wallis and Lupton, 2013). Wallis and Lupton (2013) cite the Australian Bureau of Transport and Communications Economics definition of congestion from 2000:

> *A definition of the cost of congestion based on the difference between current and hypothetical uncongested conditions is easy to understand, and appears to be a natural measure of the scale of the problem. Unfortunately, from the point of view of policy, it is a dead end. Eliminating congestion is not possible, and the cost of congestion, estimated in this way, provides no pointers to an improved use of the road network.*

It is not practical or an efficient use of resources to have the roading networks at free-flow. It would mean that the network would be under-utilised (Wallis and Lupton, 2013).

Appendix C List of interviewees

The interviewees for this project were:

- Phill Roddick, Auckland Metro Manager, Toll
- William McLaren, Operations Supervisor, Green Gorilla
- Jim Jackson, Managing Director, Jackson Electrical
- Mark Boyle, GM, Upright Access
- Ward Austin, National Transport Operations Manager, GBC Winstone.co.nz
- Paul Holdom, Project Manager, Gleeson & Cox Transport Limited
- David Lowe, Chief Executive, Stevenson Construction Materials
- Mandy Mellar, GM NZ, AA Battery Service
- Kirk Doran, Business Development Manager, Schindler Lifts (or a representative)
- Sheridan Broadbent, Chief Executive, Counties Power Ltd
- Sam Peate, General Manager Coaching and Auckland Tourism, InterCity Group
- Ben Thompson, Domestic Logistics Manager, The Warehouse Ltd
- Richard Moorcroft, National Road Operations Manager, NZ Post
- Geoff Jones, Managing Director, Geoffs Freight
- Martin Carlyle, Chief Executive Officer, Damar Coating, Chemicals and Aerosols
- Mitch Cooper, Public Policy & Government Relations, Uber

Appendix D CGE model description

CGE models are now our preferred method for assessing economic impacts and are used extensively in New Zealand and internationally. As a recent commentator noted regarding CGE modelling "a well-designed model that is used by skilled practitioners to shed light on issues the model was designed to illuminate can make a significant contribution to policy debates and decision making".[9]

Using actual economic data, CGE models estimate how an economy reacts to major projects or changes in policy, technology or other external factors. CGE models are useful whenever we wish to estimate the effect of changes in one part of the economy upon the rest of New Zealand.

CGE modelling is widely regarded as more robust and providing more credible impact assessments than input-output ('multiplier') methodologies.[10] Multiplier methodologies over-state economic impact estimates because they assume that economic resources such as land, labour and capital are infinitely available, are never idle or can be reallocated without adjustment costs.

NZIER's regional model

NZIER's regional CGE model TERM-NZ[11] is a bottom-up model of the regions in the New Zealand economy.

TERM-NZ is based on Statistics New Zealand's Input-Output table that identifies the structure of the industries involved. TERM-NZ contains information on 106 industries, 201 commodities and 15 regions.

In the TERM-NZ model, each of fifteen regions is modelled as its own economy, but all the regions are linked via inter-regional trade and flows of capital and labour. National results can be shown by the summation of the regional results.

TERM-NZ offers a unique capability to show how developments like that proposed for road decongestion would impact on Auckland region and New Zealand.

A visual representation of TERM-NZ is shown in Figure 24. It highlights how the model can capture the complex and multidirectional relationships between the various parts of each regional economy and how they interact with the rest of New Zealand and rest of the world.

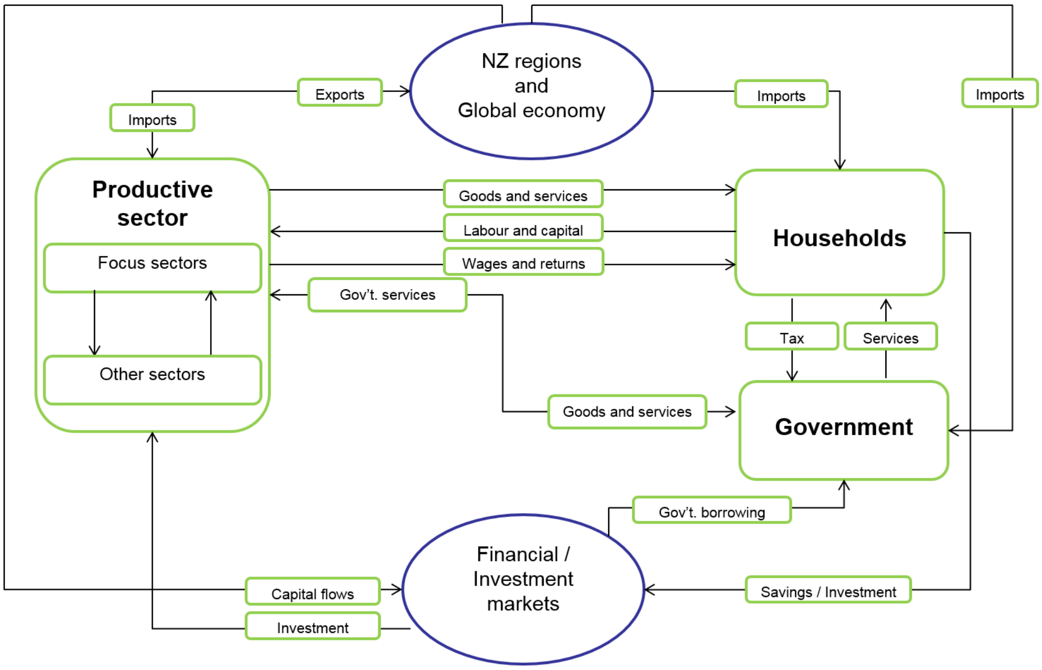
9 Denniss, R. (2012) *The use and abuse of economic modelling in Australia*, Australia Institute Technical Brief No. 12.

10 See Gretton, P. (2013) *On Input-output Tables: uses and abuses*. Australian Productivity Commission Staff Research Note for a thorough discussion of what multipliers are, how they are constructed and their short-comings as tools for assessing economic impacts.

We also note that the Australian Bureau of Statistics has ceased to provide multiplier estimates from its input output tables. http://www.abs.gov.au/ausstats/abs@.nsf/Previousproducts/5209.0.55.001Main%20Features4Final%20release%202006-07%20tables?opendocument&tabname=Summary&prodno=5209.0.55.001&issue=Final%20release%202006-07%20tables&num=&view=

11 TERM-NZ stands for "The Enormous Regional Model" of the New Zealand economy. It was developed at NZIER by Dr. Erwin Corong based on the original Australian TERM model created by Professor Mark Horridge of the Centre of Policy Studies, Victoria University-Melbourne, Australia. http://www.copsmodels.com/term.htm. NZIER maintains close connections with the Centre, ensuring that our modelling techniques reflect international best-practice.

Figure 24 A CGE model shows the whole economy



Source: NZIER

Modelling approach and results interpretation

We use the static version of our CGE model, so that we compare the economy before and after the transport productivity shock is applied. There is no time dimension in the static model, so we do not look at how the economy adjusts to a new equilibrium.[12]

We assume a long run model closure in which national employment and the long-run rates of return to capital are held constant. Labour market adjustments occur through wage movements and job shifts between sectors and regions, but the total amount of employment in the New Zealand economy remains steady. The capital market adjustment occurs through capital accumulation (i.e. investment) and industry-specific rates of return are held constant.

Results are reported as percentage changes from the counterfactual, in which no transport productivity improvement has occurred. To make it easier to understand we also quantify some variables in dollar values.

[12] These fluctuations may have significant impacts and could be captured in future research by using our more sophisticated, dynamic CGE model.

Appendix E Further literature review on the impact of congestion

Congestion's effects on emissions

The combustion of fossil fuels in road transport produces vehicle emissions which have negative environmental and public health impacts. However, the introduction of newer vehicle technology has led to decreased vehicle emissions in Auckland despite an increase in congestion and road transport use (Sridhar et al, 2014).

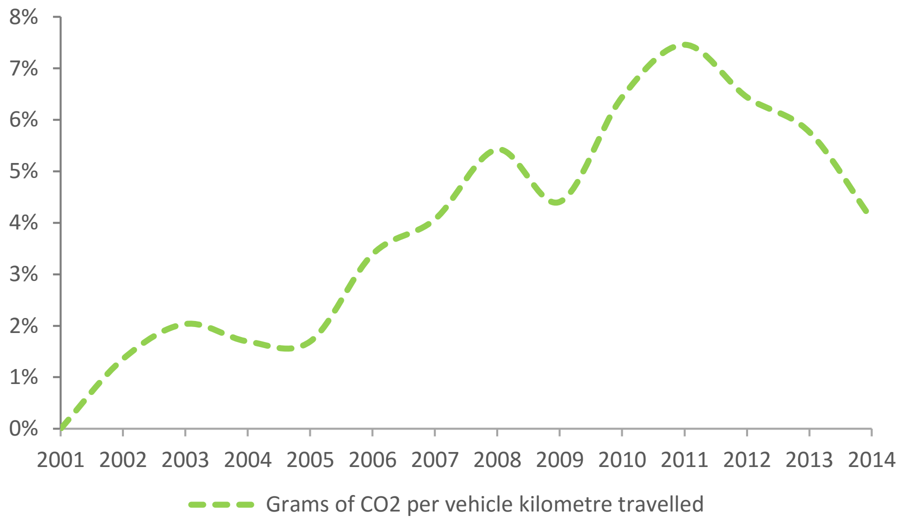
Congestion can potentially exacerbate the problems by increasing fuel consumption, idling and driver behaviour that increase the level of emissions compared with an uncongested state. Estimating the air quality benefit of decongestion is fraught with complexity because the extent of the current effect of congestion-related emissions is not clear. It depends on the vehicle type, vehicle technology, duration and severity of congestion.

Environmental impacts

Road transport contributes 91% of the estimated emissions from transport. Over time the average level of emissions per kilometre travelled in new registrations has decreased as better technology and emissions standards enter the vehicle. The overall effect is a decrease in the emissions per vehicle kilometre travelled since 2011.

Figure 25 Change in road transport CO_2 emissions per km travelled

Compared to 2001



Source: Ministry of Transport

Congestion and emissions

The relationship between congestion and vehicle emissions depends on the type of vehicle, the severity of congestion, the age of vehicles (technology) and driver behaviour.

The combination of these variables means estimates of the effect of congestion on emissions can vary significantly.

Congestion can lead to an increase in vehicle emissions in three ways:

- Congestion increases vehicle running time which causes an increase in fuel consumption and the resulting vehicle emissions (De Vlieger et al, 2000).
- The efficiency of fuel consumption decreases at low speeds, which means emissions increase in very congested conditions.
- Driving dynamics impact on the efficiency of fuel consumption and emissions (Zhang et al, 2011). The stop-go nature of severe congestion includes periods of rapid acceleration and braking. Rapid acceleration causes excessive fuel consumption at suboptimal fuel efficiency levels, which increases emissions. Braking produces particulate matter from wear and tear on the brakes.

CGE modelling of congestion

Previous overseas studies that have modelled the effects of congestion with CGE models have largely focused on a business as usual (BAU) path of congestion, versus either projected growth in congestion, or policy intervention in the form of investment and/or taxes.

A study prepared for The Sydney Morning Herald by the Centre for International Economics (CIE) modelled the effects of congestion at 2005 levels, relative to projected growth in congestion in 2020. It estimated a cost of AU$144 million from a decline in labour supply and workplace disruptions, and AU$121 million from travel delays and unavailability of vehicles because of projected growth in congestion (CIE, 2005). Such modelling requires assumptions about the projected growth of congestion to be made.

Other studies have sought to model the effects of policy interventions on congestion, with some attempting to quantify this cost. One study models the effects of investment in transport infrastructure on the German economy. It finds an improvement in efficiency, as reflected in lower growth in the “congestion index”, relative to no increase in transport capital (Conrad and Heng, 2000).

Other CGE modelling of transport policies do not explicitly account for congestion, given the complexity in defining the effects. No previous study that we are aware of has focused on modelling the downstream effects on an economy, based on the current congested state relative to an uncongested state.

Appendix F Benefit estimation methodology

This Appendix summarises how we estimate the benefits of decongestion for Auckland. We apply NZTA's EEM approach as did Wallis and Lupton (2013).

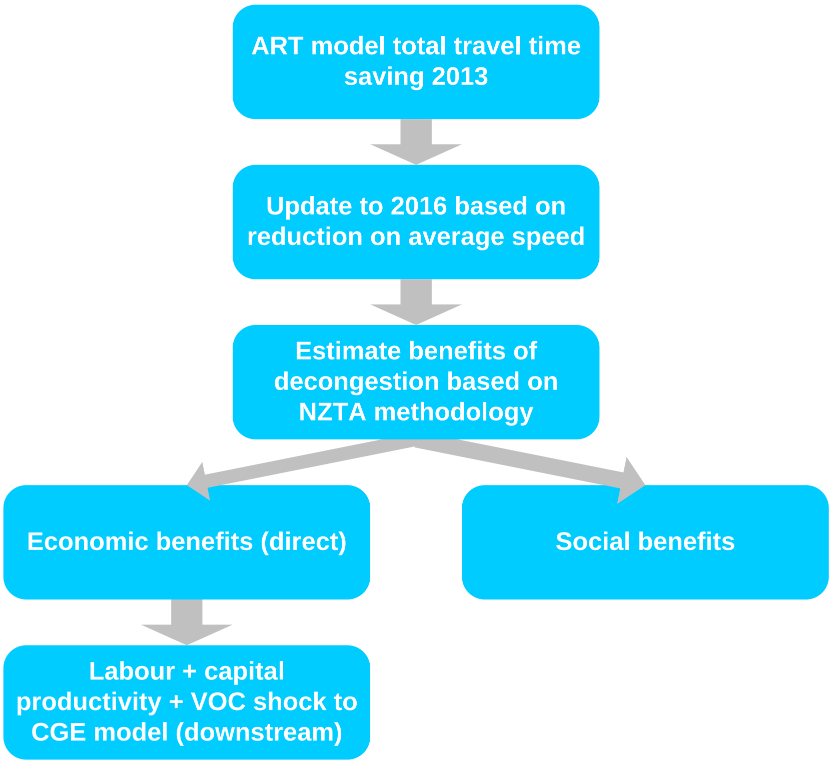
Summary of the approach

Figure 26 summarises the approach to estimating the benefits of decongestion to Auckland. We provide further detail for each stage of the approach.

Our estimate of the benefits of decongestion begins with the Auckland Transport's ART model which estimates total travel times savings in Auckland if the network was operating at capacity and at free-flow. The ART model is calibrated for the year 2013. The update of the ART model from 2013 to 2016 is based on confidential Auckland average speed data provided by BECA and the Ministry of Transport.

Using the ART model results for 2016, we replicate the Wallis and Lupton (2013) approach to the estimate the benefits of decongestion which is consistent with the EEM. The economic benefits to commuters as well as freight, trades and postal industries in the form of productivity gains (or rising labour supply for commuters) are then used as inputs to our CGE model. The economic benefits, estimated based on the Wallis and Lupton (2013) approach effectively become shocks to the Auckland economy which then leads to further downstream benefits to the remaining Auckland industries.

Figure 26 A summary of the approach to estimating the benefits of decongestion to Auckland

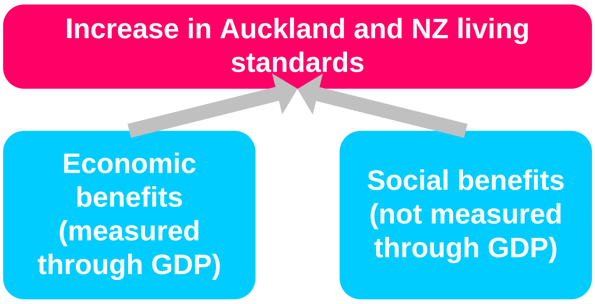


Source: NZIER

Overview of the benefits

We estimate the impact of decongestion which lifts the living standards of Aucklanders and New Zealanders. A rise in living standards can be broken down into economic (measured through GDP) and social (not measured through GDP) measures.

Figure 27 Two broad categories of benefits



Source: NZIER

The following table summarises the benefits estimated categorised into economic and social benefits.

Table 11 Summary of benefits from decongestion

Group	Benefits
Economic	Labour supply increase Labour productivity (freight, trades, postal) Capital productivity (freight, trades, postal) Vehicle operating costs
Social	Reduced commuting times Environmental Schedule delay

Source: NZIER

Total travel time savings estimates

The estimates of the travel time savings across the Auckland network if it was at capacity and free-flow are derived from Auckland Transport's ART model.

The ART model's two main relevant features for this analysis are that it:

- Is multimodal and includes private and public transport modes, daily trip generations and assignment of trips in the AM peak, inter-peak and PM peak periods. Multiple trip purposes are modelled
- Splits private and public transport modes but the public transport modes are only split into rail, ferry and bus at the assignment stage (ATAP, 2016).

The following table summarises the model results for the uncongested and free-flow scenario against the currently congested Auckland network for the AM (morning) peak.

The interpretation of the ART model outputs for the network at capacity and free-flow scenarios are, respectively

Network at capacity

- The number of vehicle trips and vehicle kilometres travelled remain constant as well as the capacity of the network
- It is assumed that the demand during the peak AM two hours is limited to the capacity of the network and the remainder of the trips are assumed to be accommodated outside the peak two hours thereby matching the capacity of the network across the day
- This is considered the most appropriate measure of an uncongested state against which to estimate travel time savings, given it represents how the network is designed to operate.

Free-flow

- The number of vehicle trips remains constant. It is assumed that the capacity of the network is increased to enable faster speeds
- We set the average speed across the network at the average speed to which vehicles would travel if the number of trips was 10% of the total number of trips in the congested scenario

- The free-flow scenario is hence based on speeds that would be possible only in the very early hours of the morning when vehicle volumes are well below capacity
- Free-flow total VKTs are slightly lower as result of having more ability to do direct trips as opposed to small re-routing to avoid congestion.

Table 12 Estimate of time lost from congestion (AM peak)

2016

Item	Congested (existing)	Network at capacity	Network at free-flow
Average speed (km/h)	41.2	50.5	56.8
Average trip time (minutes)	14.6	12.0	10.6
Total travel time (minutes)	7,371,234	6,016,045	5,341,362
Relative time to congested		1,355,189	2,029,872

Source: NZIER

Table 13 Detailed level of service across the network

Volume to capacity ratio in terms of vehicle per hour

Level of service	Motorway/Expressway	Local / Arterial	Rural (flat, near speed limit)	Rural (other, lower than speed limit)
A	<0.30	<0.26	<0.05	<0.05
B	0.30 < 0.48	0.26 < 0.43	0.05 < 0.15	0.05 < 0.17
C	0.48 < 0.70	0.43 < 0.62	0.15 < 0.30	0.17 < 0.33
D	0.70 < 0.90	0.62 < 0.82	0.30 < 0.46	0.33 < 0.58
E	0.90 < 1	0.82 < 1	0.46 < 0.9	0.58 < 1
F	> =1	> =1	>= 0.9	> =1

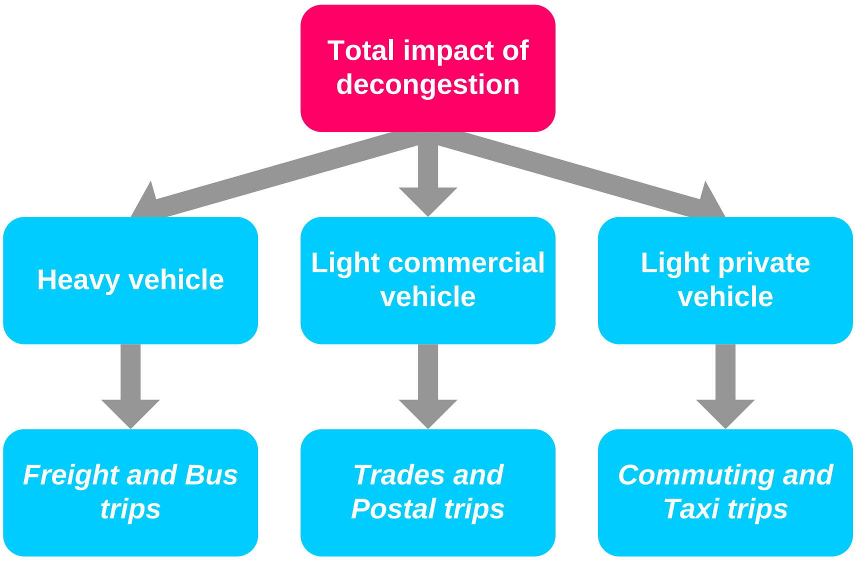
Source: Auckland Transport personal communication

Decomposing total travel time savings by vehicle type

Estimating the benefits of decongestion requires a robust decomposition of the different value of time that Aucklanders place on time lost due to congestion. The most important distinction being trips which are for work and trips which are for non-work purposes (as the value of time is much for higher for those working in their vehicle).

We decompose Auckland traffic volumes into three vehicle types which act as proxy for different trip purposes which is summarised in the following figure.

Figure 28 Decomposing the Auckland traffic volume into vehicle type



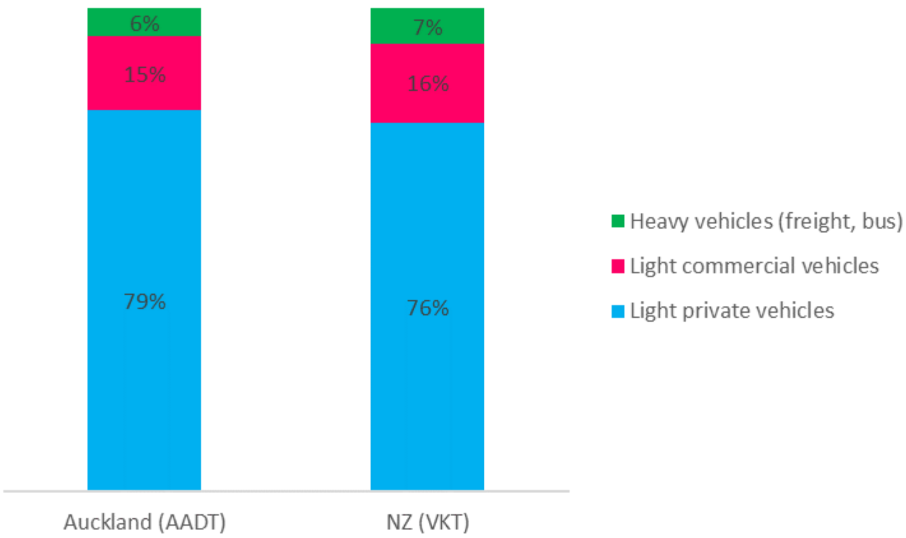
Source: NZIER

Most trips over the Auckland network are made in light private vehicles, which is largely commuting but also includes a small share of work trips (2% out of the total 79% for light private vehicles). The remaining 21% is shared between light commercial vehicles (15%) and heavy vehicles (5.8%).

We estimate the proportion of buses of total heavy vehicles based on the national share of buses to the share of total heavy vehicle kilometres travelled (buses account for 9.7% of total heavy vehicle VKT nationally). Hence the share of buses to the overall Auckland network in Average Annual Daily Traffic (AADT) terms is 0.56%.

Figure 29 Decomposing the Auckland traffic volume into vehicle type

Auckland AADT in 2015; NZ VKT for 2015



Source: Auckland Transport, NZTA, MOT

Value of time by vehicle type

Decomposing total Auckland traffic volumes by vehicle type allows us to apply a different value of time reflecting the purpose of their respective trips.

The formula to estimate the travel time savings from decongestion is

Total travel time savings =
base travel time benefits for improved flow
+ travel time benefits for reduced traffic congestion
+ travel time benefits for improved trip reliability.

Table 14 summarises the value of time used for each vehicle and trip purpose where applicable.

Table 14 Value of time by vehicle type and trip purpose

Cost per hour

Cost item	Heavy	Light commercial	Light private (work trip)	Light private (commute)	Bus (driver)	Bus (Passenger)
Driver	$20.1	$23.5	$23.9	$7.8	$20.1	NA
Passenger	$3.7	$4.3	$4.3	$1.2	$-	$126.4
Freight cost	$19.9	$1.7	NA	NA	NA	NA
Sub-total	*$43.7*	*$29.5*	*$28.2*	*$9.0*	*$20.1*	*$126.4*
Congestion increment	$3.6	$3.6	$31.8	$12.6	$3.2	$63.2
Reliability increment	$50.1	$35.0	$33.6	$13.2	$24.6	$197.8
Adjusted using NZTA's update factor (2016)	$72.7	$50.8	$48.8	$19.1	$35.6	$286.9

Source: NZTA, NZIER

The EEM provides value of time in 2002 prices. The update factor for 2016 prices is 1.45 (NZTA, 2016). As per ATAP, we assume 1.2 occupants (1 being for driver and 0.2 for passenger) per vehicle (ATAP, 2016).

We estimate the combined value of time for light private vehicles for work and commuting trip purposes. We assume 97.6% of light private vehicle trips are for commuting based on estimates from Wallis and Lupton (2013) and the NZTA's EEM.

Table 15 Light private vehicle traffic distribution by purpose

2016

Trip purpose	Share of trips	Value of time
Commuters	97.6%	$19.10
Work purposes	2.4%	$48.78
Combined	100.0%	$19.82

Source: NZIER, NZTA

We assume the following occupancy (number of passengers) for Auckland buses based on estimates from Castalia. The number of buses by type is drawn from Auckland Transport information.

Table 16 Bus travel time saving estimation supporting information

Bus type	Average occupancy	Number of buses
Single deck 2 axle	23.98	761
Single deck 3 axle	31.56	476

Source: Castalia, Auckland Council personal communication

Economic benefits

To build the shocks (direct benefits) of decongestion we then apply the following two steps simply multiply the total travel time saved by vehicle type (determined by the decomposition of the Auckland traffic by vehicle type) by their respective value of time.

Step 1: Estimate value of total travel time saved for each vehicle type and trip purpose =
*Total travel time saved from ART model **
*Share of Auckland traffic per vehicle type and trip purpose (Figure 28) **
*Value of time per vehicle type and trip purpose specific**
Annualisation factor

Step 2: Productivity shock estimate to input in CGE model in % change =
Estimate value of total travel time saved for each vehicle type and trip purpose /
(Wages paid + return on capital for the respective freight, trades, and postal industries).

The labour supply impact estimate follows the same methodology but differs because it is estimated for each 106-individual industry in the Auckland economy. The wages paid and return on capital figures are based on Statistics New Zealand's 2013 Input-Output table regionalised to the Auckland economy and updated for 2016.

The following table summarises the shocks for each vehicle type, to which industry it applies to, and the nature of the shocks.

Table 17 Direct productivity benefits (shocks) to the Auckland economy modelled through our CGE model

Vehicle	Industry shocked	Nature of shock
Light private	All Auckland industries	Labour productivity shock (increase in labour supply)
Light commercial	Postal services Construction services (trades)	Labour and capital productivity shock (time savings from decongestion and increased reliability which reduces the use of inventories) Intermediate productivity shock (vehicle operating costs benefits)
Heavy	Road transport (largely freight but includes PT buses)	

Source: NZIER

Labour supply increase

The NZTA's EEM defines labour supply changes as Wider Economic Benefits (WEBs) to transport investments.[13] The EEM provides procedures outlining how to quantify labour supply changes which are summarised in the following table.

Table 18 EEM recommended approach to estimating labour supply responses

EEM step	Our approach
Step 1: Calculate commuting costs	Estimation of the value of time in extra commuting travel time
Step 2: Labour supply response	Apply Treasury's labour supply elasticity of 0.31
Step 3: Gross labour supply impact	Estimated through CGE modelling
Step 4: Net labour supply impact	Estimated through CGE modelling

Source: NZTA, 2016

The following table provides the calculations for the labour supply increase in the Banking and financing industry in Auckland as an example of the estimation approach we apply for each industry in Auckland. We replicate this approach for each industry which provides the potential labour supply response in Auckland from shorter commuting times as a result of decongestion and use this as the basis for the upper bound estimate of total benefits from decongestion.

13 Care must be taken not to double count benefits, as the traditional benefits and WEBs are not necessarily completely separate from each other. However, international research has shown that the issue of double counting is not as prevalent as initially anticipated (Wallis and Lupton, 2013).

Table 19 Banking and financing; financial asset investing example

Light private vehicles commuting example

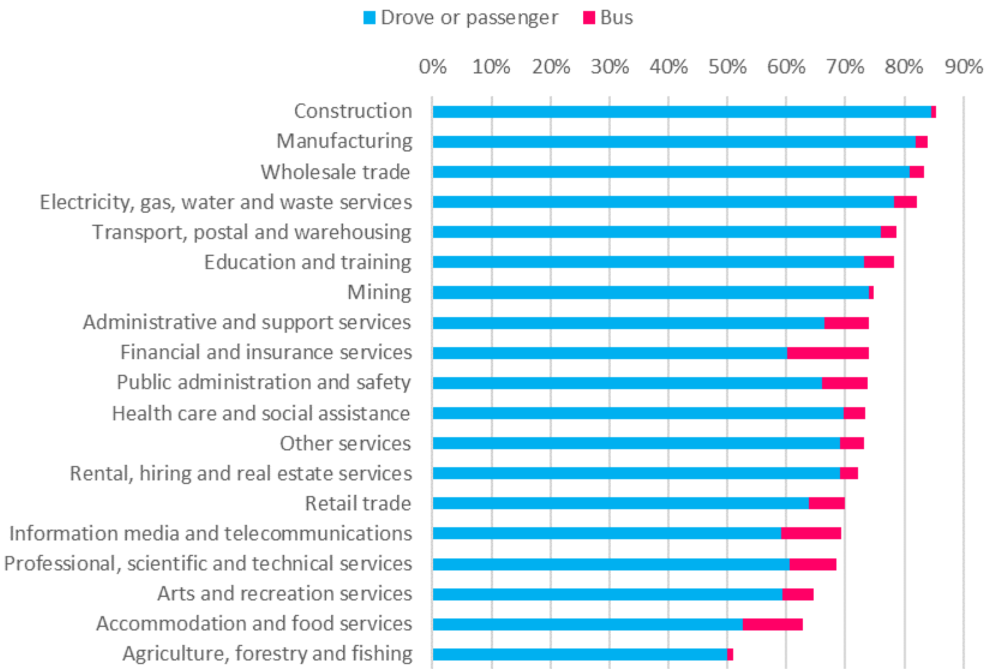
Row	Item	Value	Source
1	Banking employment (2016)	14,570	Statistics New Zealand
2	Share of banking employees which commutes using road (2013)	60%	Statistics New Zealand
3	Total banking employment affect by decongestion	8,756	
4	Share of total employment affected by decongestion	1.8%	
5	Allocation of travel time savings in minutes	18,802	1.8%*total travel time savings allocated to light private vehicles from ART model
6	Convert into hours	313	
7	Banking and financing average hourly wage	$54	
8	Daily maximum increase in wages	$24,665	
9	Annualised	$13,213,402	
10	Auckland banking industry total annual wages	$1,566,042,969	
11	% maximum increase in wages	0.84%	
12	% increase in labour supply	0.26%	Application of the Treasury labour supply elasticity

Source: NZIER

We account for commuting travel time savings for both light private vehicles and buses.

Figure 30 Share of Auckland workers who drove, were a passenger or took the bus to work by industry

Proportion of workers in the Auckland region; Census 2013



Source: Statistics New Zealand

The ART model produces travel time savings only for the typical AM peak. To annualise the estimated labour supply response the benefits need to be scaled by the number of working days (250 days). Secondly, the time savings at the Interpeak and the PM peak are also annualised while recognising the lower delays (and therefore lower impact of congestion) at those times relative to the AM peak.

Table 20 Light private vehicles annualisation factor calculations

Item	AM Peak	Interpeak	PM Peak	Calculation	Source
Minute delay by km (2015)	0.77	0.25	0.63		MOT
Relative to AM delay	100%	32%	82%	Interpeak and PM peak relative to AM peak	MOT
Light private vehicle annualisation factor	250	81	205	Annualisation factor by time of the day	
Total		536		Annualisation factor	

Source: NZIER

We use the Treasury recommended labour supply elasticity of 0.31 (Creedy and Mok, 2017). NZTA recommends to use a labour supply elasticity of 0.4 (Kernohan and Rognlien, 2011). But this estimate is drawn from various studies which are now outdated.

We use a labour supply elasticity of 0.31 (as per NZTA recommended approach but use Treasury's updated elasticity estimate) which acts as the upper bound labour supply response estimate. We estimate the labour supply increase for all 106 industries in the Auckland economy which are available in the CGE model as per the Banking industry example above. The increase in labour supply estimated for each industry is then used as input shock to the labour for each industry in the Auckland economy.

Aggregated across all 106 Auckland industries, the total increase in labour supply for the network at capacity and free-flow is estimated at $132 million and $198 million, respectively. Hence the estimated total increase in labour supply from decongestion in Auckland is 0.317% if the network was operating at capacity (which will include a combination of an increase in labour force participation and of higher productivity employees and increased wages).

Table 21 Total increase in Auckland labour supply (upper bound estimate only)

$ millions; 2016

Measure	Capacity	Free-flow
Total Auckland wages paid	$41,569	$41,569
Total increase in labour	$132	$198
% increase in Auckland labour supply	0.317%	0.475%

Source: NZIER

ATAP puts an emphasis on the improvement to job accessibility from different policies (or packages). The benefits from job accessibility are hard to precisely measure. They are an argument of labour market efficiency and could be benefits through:

- Better skills matching
- Retaining workforce (ATAP, 2016).

These benefits are not quantified in our approach.

Labour and capital productivity (freight, trades, postal)

The methodology to estimate the value of time lost to congestion for freight, trades and postal is the same as for commuters. The following table summarises the annualisation methodology of the AM benefits of decongestion for heavy and light commercial vehicles.

Table 22 Commercial (Heavy and LCV) annualisation factor

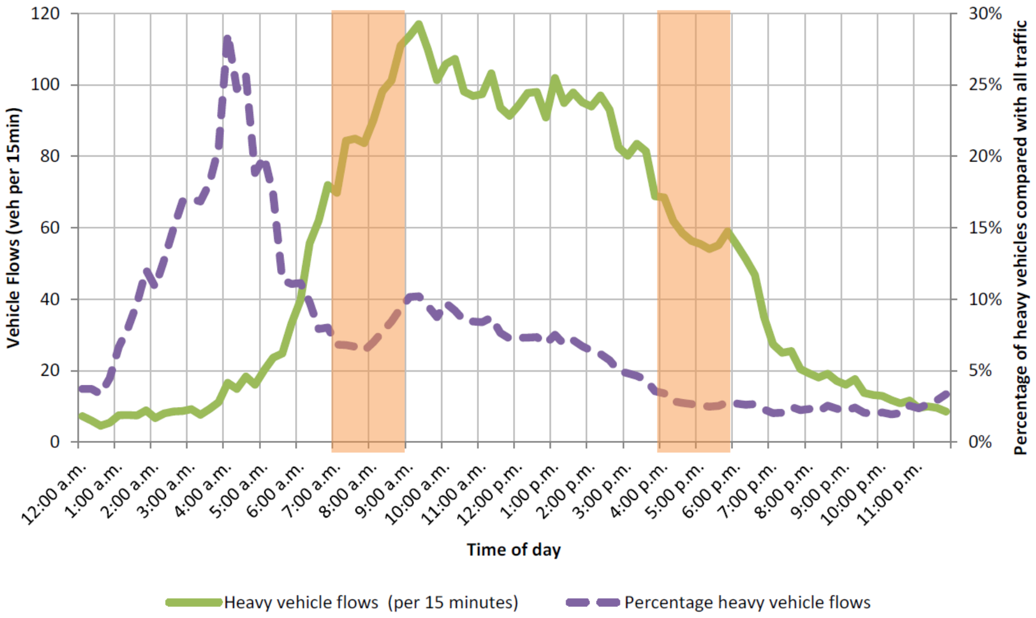
Row	Item	AM Peak	Interpeak	PM Peak	Calculation	Source
1	Minute delay by km (2015)	0.77	0.25	0.63		MOT
2	Relative to AM delay	100%	32%	82%	Interpeak and PM peak relative to AM peak	
3	Minutes saved	1,355,189	439,996	1,108,791	Scale AM ART model estimated AM peak savings to Interpeak and PM peak	ART model
4	Share of total traffic	6%	7%	4%	Share of heavy vehicles to total traffic	BECA (shown below)
5	Heavy vehicles share of total traffic	80,888	31,961	44,352	Row3*Row4	
6	Share of total cost by time of day	51%	20%	28%	Share of total minutes saved across the day	
7	Relative to AM	100%	40%	55%	Total minutes saved relative to AM	
8	Commercial annualisation factor	250	99	137	Annualisation factor by time of the day	
9	Total		486		Heavy and LCV annualisation factor	

Source: NZIER

The data for row 4 of the table above is sourced from research undertaken by BECA. It is the only available source for the distribution of heavy vehicle flows across the day on the Auckland network. BECA's survey coverage only includes the Auckland Harbour Bridge (AHB) which we take as representative of the Auckland network.

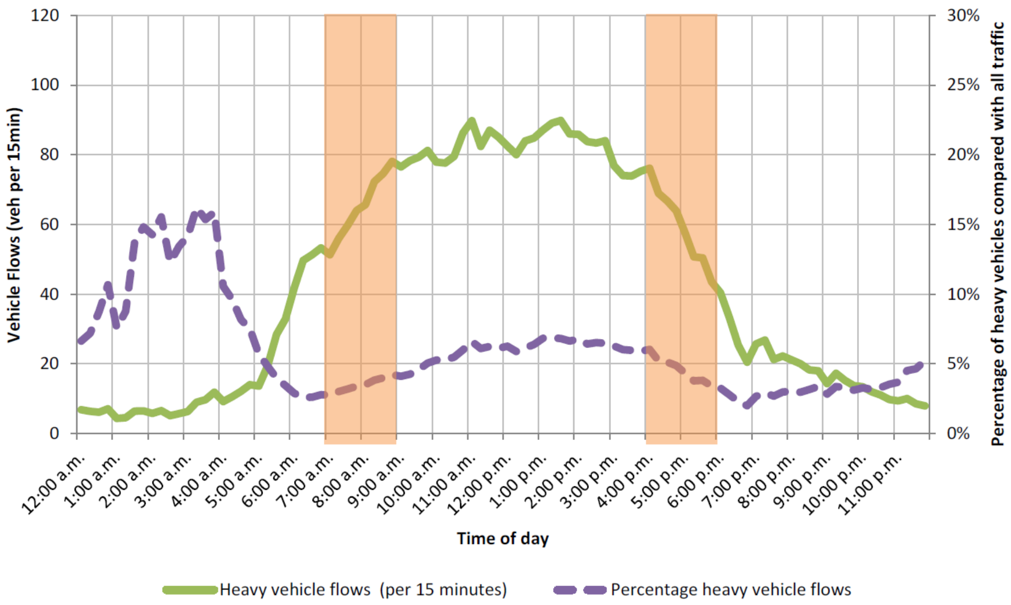
Heavy vehicles tend to avoid the AM and PM peaks. Between 3am and 5am, before the peak commuter period starts, the number of trucks heading north over the bridge reaches 25% of total traffic (despite total traffic volumes being small) (BECA, 2015).

Figure 31 AHB heavy vehicle proportions – northbound, average weekday flows



Source: BECA, 2015

Figure 32 AHB heavy vehicle proportions – southbound, average weekday flows



Source: BECA, 2015

The difference in time of travel for heavy vehicles explains the difference in the annualisation factor between commuters and heavy vehicles: heavy vehicles tend to travel when congestion is subdued. We assume that heavy and light commercial vehicles have the same distribution of time of travel across the day as no data is available for light commercial vehicles.

Table 23 Summary of productivity benefits (shocks)

$ millions; 2016

Shock	Network at capacity productivity shock ($)	Network at capacity productivity shock (%)	Free-flow productivity shock ($)	Free-flow productivity shock (%)
Trade and postal (light commercial vehicles)	$84.4	2.63%	$126.4	3.94%
Freight (heavy commercial vehicles)	$44.3	3.91%	$66.4	5.85%

Source: NZIER

Vehicle operating costs

We follow the methodology from Wallis and Lupton (2013) and assume that the vehicle operating costs (VOC) component of the cost of congestion is 6% of the travel time saving. This share includes the congestion but not the reliability increment. Furthermore, the EEM manual provides a separate update factor for vehicle operating costs for 2016 from 2002 prices which is 1.85 (NZTA, 2016).

The benefits from lower vehicle operating costs are then modelled through lower spending on fuel, tyres, maintenance and lower vehicle depreciation for households and through lower cost of intermediate inputs to production for the freight, trades and postal industries.

Table 24 Vehicle operating costs benefits

$ millions

Vehicle type	Capacity ($)	Capacity (%)	Free-flow ($)	Free-flow (%)
LPV	$15.25	0.39%	$22.85	0.58%
LCV	$6.09	0.15%	$9.13	0.22%
Heavy	$3.20	0.21%	$4.79	0.31%
Total	$24.54	NA	$36.76	NA

Source: NZIER

Social benefits

Social benefits are reported as estimated using the Wallis and Lupton approach which follows NZTA’s EEM. They are not benefits which accrue to a particular industry as they do not directly raise GDP. Hence social benefits are not inputs to the CGE model but they can nonetheless be valued following the EEM guidelines.

Lower commuting times

Table 25 summarises the benefit from lower commuting times. There is no double count across economic and social benefits. The social benefit of reduced commuting times is estimated using the NZTA EEM value of time and is therefore a willingness to pay for reduced travel times by the commuter.

The travel time savings for work purpose trips (Freights, Trades and Postal) are not included in this estimate and are solely economic benefits (and hence used as an input into the CGE model to estimate downstream impacts).

Finally, the labour supply response is modelled separately from lower commuting costs as those benefits are not based on willingness to pay but on the labour force response (either through the income or substitution effect) from potentially increasing productivity and wages. Furthermore, we allow the labour supply response to be small in the range provided by our headline estimate to allow for the uncertainty around the labour supply response to shorter commuting times.

Table 25 Annual benefit of lower commuting times

$ millions

Estimate	Benefits
Capacity	$209.1
Free-flow	$313.1

Source: NZIER

Environmental

Decongestion will reduce fuel consumption and hence GHG emissions. We follow the methodology from Wallis and Lupton (2013) which shows changes in carbon emissions are likely to be valued at around 8% of any changes in VOC.

Table 26 Annual benefit from lower emissions

$ millions

Estimate	Benefits
Capacity	$2.0
Free-flow	$2.9

Source: NZIER

Schedule delay

We follow the methodology from (Wallis and Lupton, 2013) who estimate the schedule delay cost of congestion to be 65-70% of travel time cost. We estimate the schedule delay cost at 67.5% of travel time savings.

Table 27 Annual benefit from schedule delay

$ millions

Estimate	Benefits
Capacity	$228.0
Free-flow	$341.5

Source: NZIER

Summary of estimated benefits from decongestion

Table 28 Summary of estimated benefits of decongestion excl. downstream impacts

$ millions

Group	Benefits to/from	Network at capacity	Network at free-flow
Economic (shocks only and hence excl. downstream benefits)	Labour supply	$132	$198
	Trade and postal	$84	$126
	Freight	$44	$66
	Vehicle operating costs (total)	$25	$37
Social	Lower commuting times	$209	$313
	Emissions	$2	$3
	Schedule delay	$228	$342
Total		**$724**	**$1,085**

Source: NZIER

Appendix G Detailed modelling results

This Appendix provides detailed results from the impact of decongestion on the Auckland and New Zealand economy. The New Zealand economy grows by less than the Auckland economy because the structure of our regional CGE model is predicated on constrained resources.

Productivity gains in the Auckland economy draw resources from other regions as the returns are now larger in Auckland than without decongestion. This effect dampens the net benefit of decongestion in Auckland to the rest of the New Zealand economy, but the effect is still positive.

This is a standard result in regional CGE modelling.

Table 29 Headline Auckland results, lower bound (no labour supply response to shorter commuting times)

Percentage change

Variable	Network at capacity	Free-flow	Network at capacity	Free-flow
	Auckland		New Zealand	
Real household expenditure	0.47%	0.70%	0.12%	0.18%
Real investment	0.55%	0.83%	0.14%	0.21%
Export volume	0.36%	0.54%	0.17%	0.25%
Import volume	0.40%	0.60%	0.07%	0.10%
Real GDP	0.52%	0.79%	0.13%	0.19%
Aggregate employment	0.17%	0.26%	0.00%	0.00%
Average real wage	0.31%	0.47%	0.15%	0.23%
Aggregate capital stock	0.54%	0.81%	0.14%	0.21%
GDP price index	-0.21%	-0.32%	-0.09%	-0.13%
CPI	-0.14%	-0.21%	-0.08%	-0.12%
Export Price Index	-0.07%	-0.11%	-0.03%	-0.05%
Nominal household expenditure	0.32%	0.48%	0.04%	0.06%
Nominal GDP	0.31%	0.46%	0.04%	0.06%

Source: NZIER

Table 30 Headline Auckland results, upper bound (with labour supply response to shorter commuting times)

Percentage change

Variable	Network at capacity	Free-flow	Network at capacity	Free-flow
	Auckland		New Zealand	
Real household expenditure	0.76%	1.15%	0.22%	0.34%
Real investment	0.91%	1.37%	0.25%	0.38%
Export volume	0.77%	1.16%	0.34%	0.51%
Import volume	0.65%	0.99%	0.13%	0.20%
Real GDP	0.90%	1.36%	0.24%	0.37%
Aggregate employment	0.27%	0.40%	0.00%	0.00%
Average real wage	0.48%	0.72%	0.24%	0.36%
Aggregate capital stock	0.90%	1.35%	0.26%	0.39%
GDP price index	-0.38%	-0.57%	-0.16%	-0.23%
CPI	-0.25%	-0.37%	-0.14%	-0.20%
Export Price Index	-0.15%	-0.23%	-0.07%	-0.10%
Nominal household expenditure	0.51%	0.77%	0.09%	0.13%
Nominal GDP	0.52%	0.78%	0.09%	0.13%

Source: NZIER

Table 31 Detailed industry results for network at capacity, lower bound

Change; 2016

Industry	Output increase in $ million (nominal)	% change
Horticulture and fruit growing	$0.97	0.21%
Sheep, beef cattle, and grain farming	$0.69	0.33%
Dairy cattle farming	$0.48	0.26%
Poultry, deer, and other livestock farming	$0.53	0.35%
Forestry and logging	$0.91	0.50%
Fishing and aquaculture	-$0.01	-0.02%
Agriculture, forestry, and fishing support services	$0.54	0.66%
Coal mining	$0.01	0.23%
Oil and gas extraction	$0.05	0.08%
Metal ore and non-metallic mineral mining and quarrying	$0.55	0.21%
Exploration and other mining support services	$0.81	0.75%
Meat and meat product manufacturing	$4.33	0.37%
Seafood processing	$1.16	0.30%
Dairy product manufacturing	$8.08	0.26%
Fruit, oil, cereal, and other food product manufacturing	$7.84	0.25%
Beverage and tobacco product manufacturing	$5.17	0.26%
Textile and leather manufacturing	$0.63	0.20%

Industry	Output increase in $ million (nominal)	% change
Clothing, knitted products, and footwear manufacturing	-$0.09	-0.03%
Wood product manufacturing	$8.18	0.86%
Pulp, paper, and converted paper product manufacturing	$7.06	0.51%
Printing	$2.85	0.32%
Petroleum and coal product manufacturing	$7.80	0.49%
Basic chemical and basic polymer manufacturing	$2.23	0.31%
Fertiliser and pesticide manufacturing	$0.62	0.30%
Pharmaceutical, cleaning, and other chemical manufacturing	$0.97	0.12%
Polymer product and rubber product manufacturing	$10.80	0.50%
Non-metallic mineral product manufacturing	$10.22	0.84%
Primary metal and metal product manufacturing	$6.65	0.35%
Fabricated metal product manufacturing	$15.43	0.69%
Transport equipment manufacturing	-$2.43	-0.20%
Electronic and electrical equipment manufacturing	$7.63	0.32%
Machinery manufacturing	$4.03	0.39%
Furniture manufacturing	$2.00	0.36%
Other manufacturing	$0.53	0.20%
Electricity generation and on-selling	$7.11	0.47%
Electricity transmission and distribution	$5.03	0.99%
Gas supply	$0.55	0.52%
Water supply	$2.64	0.62%
Sewerage and drainage services	$0.31	0.20%
Waste collection, treatment, and disposal services	$3.05	0.75%
Residential building construction	$34.45	1.31%
Non-residential building construction	$8.07	0.33%
Heavy and civil engineering construction	$26.10	0.59%
Construction services	$83.76	1.31%
Basic material wholesaling	$6.65	0.30%
Machinery and equipment wholesaling	-$5.48	-0.15%
Motor vehicle and motor vehicle parts wholesaling	$1.77	0.22%
Grocery, liquor, and tobacco product wholesaling	$0.34	0.01%
Other goods and commission based wholesaling	$18.43	0.47%
Motor vehicle and motor vehicle parts retailing	-$0.12	-0.02%
Fuel retailing	$0.20	0.14%
Supermarket and grocery stores	$3.34	0.29%
Specialised food retailing	$0.34	0.13%
Furniture, electrical, and hardware retailing	$1.36	0.11%
Recreational, clothing, footwear, and personal accessory retailing	$6.02	0.55%
Department stores	$1.27	0.21%
Other store based retailing; non-store and commission based retailing	$4.94	0.33%
Accommodation	$3.42	0.54%
Food and beverage services	$8.72	0.31%
Road transport	-$11.58	-0.43%
Rail transport	$1.12	0.29%
Other transport	-$1.04	-0.36%
Air and space transport	$8.99	0.22%
Postal and courier services	$10.14	0.97%
Transport support services	-$1.13	-0.04%
Warehousing and storage services	$0.33	0.06%
Publishing (except internet and music publishing)	$2.67	0.43%

Industry	Output increase in $ million (nominal)	% change
Motion picture and sound recording activities	$5.18	0.47%
Broadcasting and internet publishing	$3.17	0.21%
Telecommunications services	$15.16	0.25%
Library and other information services	$0.02	0.01%
Banking and financing; financial asset investing	$27.18	0.46%
Life insurance	$2.38	0.27%
Health and general insurance	$7.70	0.30%
Superannuation and individual pension services	$0.31	0.50%
Auxiliary finance and insurance services	$6.01	0.28%
Rental and hiring services (except real estate); non-financial asset leasing	$3.12	0.15%
Residential property operation	$28.79	0.60%
Non-residential property operation	$15.81	0.49%
Real estate services	$7.34	0.38%
Owner-occupied property operation	$47.23	0.56%
Scientific, architectural, and engineering services	$20.31	0.50%
Legal and accounting services	$10.70	0.39%
Advertising, market research, and management services	$14.66	0.25%
Veterinary and other professional services	-$0.08	-0.02%
Computer system design and related services	$10.14	0.28%
Travel agency and tour arrangement services	$0.80	0.17%
Employment and other administrative services	$9.50	0.33%
Building cleaning, pest control, and other support services	$1.36	0.13%
Local government administration services	-$2.26	-0.31%
Central government administration services	$2.73	0.22%
Defence	-$4.39	-0.54%
Public order, safety, and regulatory services	-$0.14	-0.01%
Preschool education	$0.51	0.11%
School education	$0.69	0.03%
Tertiary education	$0.76	0.03%
Adult, community, and other education	$2.53	0.47%
Hospitals	$1.72	0.05%
Medical and other health care services	$1.75	0.05%
Residential care services and social assistance	$4.35	0.30%
Heritage and artistic activities	$0.94	0.33%
Sport and recreation services	$2.31	0.23%
Gambling activities	$4.60	0.33%
Repair and maintenance	$6.02	0.45%
Personal services; domestic household staff	$5.70	0.67%
Religious services; civil, professional, and other interest groups	-$2.97	-0.36%

Source: NZIER

Table 32 Detailed industry results for network at capacity, upper bound

Change; 2016

Industry	Output increase in $ million (nominal)	% change
Horticulture and fruit growing	$2.51	0.53%
Sheep, beef cattle, and grain farming	$1.17	0.55%
Dairy cattle farming	$0.73	0.40%
Poultry, deer, and other livestock farming	$1.02	0.67%
Forestry and logging	$1.21	0.67%
Fishing and aquaculture	-$0.01	-0.02%
Agriculture, forestry, and fishing support services	$0.63	0.77%
Coal mining	$0.02	0.40%
Oil and gas extraction	$0.07	0.13%
Metal ore and non-metallic mineral mining and quarrying	$0.87	0.33%
Exploration and other mining support services	$1.04	0.96%
Meat and meat product manufacturing	$8.26	0.71%
Seafood processing	$2.62	0.68%
Dairy product manufacturing	$12.08	0.38%
Fruit, oil, cereal, and other food product manufacturing	$16.34	0.52%
Beverage and tobacco product manufacturing	$10.28	0.52%
Textile and leather manufacturing	$3.47	1.11%
Clothing, knitted products, and footwear manufacturing	$1.66	0.66%
Wood product manufacturing	$12.87	1.35%
Pulp, paper, and converted paper product manufacturing	$11.63	0.84%
Printing	$6.12	0.69%
Petroleum and coal product manufacturing	$11.26	0.71%
Basic chemical and basic polymer manufacturing	$3.60	0.51%
Fertiliser and pesticide manufacturing	$0.93	0.46%
Pharmaceutical, cleaning, and other chemical manufacturing	$3.95	0.49%
Polymer product and rubber product manufacturing	$18.30	0.85%
Non-metallic mineral product manufacturing	$14.96	1.23%
Primary metal and metal product manufacturing	$12.54	0.66%
Fabricated metal product manufacturing	$25.12	1.12%
Transport equipment manufacturing	-$1.54	-0.12%
Electronic and electrical equipment manufacturing	$16.46	0.70%
Machinery manufacturing	$9.66	0.94%
Furniture manufacturing	$3.89	0.70%
Other manufacturing	$1.90	0.72%
Electricity generation and on-selling	$10.99	0.72%
Electricity transmission and distribution	$9.22	1.81%
Gas supply	$0.89	0.84%
Water supply	$3.89	0.91%
Sewerage and drainage services	$0.44	0.29%
Waste collection, treatment, and disposal services	$5.21	1.28%
Residential building construction	$47.18	1.79%
Non-residential building construction	$15.47	0.63%
Heavy and civil engineering construction	$40.29	0.91%
Construction services	$107.28	1.68%
Basic material wholesaling	$10.76	0.49%
Machinery and equipment wholesaling	-$1.81	-0.05%
Motor vehicle and motor vehicle parts wholesaling	$3.57	0.44%

Industry	Output increase in $ million (nominal)	% change
Grocery, liquor, and tobacco product wholesaling	$0.88	0.03%
Other goods and commission based wholesaling	$23.66	0.61%
Motor vehicle and motor vehicle parts retailing	-$3.20	-0.48%
Fuel retailing	$1.02	0.70%
Supermarket and grocery stores	$8.07	0.70%
Specialised food retailing	$3.78	1.41%
Furniture, electrical, and hardware retailing	$0.81	0.06%
Recreational, clothing, footwear, and personal accessory retailing	$9.45	0.87%
Department stores	$0.62	0.10%
Other store based retailing; non-store and commission based retailing	$4.04	0.27%
Accommodation	$6.08	0.96%
Food and beverage services	$20.62	0.74%
Road transport	-$5.25	-0.20%
Rail transport	$1.56	0.41%
Other transport	-$0.22	-0.08%
Air and space transport	$18.59	0.45%
Postal and courier services	$13.92	1.33%
Transport support services	$1.45	0.06%
Warehousing and storage services	$3.05	0.53%
Publishing (except internet and music publishing)	$5.13	0.82%
Motion picture and sound recording activities	$10.06	0.91%
Broadcasting and internet publishing	$4.54	0.30%
Telecommunications services	$26.29	0.44%
Library and other information services	$0.06	0.04%
Banking and financing; financial asset investing	$44.50	0.75%
Life insurance	$4.75	0.55%
Health and general insurance	$13.89	0.54%
Superannuation and individual pension services	$0.48	0.79%
Auxiliary finance and insurance services	$12.73	0.60%
Rental and hiring services (except real estate); non-financial asset leasing	$9.85	0.47%
Residential property operation	$41.42	0.86%
Non-residential property operation	$26.85	0.83%
Real estate services	$12.45	0.65%
Owner-occupied property operation	$71.88	0.86%
Scientific, architectural, and engineering services	$34.05	0.84%
Legal and accounting services	$19.50	0.71%
Advertising, market research, and management services	$33.67	0.58%
Veterinary and other professional services	-$1.30	-0.27%
Computer system design and related services	$21.19	0.60%
Travel agency and tour arrangement services	$4.36	0.94%
Employment and other administrative services	$22.22	0.76%
Building cleaning, pest control, and other support services	$6.00	0.58%
Local government administration services	-$2.92	-0.40%
Central government administration services	$9.66	0.77%
Defence	-$7.87	-0.96%
Public order, safety, and regulatory services	$2.07	0.11%
Preschool education	$0.48	0.11%
School education	-$0.34	-0.01%
Tertiary education	$5.03	0.20%
Adult, community, and other education	$7.98	1.48%

Industry	Output increase in $ million (nominal)	% change
Hospitals	-$0.38	-0.01%
Medical and other health care services	$1.41	0.04%
Residential care services and social assistance	$10.53	0.72%
Heritage and artistic activities	$1.63	0.57%
Sport and recreation services	$4.18	0.42%
Gambling activities	$7.37	0.54%
Repair and maintenance	$14.76	1.10%
Personal services; domestic household staff	$5.50	0.64%
Religious services; civil, professional, and other interest groups	$3.06	0.37%

Source: NZIER

Appendix H ATAP policy proposals

ATAP proposes several policies, including long-term investments, to address the growing transport needs for Auckland over the coming decades. A full cost-benefit analysis of these investments would require an estimate of benefits of decongestion which considers a worsening of congestion over the coming decades.

ATAP has proposed policies which could potentially manage demand in the next few years such that it meets the current capacity of the Auckland road network. These policies include:

- Smarter pricing
- Emerging transport technologies (ATAP, 2016).

Smarter pricing

ATAP (2016) has explored the potential to use variable road network pricing as a demand management tool to achieve better network performance. Three approaches were considered:

- City centre cordon scheme (a peak-time only charge for vehicles entering the city centre)
- Motorway network charge (a flat-rate charge for vehicles entering the motorway network, with a higher charge at peak times)
- Whole of network charge (a per kilometre charge across all parts of the road network, with a higher rate at peak times).

ATAP (2016) concluded that the:

- City centre cordon charge had the smallest regional impact on travel times but was effective at achieving modal shift to public transport and a corresponding reduction in car trips to the city centre
- Motorway charge scheme improved regional congestion, particularly on the motorway network. A distance-based motorway charge was considered more likely to be successful than other forms of congestion charging
- Comprehensive network charge with its region-wide impact has by far the greatest positive effect on improving access, reducing congestion and increasing public transport mode-share. But it was expensive for all users, particularly for those traveling long distances in outer areas. Further analysis should weigh up the costs and benefits of each option to determine what would be the most appropriate way to reduce congestion.

Emerging transport technologies

ATAP (2016) has also explored the development of transport technologies to increase:

- Vehicle occupancy rates
- The uptake of connected vehicles.

ATAP concluded that:

- The benefits of developing vehicle technologies are likely to be substantial, and strongest on the motorway network
- One way to reduce congestion was by increasing vehicle occupancy rates
- Ride sharing also has the potential to complement road pricing (ATAP 2016).

The New Zealand Productivity Commission (NZPC) similarly notes that the uptake of driverless vehicles over the next decade has implications for future investment in transport infrastructure. Driverless vehicles would reduce the required number of vehicles, increase vehicle efficiency and reduce the amount of transport infrastructure investment to meet a city's transport needs (NZPC, 2017).

Congestion leads businesses to invest in new logistics and production technologies, with an increasing reliance on just-in-time supply chains, overnight courier deliveries and intermodal facilities (Weisbrod and Fitzroy, 2007).

For the broader economy, widespread adoption of autonomous vehicles would reduce motorway congestion and hence boost economic growth (Karpilow and Winston, 2016).

Costs and benefits are both a function of travel time

An understanding of the travel time savings and average speed achieved across the network would need to be modelled for the different policies/packages implemented. This is necessary to compare the net present value of benefits and costs and justify investments. Both costs and benefits should be modelled as a function of total travel time saved across the network to be comparable.

If smarter pricing and transport technologies were to bring travel volumes back to the capacity of the Auckland network, their costs (annualised) to achieve the same total travel times saving across the network can therefore be weighed against our estimate of the total benefits of decongestion.

ATAP outlines different investments over a 30-year period. But a direct comparison with the indicative package costs outlined by ATAP is not feasible because there is no distinction made between the investment cost to prevent future growth in congestion (keep Auckland's congestion at its current level) and the investment to reduce congestion (reduce Auckland's congestion below its current level).

Our headline estimates only represent the benefits of reducing congestion in Auckland below its current level.

Our recommendation for next steps is to estimate the cost of the different policy options to achieve different average speeds across the Auckland road network as well as the aggregate time savings, particularly for smarter pricing and transport technologies.