Buying time: Toll roads, congestion charges, and transport investment

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Te Waihanga seeks to transform infrastructure for all New Zealanders. By doing so our goal is to lift the economic performance of Aotearoa and improve the wellbeing of all New Zealanders.

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Cut to the chase

Today's situation

If we want to have high-quality infrastructure, we need to be able to pay for it. Infrastructure is not free: Significant resources are needed to build it, maintain it, and replace it when it wears out.

Prices provide revenue to help pay for investment…

We use prices to raise most of the money we need to **pay for infrastructure**. In the most general sense, prices are the cost that we have to pay to obtain what we want.

Some infrastructure prices are direct and visible to users. Examples of direct charges include public transport fares, monthly electricity bills, and monthly mobile phone bills.

Other infrastructure prices are indirect, bundled with other prices, or less visible to users. Examples of indirect charges include petrol tax, which is included in the retail price of petrol, development contributions, which pass through to the price of housing, and central government taxes and local government rates, a portion of which is used to pay for infrastructure investment and services.

… and they provide information about what people value to guide investment

Prices also provide **information** that can be used to inform decisions.

Well-functioning prices can send signals about what we should do more or less of. For example, if people are willing to pay a premium for higher-capacity mobile broadband services, it's a sign that telecommunications providers should expand mobile broadband networks to meet that demand.

Likewise, if a council finds that it needs to charge high development contributions in a specific area to cover the cost of providing infrastructure for new housing in that location, this is a signal to housing developers and home-buyers to choose other, lower-cost locations instead.

Without good price signals, infrastructure providers will find it more difficult to raise the right amount of money to maintain and improve their assets. They may face greater challenges identifying the highest-value areas for investment. Poorly-priced networks also tend to operate less efficiently, as users lack good information and incentives to optimise their use.

Land transport pricing is under pressure

Land transport, which includes the road, rail and public transport networks, is New Zealand's largest single category of infrastructure investment. It accounts for more than 20% of total investment. However, it also faces challenges like deferred maintenance and renewal, rising urban congestion in Auckland and (to a lesser extent) smaller cities, and high carbon emissions. These challenges are placing pressure on transport pricing and funding.

Three key features of land transport funding and investment

Land transport funding is designed as a cost-recovery, user-pays model. What this means is that revenues raised from transport users are intended to cover the overall cost of providing transport infrastructure and services, although not every road or public transport route pays its own way.

Elected members play a role in determining the level of land transport investment and the desired outcomes from investment. Several changes to the structure of the land transport sector in 2008 increased this role. Within the current system, the Government Policy Statement on Land Transport enables elected members to specify both the level of investment and how much should be spent on new investment versus operating and maintaining existing infrastructure.

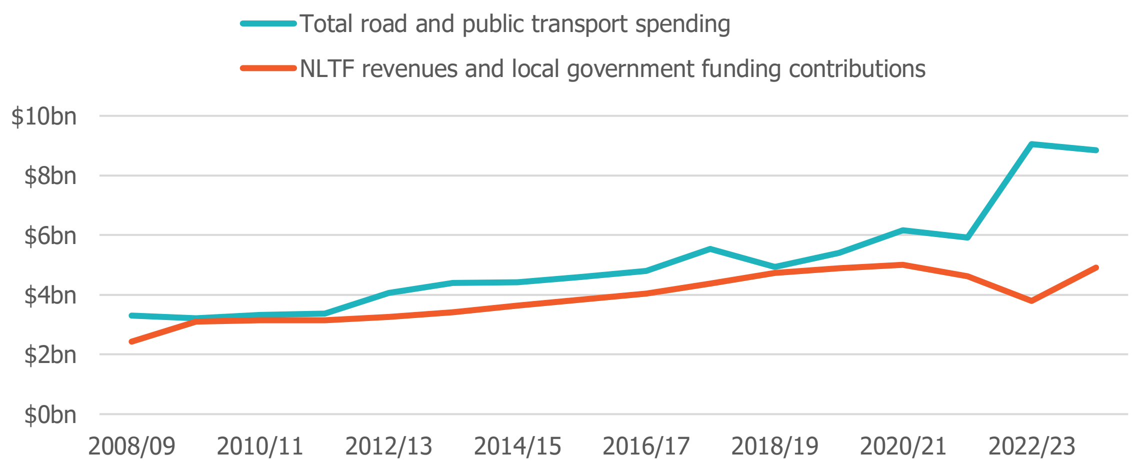
Elected members also play a key role in setting transport prices. The main user charges in transport, such as fuel taxes and road user charges (RUC), are informed by a Cost Allocation Model but ultimately set by elected members.

Land transport investment now exceeds current land transport revenues

When prices and investment are both set through policy, rather than allowed to adjust as needed to meet demand, it tends to undermine cost recovery from user charges.

Figure 1 shows that this is currently happening in the land transport sector. In recent years, spending has significantly exceeded current revenues from user charges. This is because land transport prices have been set below the full cost of recent spending increases. Crown grants and loans, plus long-term borrowing like public private partnerships, have filled the gap.

Figure 1: Road and public transport spending funded from current user charges, 2008/09-2023/24



Source: Te Waihanga analysis of Treasury annual Budget statements and NZTA NLTF reporting. 2023/24 local government funding contributions are not yet available and hence are imputed using 2022/23 data.

The breakdown of cost recovery weakens price signals for both infrastructure providers, who seem to primarily respond to policy signals when choosing how to invest, and users, who may over-use transport networks because prices are set too low.

Price signals for users are also limited by the fact that externalities arising from road use, such as congestion and the local impacts of traffic noise and emissions, are imperfectly priced. This can encourage overuse in some places, such as congested urban areas, and underuse in others.

Two specific opportunities to improve transport pricing

To close the gap between land transport spending and land transport revenues, it is necessary to reduce investment, increase prices, or a mix of the two.

The long-term solution to this issue is to reform the transport funding system (as suggested in *Infrastructure Strategy* Recommendation 48), improve long-term investment planning (Recommendation 39), and strengthen independent advice on infrastructure prioritisation to ensure that investments maximise value for money (Recommendation 40).

A full consideration of these issues goes beyond the scope of this paper. Rather, we focus on two specific, near-term opportunities to incrementally improve transport pricing: Road tolls to help pay for new investment, and congestion pricing to improve the efficiency of urban road networks (Recommendation 21). These measures could be implemented alongside existing land transport prices, or as part of broader reforms to land transport funding.

These two pricing mechanisms are related, as they involve placing additional charges on road networks in addition to existing transport charges. They can also be implemented in somewhat similar ways. For instance, both road tolls and congestion charges can vary between peak and off-peak periods, meaning that road tolls can have some congestion reduction benefits.

In spite of their similarities, these pricing mechanisms have different purposes, different price-setting rules, and different impacts on land transport investment levels (Table 1).

Table 1: Key features of road tolling and congestion pricing

Pricing mechanism	Road tolling		Congestion pricing
Policy objective	**Raise money** to pay for specific new investments		**Improve efficiency** of an existing urban road networks
Price-setting rule	Set prices to **maximise total revenue** raised from users of a new road		Set prices to **maximise total throughput** on an existing road network
Expected impact on investment levels	**Increase investment** when user willingness to pay is high	**Reduce investment** when user willingness to pay is low	**Reduce investment** by mitigating excess congestion and allowing some projects to be deferred

Road tolling enables increased investment when willingness to pay tolls is high, and vice versa

The main purpose of tolls is to raise money to help pay for new roads. Where users are willing to pay higher tolls, use of tolling can enable higher investment levels. However, this is not possible in all situations. (See Box 1.)

When new roads are relatively cheap to build, when traffic volumes are relatively high, and when the new roads offer large travel time savings relative to existing routes, then toll revenues can cover a significant share of cost of a new road.

However, when roads are more expensive to build, when traffic volumes are lower, or when new roads offer small travel time savings, then toll revenues will only make a small contribution to the cost of a new road.

What this means is that, if tolls are needed to pay for new investment due to unavailability of other funding sources, investment will increase when users are willing to pay higher tolls for new roads, but reduce when users are not willing to pay tolls. Even if tolls do not get to full cost recovery, toll analysis can also help to prioritise new investment, as roads with higher toll revenue potential are likely to be the roads with the highest value to users.

Congestion pricing reduces investment pressure in congested urban areas

The basic idea of congestion pricing is to charge people more to drive on busy roads at peak times. If these charges are set to reflect the cost of the extra delay that each added driver imposes on other road users, they can encourage people to avoid creating excess congestion. This will in turn maximise the overall capacity of the road network to move people and goods.

In Auckland, transport modelling suggests that congestion pricing could reduce morning peak traffic delays by up to 35%, depending upon scheme design. However, citywide changes in travel demand are expected to be modest – a less than 2% reduction in total peak period car trips and less than 2% increase in public transport trips. This is consistent with international experience.

This means that congestion pricing would allow us to defer or avoid some urban road capacity investments, without the need for much added investment to deal with shifts in travel demand. (See Box 2.) In the longer term, monitoring how travel demands change in response to congestion charging will also help to target future investment to areas where it is most needed.

We also consider affordability and equity impacts

Introducing new charges or increasing existing charges often poses affordability challenges and concerns about disproportionate impacts on low-income households.

In the context of a user-pays cost recovery funding model, it is hard to improve affordability by changing transport prices. If one transport price is reduced without matching cuts to transport investment, it will be necessary to increase other transport prices or raise taxes or rates to make up the difference. (See Box 3.)

As a result, the best way to address affordability concerns for low- and middle-income households is to seek opportunities to avoid or defer investment and pass these cost savings on through lower prices. Remaining issues can be addressed with targeted assistance for vulnerable people.

Do we have a transport pricing problem, or an investment deficit?

An infrastructure deficit can be thought of as a shortfall of infrastructure relative to what we want or need. However, our wants and needs are in turn a function of how things are priced.

Think about how people often act at a party with free pizza. They tend to eat until they're full – and then go back for another slice. And people who arrive late may not get *any* pizza.

People behave differently when they have to pay for pizza. Rather than eating half a pizza, they may only have a slice or two. Are they experiencing a 'pizza deficit' as a result? Probably not. Instead, they're simply choosing an amount that reflects their true willingness to pay for pizza.

The same principle applies to infrastructure. When we don't pay for things, or when it's not obvious how we're paying, we often respond by using more than we otherwise would.

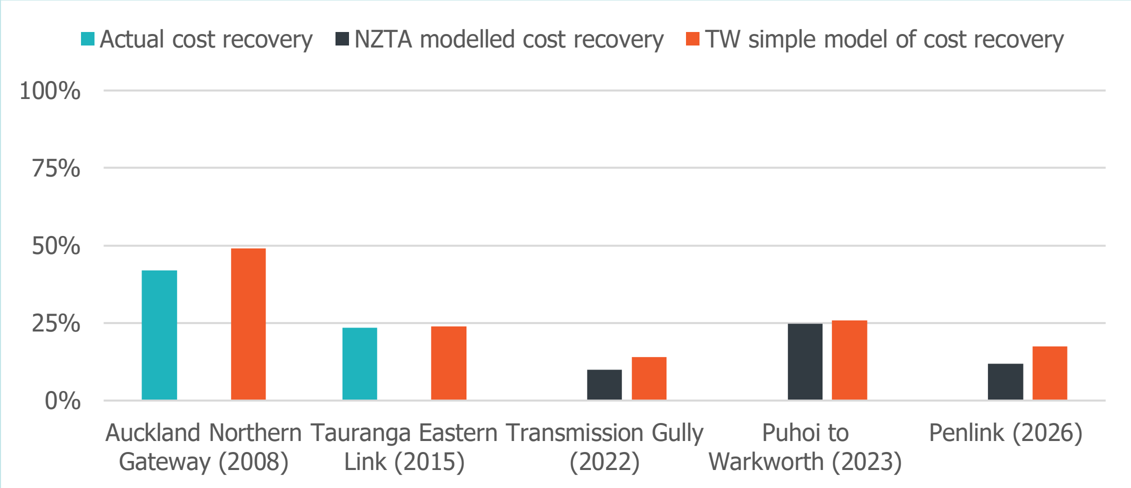
As a result, improving how transport is priced, for instance through greater use of road tolls and congestion pricing, can help us discover what our infrastructure needs actually are – and identify a path to pay for what we need.

Box 1: When can tolls pay for new roads?

While tolls paid for most or all of the cost of some historical investments, like the Auckland Harbour Bridge, cost recovery on more recent toll roads has been much lower. Figure 2 shows that cost recovery for existing or recently investigated toll roads in New Zealand ranges from around 10% to around 40%.

Low cost recovery is due to demand factors, rather than policy decisions to set tolls at a low level. Using a simple quantitative model of toll revenue potential, we show that actual or predicted toll revenue outcomes for these roads reflect the fact that they are built in relatively low-traffic locations and offer modest travel time savings to their users.

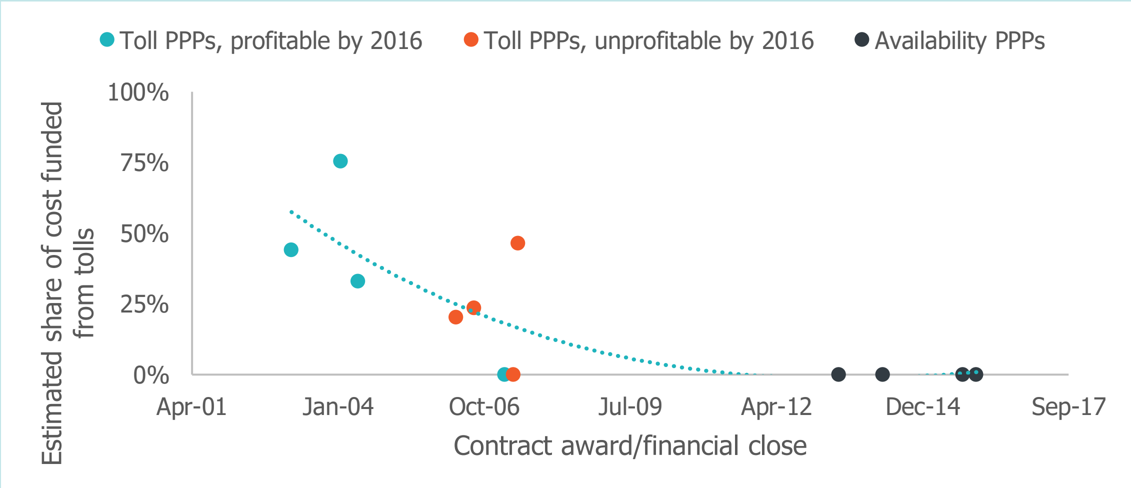
Figure 2: Cost recovery for existing or potential New Zealand toll roads



Source: Te Waihanga analysis based on data in Table 15 in Appendix 2.

Toll cost recovery may decline throughout a large investment programme, as higher-traffic roads that offer larger travel time savings tend to be built first. Figure 3 shows that this happened in Ireland's motorway investment programme, which involved the construction of 12 major new roads. The first eight roads were part-funded through tolls, but toll cost recovery declined throughout the programme. The last four roads were not tolled, as users' willingness to pay tolls and investors' willingness to be repaid through tolls had declined significantly.

Figure 3: Trends in toll cost recovery for Irish PPP roads



Source: Te Waihanga adaptation of data from Tables 2, 3, and 4 in Palcic et al. (2018).

We show that tolls can fully fund new roads only if three conditions are met. First, **high traffic volumes** of 40,000 vehicles per day or more are needed, which is equivalent to the highest-traffic parts of the Christchurch motorway network. Second, **new roads need to be cheap to build**, such as motorways in flat terrain with low land purchase costs. Third, the **new roads need to be at least 15 minutes faster** than the existing route. By comparison, Auckland's Northern Gateway toll road saves its users roughly 10 minutes in uncongested conditions.

While these conditions are hard to meet in the context of a reasonably mature road network, tolls can still play a useful role in investment. They can raise some additional money to accelerate delivery of some projects. Toll revenue analysis can also be used to identify and prioritise the projects that are likely to lead to the largest benefits for their users.

Box 2: The impact of congestion pricing on investment needs

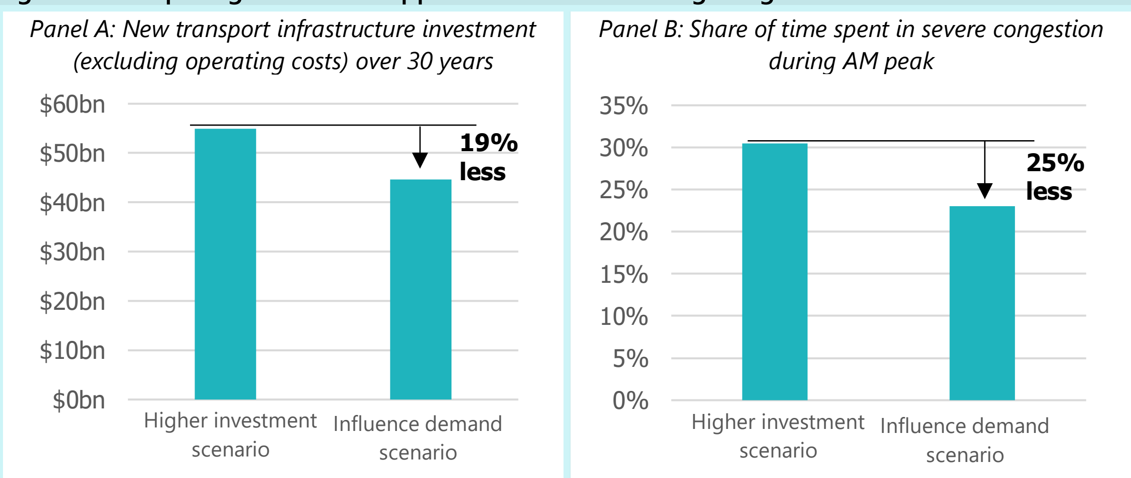
Congestion pricing uses time- and location-varying charges to encourage people to avoid congested parts of an urban road network at peak times.

Congestion is only a problem on a small part of the national road network, at specific times. Because transport prices like fuel excise duty (FED) and road user charges (RUC) are set at a national level, they do not signal location-specific congestion costs to users. This encourages additional driving in congested urban areas, leading to excess traffic congestion, and, in the long run, pressure for higher spending on urban transport networks.

As a result, urban congestion pricing can help to both improve the functioning of an existing urban road network and reduce demand for transport investment.

Figure 4 compares two investment and pricing scenarios for Auckland. While each scenario comes with broader costs and benefits, transport modelling suggests better congestion outcomes would be achieved in a scenario where the city invested 19% less in new transport infrastructure while implementing network-wide congestion pricing.

Figure 4: Comparing alternative approaches for addressing congestion in Auckland



Source: Te Waihanga analysis of data from ATAP (2016b), updated to 2023 New Zealand dollars.

This is consistent with other cities' real-world experience. While cities that have implemented congestion pricing tend to implement it alongside mitigations like improved public transport services, reductions in road congestion tend to be immediate and shifts in travel demands can often be accommodated within existing transport network capacity, rather than triggering the need for large upgrades to transport infrastructure or services.

Box 3: Affordability impacts of transport pricing

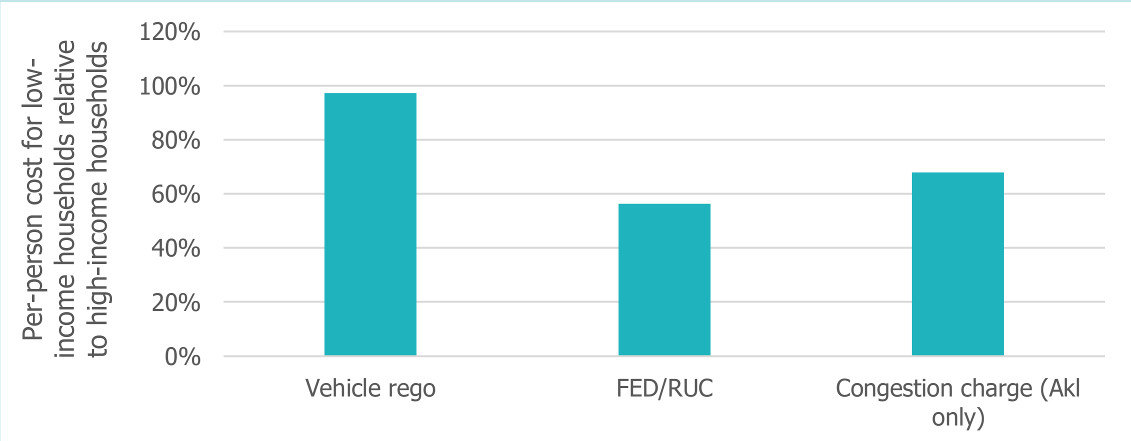
In dollar terms, high-income households tend to spend more on transport than low-income households. They are likely to own more cars, drive more, and use public transport more frequently. However, lower-income households tend to spend a larger *share* of their after-tax income on transport.

This can drive concerns about the affordability of transport prices for low-income households or other vulnerable households.

We analysed the household budget impacts of raising roughly $250 million in new revenues by either increasing vehicle registration fees or fuel excise duties/road user charges at a national level or implementing a congestion charge in Auckland. All three types of charges are expected to have roughly similar impacts on the average household.

Figure 5 shows financial impacts on low-income households relative to high-income households. In dollar terms, increasing fuel excise duties or implementing congestion charging affects low-income households less than increasing fixed charges like vehicle rego. This is because low-income households own cars at a similar rate to high-income households but tend to drive much less. However, low-income households have much lower incomes so they end up paying a slightly larger share of their income than higher-income households under all options.

Figure 5: Financial impacts of increasing transport prices on low-income households, relative to impacts on high-income households



Note: Te Waihanga re-analysis of data in PwC (2024b) and Covec and MRCagney (2018).

This analysis suggests that problems related to the affordability of transport infrastructure and services are hard to address by changing the structure of prices. As long as the total amount of money that is spent on transport networks remains the same, changing how this money is gathered will only lead to small changes in affordability for low- and middle-income households.

Introduction

Good infrastructure requires good pricing practices

If we want to have high-quality infrastructure, we need to be able to pay for it. Infrastructure is not free: Significant resources are needed to build it, maintain it, and replace it when it wears out.

In previous research, we showed that New Zealand spends around 5.8% of gross domestic product (GDP) – more than one out of every 20 dollars we earn as a country – on capital investment in infrastructure (New Zealand Infrastructure Commission, 2024). The cost of this investment is ultimately borne by New Zealanders.

Prices are how we raise the money we need to pay for infrastructure

We use **prices** to raise most of the money we need to pay for infrastructure. In the most general sense, prices are the cost that we have to pay to obtain what we want.

Some infrastructure prices are direct and visible to users. Examples of direct charges include public transport fares, monthly electricity bills, and monthly mobile phone bills.

Other infrastructure prices are indirect, bundled with other prices, or less visible to users. Examples of indirect charges include petrol tax, which is included in the retail price of petrol, development contributions, which are levied on new housing development and bundled into overall house sale prices, and central government taxes and local government rates, a portion of which is used to pay for infrastructure investment and services.

Prices also provide information to guide infrastructure decisions

Although we usually think about prices as a way of raising money, prices also provide **information** that can be used to inform decisions.[1]

Well-functioning prices can send signals about what we should do more or less of. For example, if people are willing to pay a premium for higher-capacity mobile broadband services, it's a sign that telecommunications providers should expand mobile broadband networks to meet that demand.

Likewise, if a council finds that it needs to charge high development contributions in a specific area to cover the cost of providing infrastructure for new housing in that location, this is a signal to housing developers and home-buyers to choose other, lower-cost locations instead.

Infrastructure pricing needs to consider the engineering and demand characteristics of networks

Infrastructure networks all share some common features that set them apart from other parts of the economy, although the physical and engineering details vary somewhat between sectors. These

[1] The Commission has previously highlighted the importance of using price signals to guide decisions about urban planning. For instance, when the price of urban-zoned land is significantly higher than the price of nearby rural-zoned land, it is a signal that overall urban development capacity (both for intensification and greenfield development) is insufficient (Covec & MRCagney, 2016; New Zealand Infrastructure Commission, 2023b). A similar approach can be taken to assess whether public infrastructure is currently under- or over-supplied.

common features drive best practice pricing approaches for infrastructure and make it possible to learn lessons from comparing pricing in different infrastructure networks.

First and foremost, infrastructure networks are **networks** – they don't work unless they connect lots of places and people together. The value of an individual part of a network depends upon how it connects to the rest of the network. This makes it difficult to charge a separate price for each individual part of the network, in the same way that a supermarket charges you a separate price for each ingredient you buy for your dinner.

Second, they are **capital-intensive** – providing infrastructure often means making large, lumpy up-front investments that must be recouped over a large user base or a long period of time. Prices need to be set to cover both the up-front costs of infrastructure provision as well as the ongoing costs of operating and maintaining networks, rather than just the costs that arise at a single point in time.

Because it tends to be costly to add significant network capacity, infrastructure networks tend to experience **congestion** when more people are trying to use networks at peak times (Box 4). A certain level of congestion is desirable as it means that networks are well used. However, network operators need to consider how to respond to excess peak-time use, including by using prices to encourage people to shift their use into off-peak times.

Third, infrastructure networks often have significant economic, social, and environmental **spillovers** that must be considered and managed. An example is externalities like carbon emissions and local air quality impacts of fossil-fuelled electricity generation and transport. Infrastructure prices may need to take these into account when setting prices, to avoid encouraging socially costly use of networks.

Lastly, consumer demand for infrastructure services is relatively **inelastic**, or unresponsive, to both incomes and prices. This is because infrastructure is needed to enable many other things people want to do, rather than being an end in itself. A 10% change in people's incomes or infrastructure prices leads to a smaller percentage change in people's use of infrastructure.[2] Increased infrastructure prices tend to reduce usage but increase the share of household incomes spent on infrastructure. Low-income households, which tend to spend more of their income on infrastructure to start with, are affected more as a result. This means that infrastructure prices are often the focus of affordability and equity concerns.

[2] According to the UK National Infrastructure Commission (2018), income elasticities range from 0.2 to 0.9 for residential electricity use (meaning that a 10% increase in income results in a 2% to 9% increase in use), 0.2 to 1.1 for passenger land transport, around 0.8 for digital infrastructure, and 0.2 to 0.3 for water infrastructure. Price elasticities are negative meaning that as prices rise demands fall and range from -0.1 to -0.8 for residential electricity use (a price rise of 10% is associated with a 1-8% decline in demand), -0.1 to -0.8 for passenger land transport, -0.4 to -0.6 for digital infrastructure, and -0.2 to -0.3 for water infrastructure.

Box 4: Congestion costs in different infrastructure networks

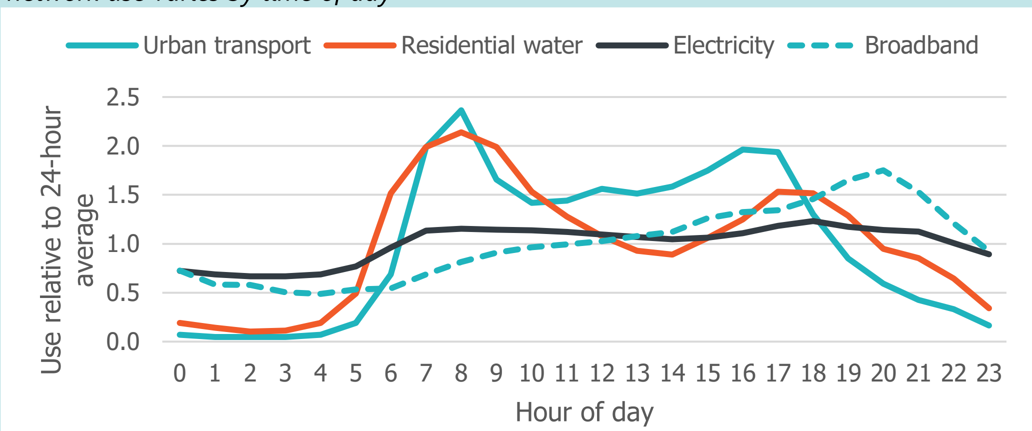
Congestion arises when people's use of a network reduces level of service for other users.

Up to a certain point, infrastructure networks can accommodate more users without severely declining levels of service. A certain level of congestion is a good thing, as it means that networks are well utilised. But beyond a certain point, more usage can result in large losses in levels of service for other users. There is an upside to this, in that a relatively small reduction in traffic can result in very large increases in level of service.

Although we usually think of congestion as a problem in road networks, all infrastructure networks experience forms of congestion. In water networks, high peak-time usage can reduce water pressure for users. In telecommunication networks, it leads to reduced speeds for users. In electricity networks, it can prevent power from being transmitted to users to avoid overheating or loss of transmission system stability.

Congestion happens because the capacity of infrastructure networks (or elements of those networks) is fixed but demand to use the network varies considerably by season or time of day. This is illustrated in the following chart. While all infrastructure networks have distinct peaks in the morning and evening, urban transport and residential water use is much 'peakier' than electricity and telecommunications use. This reflects different types of use and different approaches to shifting load away from congested peak periods.

How network use varies by time of day



Source: Te Waihanga analysis of data from NZTA, Transpower, Chorus, and Beal and Stewart (2014). These are specific case studies that should be treated as realistic but indicative.

Infrastructure pricing works better in some sectors than others

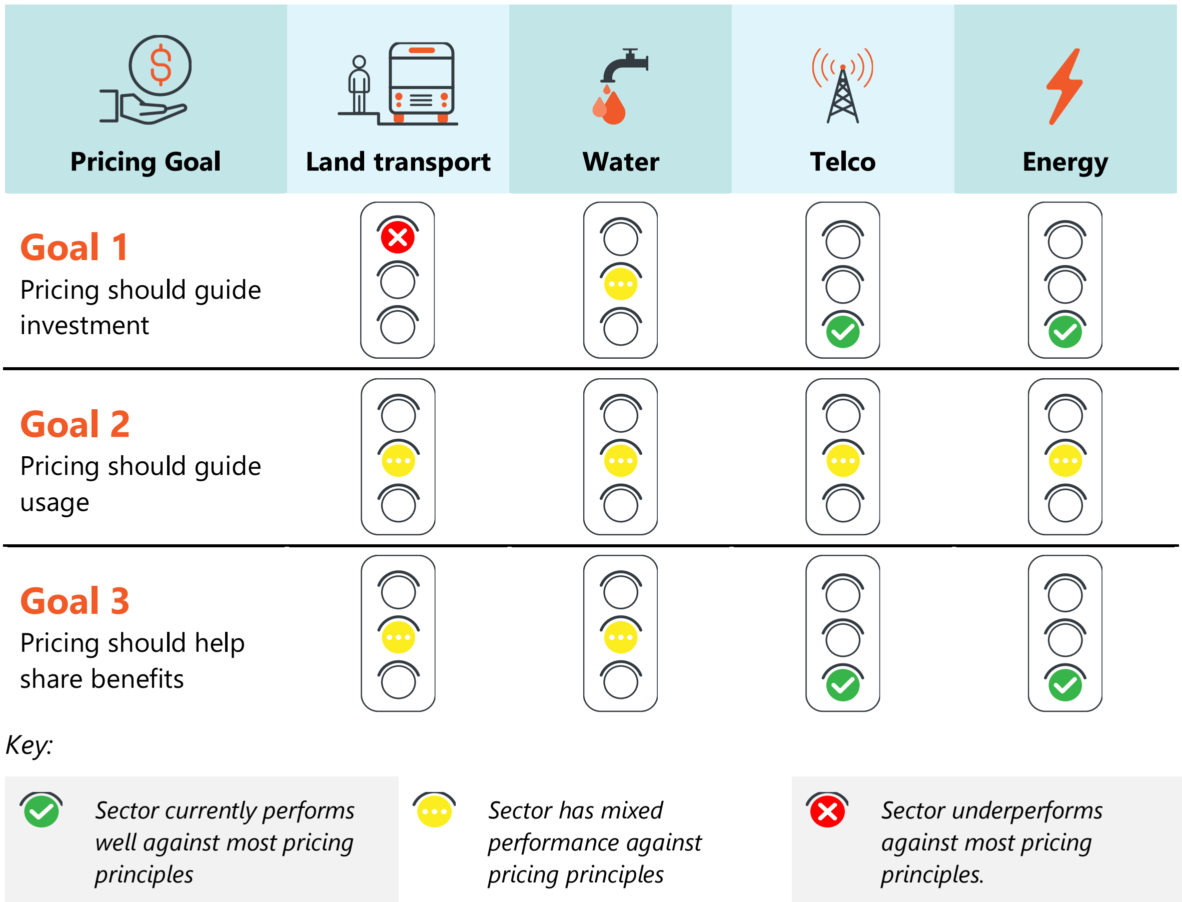
We commissioned PwC New Zealand (2024a) to study how pricing currently works in four network infrastructure sectors: land transport, water, telecommunications, and energy.

In their report, PwC emphasised the importance of using **pricing to provide information to guide decisions by infrastructure providers and users**. They identified three broad goals for infrastructure pricing:

- **Goal 1** outlines how pricing should guide infrastructure investment to ensure that we can provide and maintain the infrastructure we need. This is the most important to get right, as it guides decisions about how to invest in networks that can have long-lived impacts on how we can use and improve infrastructure.
- **Goal 2** outlines how pricing should guide usage to ensure that networks are used in socially beneficial ways. This is the next most important, as it sends signals to users about when, where, and how they should use infrastructure networks to maximise the overall benefits of those networks.
- **Goal 3** outlines how pricing should be used to share the benefits of providing networks widely through society. This should be addressed through adjustments to pricing once the previous goals are achieved, rather than as an alternative to the other goals.[3]

As shown in Figure 6, PwC's key finding is that **infrastructure pricing is better aligned with best practice principles in electricity and telecommunications, and worse aligned in land transport and water**. There are incremental opportunities to improve pricing practices in electricity and telecommunications, and transformative opportunities to improve in land transport and water.

Figure 6: PwC's benchmarking of infrastructure sectors against best practice pricing principles



Source: Adapted from page 8 in PwC (2024a). PwC's assessment focuses on scoring overall pricing system settings and practices as of late 2023. This is a broad, desktop-based exercise, supported by a qualitative assessment of key system settings that are relevant to individual pricing principles, plus a set of quantitative case studies of specific pricing practices.

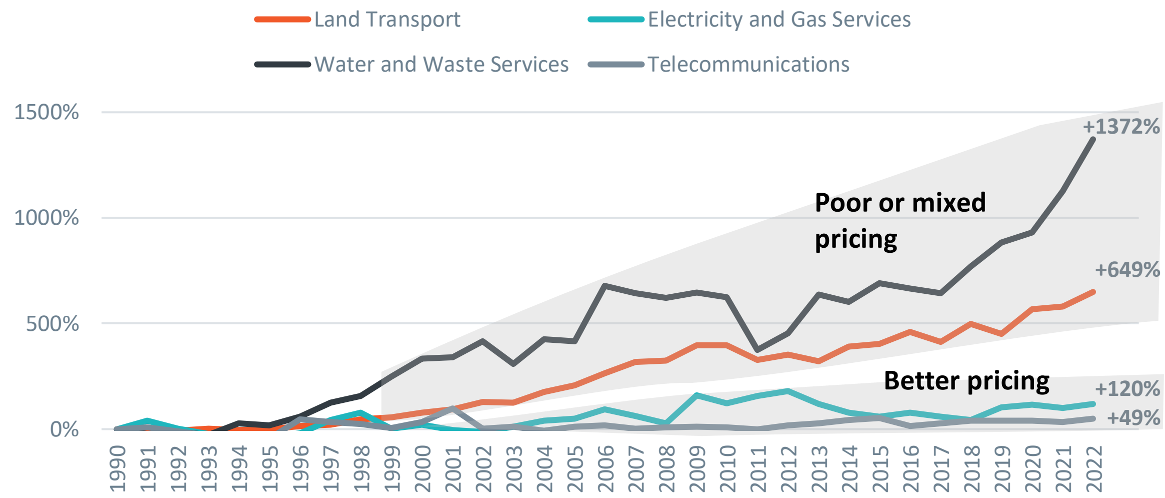
[3] In economic terms, the first goal relates to *dynamic efficiency*, which is about continuous improvement of networks over time, the second goal relates to *allocative efficiency*, which is about maximising outcomes at a point in time in an existing network, and the third goal relates to *equity*, which is about sharing the benefits of networks.

Weaker price signals are associated with rising investment

We would expect infrastructure sectors that are further away from best practice pricing principles to find it more difficult to raise the right amount of money to maintain and improve their assets. In the absence of good price signals, we would expect them to face greater challenges identifying the highest-value areas for investment. We would also expect their networks to operate less efficiently, as users lack good information and incentives to optimise their use.

In principle, this could lead to either over-investment or under-investment by infrastructure providers. However, in the specific case of New Zealand infrastructure networks, weaker price signals appear to be associated with more rapidly rising investment and asset values. Figure 7 shows that, since 1990, capital investment in land transport and water and waste services has risen much more rapidly than investment in electricity and gas services or telecommunication.

Figure 7: Growth in inflation-adjusted capital investment, by infrastructure network



Source: Adapted from New Zealand Infrastructure Commission (2024). Note: In 1990, annual capital investment was: land transport: $721 million; electricity and gas: $1,198 million; water and waste: $235 million; and telecommunications: $1,723 million. In 2022, annual capital investment was: land transport: $5,405 million; electricity and gas: $2,633 million; water and waste: $3,454 million; and telecommunications: $2,570 million. All values are inflation-adjusted 2022 New Zealand dollars.

These large divergences in capital investment are notable because all four network infrastructure sectors were run in similar ways prior to 1990. Infrastructure and services were provided directly by central or local government and prices were set by elected members. All sectors underwent reforms in the late 1980s and early 1990s, but the electricity and telco sectors experienced more fundamental reforms that resulted in a significantly different approach to pricing these networks.

Weaker price signals are associated with perceived infrastructure deficits

There is a widespread perception that New Zealand has an 'infrastructure deficit'. This is not a clearly defined term, but it is generally used to refer to a shortfall of infrastructure relative to what we want or need.

Several studies have identified ongoing issues in land transport and water in spite of rapid increases in investment in these sectors. These include deferred maintenance and renewal investment (New Zealand Infrastructure Commission, 2024; Water Industry Commission for Scotland, 2021) and level of service gaps with existing infrastructure, such as urban traffic congestion in Auckland and to a lesser extent smaller cities like Wellington and Tauranga (Ministry of Transport, 2023a; New Zealand Institute of Economic Research, 2017).

In the past, the electricity and telecommunications sectors also experienced ongoing perceived infrastructure deficits. Engineering New Zealand notes that: 'throughout the 30 year post-war period, the country was never entirely free of the need for some measure of restraint on use of electricity' to avoid blackouts.[4] In telecommunications, the number of people waiting for a telephone connection ranged from a low of around 10,000 to a high of over 50,000 from 1950 to 1987. After reforms in 1987, telephone waiting lists quickly declined to less than 1,000 people.[5]

Today, electricity and telecommunications face some future investment challenges that might require additional investment, such as increasing renewable electricity supply to decarbonise New Zealand's economy (Boston Consulting Group, 2022; Sapere, 2023). However, the pricing approaches taken in these sectors, which send good signals for investment and usage, ensure that challenges can be met rather than turning into deficits.

A closer look at land transport pricing

In this paper, we explore land transport pricing in more detail, as PwC's report finds that land transport is further away from best practice pricing principles than other sectors. Land transport is also our largest single category of infrastructure investment, accounting for more than 20% of total investment, and an area of large perceived infrastructure deficits.[6]

PwC finds that land transport pricing has mixed performance against many best practice pricing principles, and that it underperforms against several principles. Particular challenges are weak price signals to guide investment and poor signalling of externality costs to transport users.

How land transport prices and investment currently work

New Zealand's land transport sector includes the road, rail and public transport networks. It is mainly publicly owned and operated, with responsibility for governance, planning, operations and maintenance spread across various central and local government agencies.

Appendix 1 outlines several key features of New Zealand's land transport investment and pricing system. Land transport is designed to run on a cost-recovery, user-pays model. What this means is that revenues raised from transport users are intended to cover the full cost of providing transport infrastructure and services.

Within this system, elected members have always played a role in determining the level of land transport investment and the desired outcomes from investment. Several changes to the structure of the land transport sector in 2008 increased this role. Within the current system, the Government Policy Statement on Land Transport enables elected members to specify both the level of investment and how much should be spent on new investment versus operating and maintaining existing infrastructure.

[4] https://www.engineeringnz.org/programmes/heritage/heritage-records/new-zealand-electricity-system/
[5] Based on data from the New Zealand Official Yearbook for relevant years. See https://www.stats.govt.nz/indicators-and-snapshots/digitised-collections/yearbook-collection-18932012/
[6] From 2013 to 2022, New Zealand invested 1.1% of GDP in road infrastructure and 0.2% of GDP in rail infrastructure, compared with overall infrastructure investment of 5.8% of GDP (New Zealand Infrastructure Commission, 2024).

Elected members also play a key role in setting transport prices. The main user charges in transport, such as fuel taxes and road user charges, are informed by a Cost Allocation Model but ultimately set by elected members. Something similar is true for transport prices set by local governments, such as public transport fares and development contributions.

Starting in the 2010s, direct Crown funding, paid for by general taxes, has flowed into both road and rail networks. Crown loans and grants are ongoing and appear to have risen in recent years (see Table 6 in Appendix 1). The fundamental reason for this seems to be that land transport prices have been set too low to cover the full cost of planned or actual spending.

This weakens price signals for both infrastructure providers, who seem to primarily respond to policy signals when choosing how to invest, and users, who may over-use transport networks because prices are set too low.

Price signals for users are also limited by the fact that externalities arising from road use, such as congestion and the local impacts of traffic noise and emissions, are imperfectly priced. This encourages overuse, particularly in congested urban areas.

We examine two opportunities to improve land transport pricing

Rautaki Hanganga o Aotearoa, the New Zealand Infrastructure Strategy 2022–2052 outlines two specific opportunities to improve transport pricing: Greater use of road tolling to help fund investment and implementation of congestion pricing to improve the efficiency of urban road networks (Recommendation 21: Reduce congestion and improve urban mobility).

These two pricing mechanisms are related, as they involve placing additional charges on road networks in addition to existing transport charges, but they have different objectives (Table 2). As a result, the prices that you would choose for a road tolling scheme might be different than the prices you would choose for a congestion pricing scheme, at least in the short term.[7] Both road tolls and congestion charges can vary between peak and off-peak periods, meaning that road tolls can have some congestion reduction benefits. And while revenue raising is not the main purpose of congestion pricing, introducing a new charge on the network *will* raise some new revenue.

Table 2: Key features of road tolling and congestion pricing

Pricing mechanism	Road tolling	Congestion pricing
Policy objective	**Raise money** to pay for specific new investments	**Improve efficiency** of an existing urban road networks
Price-setting rule	Set prices to **maximise total revenue** raised from users of a new road	Set prices to **maximise total throughput** on an existing road network

[7] In the long run, we would expect convergence between these two prices on an urban road network. This is because demand growth and investment in new road capacity will, over time, bring the long-run costs of capacity expansion (signalled by tolls) into line with the short-run costs of traffic congestion (signalled by congestion charges). Small and Verhoef (2007) outline conditions under which road investment can be fully self-financing from optimally chosen congestion charges, which include the presence of neutral scale economies in road capacity provision. On this point, Wallis and Lupton (2013) find that, in the early 2010s, the short-run costs of congestion on the Auckland road network were similar to the average cost of new road capacity. Both road tolls and congestion charges could be implemented as part of a broader system of time- and location-varying road user charges.

We therefore consider these two pricing mechanisms against separate Pricing Goals.

The first section of the report assesses **how road tolling could help to improve performance against Goal 1 (Pricing should guide investment)**. We examine how information from road tolling might help to guide decisions about how much to invest in new roads, and how to prioritise investment.

The second section of the report assesses **how congestion pricing could help to improve performance against Goal 2 (Pricing should guide usage)**. We examine how charging people more to travel on congested peak-time roads, and less to travel at off-peak times, can affect network efficiency and perceived investment needs.

The third section of the report considers **how road tolling and congestion pricing align with Goal 3 (Pricing should help share benefits)**. We examine how introducing new prices and charges might affect affordability for different types of households.

To conclude, we reflect upon how the pricing of infrastructure can affect our perceptions about current and future infrastructure investment needs, and whether improvements to pricing are likely to lead to higher or lower transport investment.

Tolls: Pricing to guide investment

PwC assessed the land transport's pricing system settings as **underperforming against Pricing Goal 1** (see Figure 6). The primary reason for this rating is that price-setting systems are complex and fragmented, preventing price signals from informing investment decision-making. Central and local governments make investment decisions based on policy signals, rather than price signals.

As outlined in Appendix 1, the existing land transport funding system does not provide clear price signals to optimise the mix and level of investment.[8] Transport decision-makers choose how much money to invest in new and existing infrastructure, and then set user charges to cover a portion of the planned investment from road users, in proportion to how much they use the network.

Because planned expenditure is an input to pricing calculations, it would be circular to use the resulting user charges, such as fuel excise duty and road user charges, as a price signal to guide investment.

However, New Zealand's Land Transport Management Act 2003 allows another type of price to be set to help pay for new roads: **tolls**. In this section, we show how toll revenue analysis for new roads provides a price signal that can help to guide decisions about new investment.

The basics of toll roads

A toll road is a road for which users must pay a direct charge to use, in addition to existing transport user charges.

Subpart 2 of the Land Transport Management Act 2003 enables tolls to be levied on new roads to help fund their construction, maintenance, or operation.[9] It requires a 'feasible, untolled alternative route' to be available to road users, meaning that new toll roads must compete with existing untolled roads for traffic.

It is not always technically feasible or efficient to toll new roads. The cost of toll administration and tolling infrastructure, like license-plate recognition systems and toll gantries, may be prohibitively high for short sections of road or roads with many entry and exit points. As a result, tolls are most commonly applied to long sections of motorways and bridges and tunnels, both of which have limited entry and exit points.

Toll roads have been used extensively in some countries to pay for new road construction. For instance, many European motorways are tolled (Garcia-López et al., 2022).[10] Tolls have been used from time to time in New Zealand. Historical examples include toll roads in various provinces prior to the 1920s, Auckland Harbour Bridge (1959), Lyttelton Tunnel (1964), and the first Tauranga Harbour Bridge (1988). New Zealand has three toll roads in operation: Auckland's Northern Gateway (2008), the Tauranga Eastern Link (2015), and Tauranga's Takitimu Drive (2003).

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[8] In principle, cost benefit analysis of proposed investments can be used as a type of 'price signal' to guide investment. NZTA's (2023) *Monetised Benefits and Costs Manual* outlines requirements for cost benefit analysis of new investments. However, information presented in Appendix 1 suggests that the role of cost benefit analysis has declined over time, relative to government policy.

[9] https://www.legislation.govt.nz/act/public/2003/0118/latest/DLM226230.html

[10] Out of the 545 largest European urban areas, 260 had road tolls on at least some highways, and 77 had tolls on all their major highways. The average European city has tolls on 25% of its highway network.

Tolls reflect the value of new roads to users

The main reason to toll a new road is to raise money to pay for the construction, operation, and maintenance of the road. However, toll revenue also provides **information about the value that users place on the road** that can be used as an input to decision-making. When there is a need to pay for infrastructure partly out of direct user revenues, this can incentivise better project selection and risk management (Flyvbjerg, 2009; Glaeser & Poterba, 2021).

If toll revenues are expected to be high enough to cover the costs of the new road, then this is a strong signal that people value the new road and are willing to pay to have it built. However, if they are not, it is a signal that increased road investment should be weighed up carefully against other investment needs, like maintenance.

Some transport investments also have significant benefits for non-users

This sort of analysis is most appropriate when most project benefits accrue directly to users. When a large share of total benefits accrue to non-users, it may be appropriate to seek other sources of funding rather than attempt to recover the full costs of the project from users.

On this point, Table 3 shows the composition of modelled benefits for several major road and public transport projects. For the road projects, travel time savings for users account for 74% to 79% of total benefits. Total direct user benefits, including travel time savings and other benefits like travel time reliability and safety, account for 91% to 97% of total project benefits. Because the non-user benefits of these projects are small, tolls are an effective way of recovering the costs of investment from the people who benefit.

For the public transport projects, non-user benefits tend to be proportionately larger. In urban areas, public transport investment may enable people to switch from driving, reducing the need to pay for more road capacity, or increase economic productivity by enabling urban agglomeration economies (Adler & van Ommeren, 2016; Australian Productivity Commission, 2021; Maré & Graham, 2009; Melo & Graham, 2018; Venables, 2007). As a result, direct user benefits only account for 37% to 70% of the total benefits of the three public transport projects in Table 3. This means that direct user charges are unlikely to be as effective at recovering the full costs of investment from beneficiaries.

Table 3: User and non-user benefits for selected road and public transport projects

Share of benefits related to:	Road projects		Public transport projects		
	Puhoi to Warkworth	Otaki to N of Levin	City Rail Link	Northwest Busway	Lower North Island Rail
Travel time savings for users	74%	79%	54%	56%	37%
Other direct user benefits	23%	12%	12%	14%	0%
Benefits to road users	0%	0%	3%	2%	40%
Reduced environmental externalities	1%	1%	0%	1%	14%
Other non-user benefits	2%	8%	31%	28%	9%

Source: Table 8-2 in Puhoi to Warkworth Implementation Business case; Table 3-23 in Otaki to North of Levin Detailed Business Case; Figures 67 and 68 in City Rail Link Detailed Business Case; Page 6-34 in Northwestern Rapid Transit Indicative Business Case; and Table 6-2 from Lower North Island Integrated Rail Mobility Detailed Business Case.

We develop a simple model of cost recovery for toll roads

Toll revenue analysis is typically done for individual projects to help project sponsors understand what share of a new road can be paid for by tolls. Project teams use transport models that are maintained and operated by regional or national transport agencies to undertake detailed analysis of the impact of levying specific charges on specific proposed new roads.

While the specifics vary from project to project, toll cost recovery is primarily driven by a few basic factors:

- The first factor is how many people would choose to use the new road, rather than the untolled alternative route, if it was tolled. This is largely determined by how large the travel time savings are on the new road, and how high the toll is.
- The second factor is how much it costs to build the road, and potentially also to operate and maintain it.

Based on these factors, we develop a simple theoretical model of cost recovery for new toll roads and use it to identify the conditions under which tolls will be able to fully or largely recover the cost to build and maintain a new road.[11] This model is explained in Appendix 2.

As noted above, the value of new road investment to users and to society is likely to be highest in places where users are willing to pay for it. Toll revenue analysis, even done in a very simple way, can help us to identify situations where this is most likely to be the case. This can act as a price signal to guide prioritisation of new investment and choices about whether there is an economic case to significantly increase investment.

Users will pay a higher toll if a new road saves them more time

People are willing to pay higher tolls if they receive larger benefits from using the new road than from using the existing, untolled road. The largest benefit that people typically receive from a new road is faster travel times, although factors like comfort, reliability, or safety can also play a role (Bain & Senechal, 2022).

If tolls are high relative to travel time savings, people will choose to divert back to the untolled route rather than pay the toll. As a result, tolls cannot be set at an arbitrarily high level. When the new road is a large improvement to the existing road, then they will be able to charge a large toll. When it only makes a small improvement, they will only be able to charge a small toll.

We model light vehicle users' willingness to pay tolls using a simple transport route choice model, following McFadden (1974) and Train (2009). This model captures users' trade-off between travel time savings and financial costs. We use this to estimate the revenue-maximising light vehicle toll that could be charged on roads that offer different levels of travel time saving.[12]

Figure 8 shows how revenue-maximising tolls depend upon how much time the new road saves its users, and how many users would be diverted away to the untolled road by such a toll.

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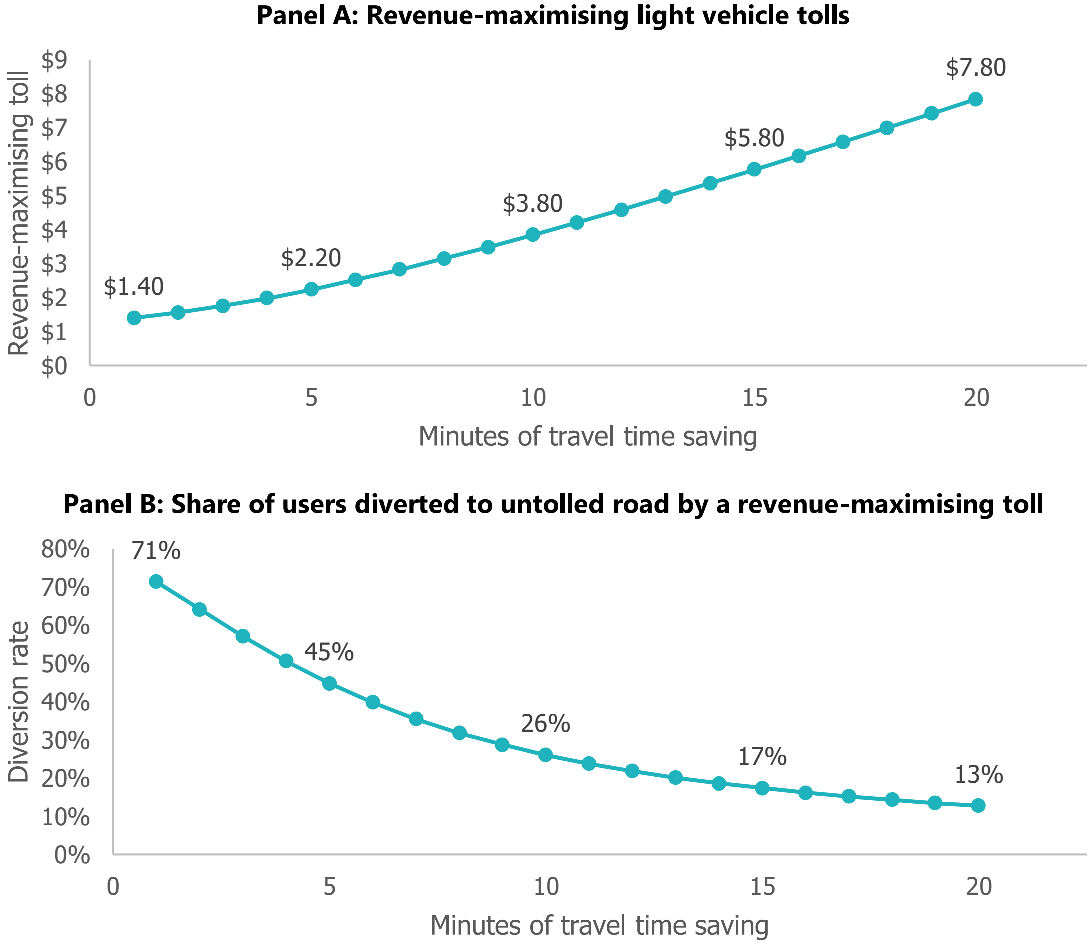
[11] We note previous work by Douglas, Brennand, and Wignall (2021), who develop a simple gravity model to analyse toll revenue potential for hypothetical new roads. However, their analysis did not extend to cost recovery potential.

[12] Heavy vehicles, like freight, tend to be willing to pay higher tolls as they typically place a higher average value on travel time. On existing New Zealand toll roads, heavy vehicle tolls are twice as high as light vehicle tolls. We use this ratio for our toll revenue calculations, noting that some categories of heavy vehicles may be willing to pay higher tolls.

For instance, we estimate that a new road that saved 5 minutes of travel time would maximise total revenues with a toll of $2.80. Under any toll, some people will divert to the untolled road. At $2.80, even though revenue is maximised, 45% of potential users still divert to the free option. Increasing the toll further would result in a net loss of revenue as the toll increase would not be enough to offset the decrease in traffic.

As time savings from a new road increase, a higher toll can be charged and fewer drivers will divert to the untolled alternative. For instance, a new road that saved 10 minutes of travel time would be able to charge a toll of $3.80, which would result in up to 26% of users diverting onto the untolled road. To put this in context, this level of travel time saving could be achieved if the new tolled route was a 20 kilometre motorway that shortened the distance of the route by 7.5 kilometres and increased average speeds from 75km/hr to 100km/hr.

Figure 8: Estimated revenue-maximising tolls for new roads



Source: Te Waihanga analysis. We estimate light vehicle users' willingness to pay tolls based on value of travel time savings parameters from NZTA's (2023) Monetised Benefits and Costs Manual. Results only depend upon the size of travel time savings, rather than the length of the road. Revenue-maximising tolls are rounded to nearest 10 cents.

Tolls need to be higher to recover costs for more expensive roads in lower-demand locations

The size of the toll that would be required to cover the costs of the road depends upon the overall cost to build and maintain the road and the number of current and future users of the road.

We model required tolls using a simple cost-recovery model in which the whole-of-life costs to build and maintain the road are spread over road users over a defined tolling period. Traffic volumes are assumed to grow in line with population forecasts, and future toll revenues are discounted to adjust for the costs to finance the construction of the road.[13]

We estimate the tolls that are needed to achieve full cost-recovery for three types of roads: low-cost motorways (similar to costs for motorways built in greenfield areas in Canterbury), high-cost motorways (similar to costs for motorways built in Auckland, Wellington, or Tauranga), and urban road tunnels (based on the average of completed or planned road tunnel projects).[14]

For each type of road, we calculate required tolls for starting traffic volumes ranging from 10,000 to 50,000 vehicles per day. To put these figures in context, traffic volumes on Christchurch's urban motorway network range from around 20,000 vehicles per day, in places like SH1's Western Belfast Bypass and SH74 through Belfast, to a maximum of slightly more than 40,000 vehicles per day, in places like SH76 through Wigram and SH1 crossing the Waimakariri River. Traffic volumes on SH1 decline to around 13,000 vehicles per day on north of Woodend and south of Burnham.[15]

Figure 9 shows how required tolls for a new road vary based on construction cost and traffic volumes. We find that:

- Required tolls escalate rapidly for higher-cost roads. They are over twice as high for a high-cost motorway as for a low-cost motorway, and over three times as high for a 5-kilometre road tunnel.[16]
- Required tolls escalate rapidly in low-traffic contexts. An $8.80 toll is required for a high-cost motorway that carries 40,000 vehicles per day. For daily traffic volumes of 20,000, this rises to $16.60 (two times higher). For daily traffic volumes of 10,000, required tolls rise further to $32.20 (four times higher).

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[13] The analysis reported here assumes a 25-year tolling period, traffic growth in line with Statistics New Zealand's 50th percentile population projection, and a discount rate of 5%, in line with Treasury's real discount rate for transport infrastructure. We further assume that the road carries an average mix of light vehicles and heavy vehicles, and that heavy vehicles tolls are twice as high as light vehicle tolls. In Appendix 2, we sensitivity test these assumptions.

[14] Unit cost data for motorways and road tunnels is sourced from New Zealand Infrastructure Commission (2022b) and updated to 2023 New Zealand dollars using Statistics New Zealand's Capital Goods Price Index for Civil Construction.

[15] https://www.nzta.govt.nz/resources/state-highway-traffic-volumes/

[16] Because the road tunnel that we have modelled is much shorter than the motorway, per-kilometre tolls are over 12 times as high for the road tunnel.

Figure 9: Required light vehicle tolls to achieve full cost recovery for new roads

Source: Te Waihanga analysis. Note: Required tolls are rounded to the nearest 10 cents and stated in 2023 New Zealand dollars. Heavy vehicle tolls are assumed to be twice as high as light vehicle tolls.

Tolls can fully fund roads in certain specific circumstances

We combine the information from Figure 8 and Figure 9 to estimate the maximum cost recovery potential for new toll roads that vary in terms of construction cost, traffic volumes, and travel time savings relative to the existing, untolled route. Figure 10 reports the resulting estimates.

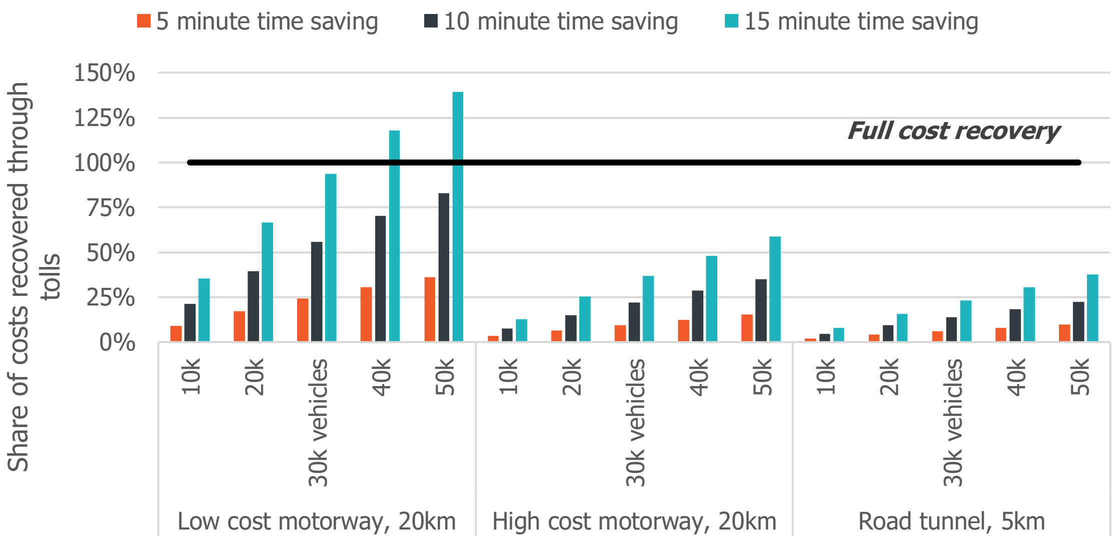
Full cost recovery is only achievable in certain specific circumstances. Tolls can fully fund new roads that satisfy all of the following key criteria:

- **Large travel time savings**: Roads must save their users around 15 minutes relative to the existing untolled road.
- **Low construction cost**: Roads must be relatively straightforward to build, like motorways built in flat terrain on cheap land.
- **High traffic volumes**: Roads must attract daily traffic volumes of at least 40,000 vehicles, equivalent to high-traffic parts of the Christchurch urban motorway network.

By contrast, cost recovery potential tends to be minimal – less than 20% – for roads that offer small travel time savings (5 minutes or less) that are costly to build or which are built in low-traffic locations (less than 20,000 vehicles per day). In these cases, administration costs and diversion of traffic away from the new road may be too high for tolling to be perceived as worthwhile.

In Appendix 2, we show that these broad conclusions are robust to a number of model extensions and sensitivity tests.

Figure 10: Modelled cost recovery potential for new roads



Source: Te Waihanga analysis. The analysis reported here assumes a 25-year tolling period, traffic growth in line with Statistics New Zealand's 50th percentile population projection, and a discount rate of 5%, in line with Treasury's real discount rate for transport infrastructure. We estimate light vehicle users' willingness to pay tolls based on value of travel time savings parameters from NZTA's (2023) Monetised Benefits and Costs Manual, and set heavy vehicles tolls to be twice as high as light vehicle tolls. Table 14 in Appendix 2 shows that our key results are not sensitive to changes in any of these assumptions.

Real-world examples of tolling

Financial outcomes for toll roads that have been built or proposed in New Zealand and other countries reinforce our finding that cost recovery from tolling new roads can be significant in cases where the new roads offer large travel time savings for a large number of users, but that it is likely to be low in cases where roads offer small travel time savings, serve low traffic volumes, or are expensive to build.

Actual or proposed toll roads in New Zealand are consistent with our model

The Auckland Harbour Bridge is the most well-known example of a new road that was fully or primarily funded from tolls. While this was a high-cost link, by the standards of the time, it served high traffic volumes, as it was built in a fast-growing urban area. It also provided large travel time savings relative to the previous alternatives of a car ferry or a long detour around the Waitematā Harbour.

As a result, many people were willing to pay a large toll to use the bridge. When it first opened in 1959, a toll of two shillings and sixpence was charged to cross the bridge. As a share of the average income, this would be equivalent to a toll of roughly $17.80 today.[17] In its first full year of operation, an average of almost 14,000 vehicles a day used the bridge, and by 1975, average daily traffic volumes had risen fivefold to around 65,000 vehicles per day.[18]

[17] Two shillings and sixpence is equivalent to 25 cents in decimal currency. New Zealand's GDP deflator (a measure of price inflation) increased by a factor of 27.4 from 1959 to 2023, while inflation-adjusted GDP per capita (a proxy for average incomes) has risen by a factor of 2.6. Source: NZIER *Data1850* https://nzier.shinyapps.io/data1850/

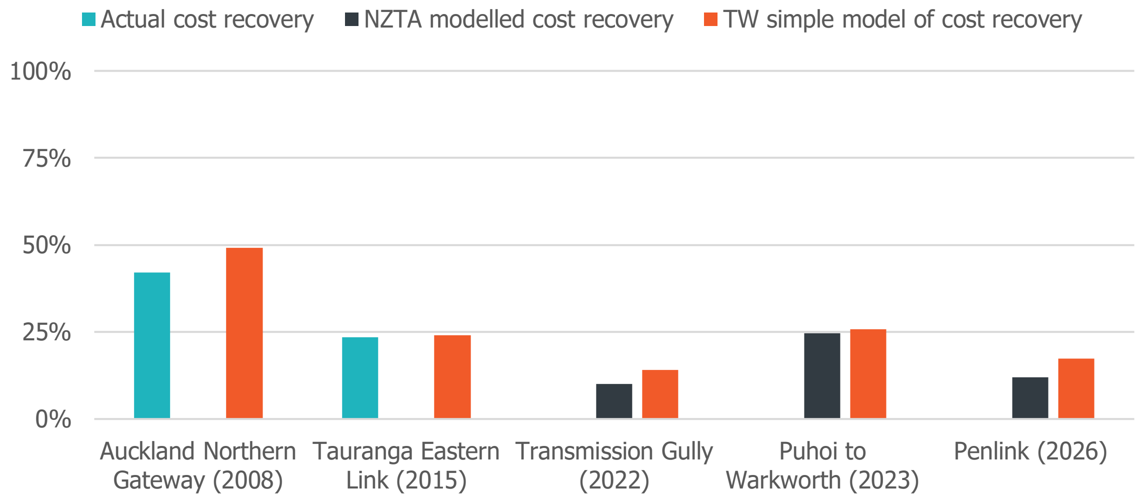
[18] https://www.nzta.govt.nz/projects/auckland-harbour-bridge/history/; NZOYB 1976.

More recent toll roads have significantly lower cost recovery, because they tend to serve lower traffic volumes and offer smaller travel time savings relative to existing roads.

Figure 11 summarises data on cost recovery for two existing toll roads and three other roads where NZTA estimated toll revenue potential using a more sophisticated model.

Traffic volumes on these roads range between 10,000 and 25,000 vehicles per day, and travel time savings in off-peak conditions range from 7 to 10 minutes. Cost recovery ranges from less than 10% (for a relatively high-cost road with lower low travel time savings – this road was ultimately not tolled) to nearly 40% (for a relatively high-cost road with larger travel time savings). Our simple model predicts similar but slightly higher cost recovery for all five roads.

Figure 11: Actual vs model-estimated cost recovery for existing or proposed New Zealand toll roads



Source: Te Waihanga analysis based on data in Table 15 in Appendix 2.

These real-world cases suggest that, in the current New Zealand context, tolls will tend to recover less than 25% of the cost to build new roads, and sometimes much less. This reflects our traffic volumes, cost to build roads, and the travel time savings that are possible in the context of a mature road network with relatively few 'missing links' to complete.

Partial cost recovery from tolls can allow some projects to be built earlier than they otherwise could be. For instance, charging a toll on the Auckland Northern Gateway and Tauranga Eastern Link enabled the roads to be built earlier than originally planned. Toll revenues were used to repay loans that were taken out to finance a share of the up-front cost of the roads.

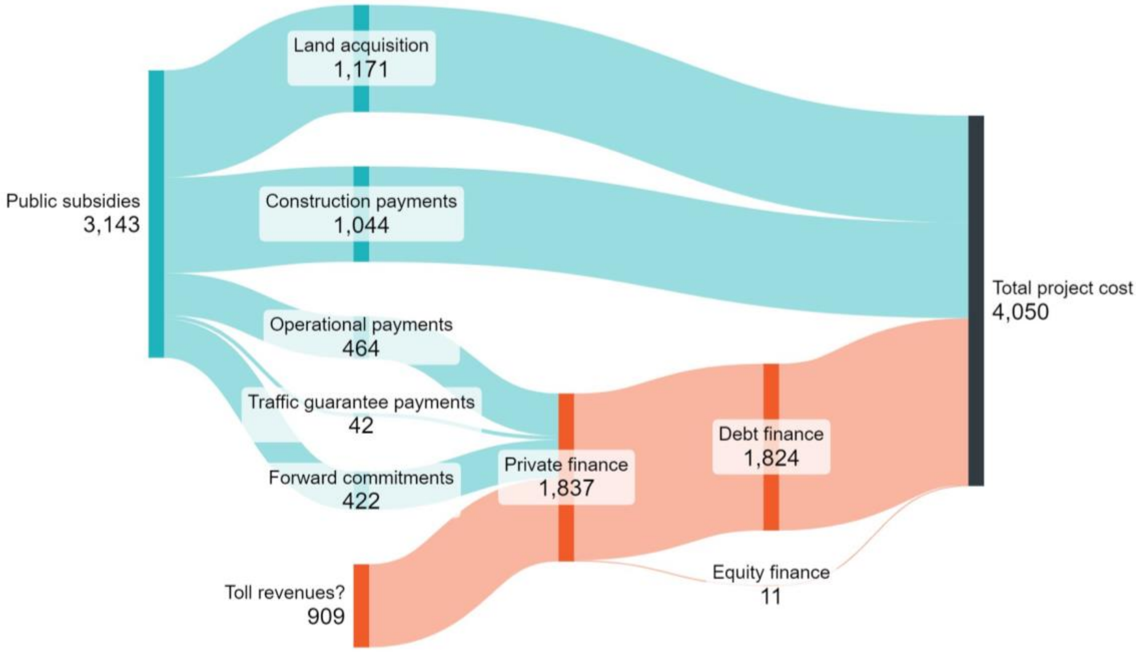
Irish toll roads show how cost recovery can decline throughout an investment programme

While our model is calibrated to New Zealand parameters, the economic fundamentals of road tolling are similar in other countries. To demonstrate this, we examine the case of Ireland, which pursued a large programme of toll road construction during the 2000s.

From 2005 to 2010, Ireland built nine toll roads, which were financed through public private partnership (PPP) deals. These roads added 300 kilometres to Ireland's motorway network at a total cost of more than €4 billion (not adjusted for inflation).[19] Average daily traffic volumes on these roads are generally in the 20,000 to 30,000 range.[20]

Figure 12 summarises data from Palcic et al's (2018) financial analysis of eight of these nine roads, which provides information on what they cost to build, how construction costs were funded and financed, and the revenue earned by the PPP companies through 2016.

Figure 12: How eight Irish toll roads were funded and financed



Source: Te Waihanga adaptation of data from Tables 2 and 3 in Palcic et al. (2018).

The total cost to build these roads, including land acquisition and design costs, was approximately €4 billion. €2.2 billion of this cost was directly funded by the Irish government, which paid for land acquisition, design, and a portion of construction costs.

The remaining €1.8 billion of the construction cost was privately financed by the PPP partners. Shareholders of the PPP companies financed their contribution primarily through debt, which accounted for more than 99% of the private finance injected into the project. [21] Less than 1% of the financing, or €11 million, was their own equity capital.

The private partners to the PPP deals expected to recoup their costs partly through toll revenues. As of 2024, tolls on these roads range from €1.70 to €3.40, mostly at the lower end of this range.[22] The other part would come from operational payments and traffic guarantee payments from the Irish government.

As of 2016, around €1.2 billion had been collected by the PPP partners. Around €0.5 billion, or 40% of total receipts, consisted of payments from the Irish government, with the rest being toll revenue.

[19] In the New Zealand context, these would be considered relatively low-cost roads.
[20] https://trafficdata.tii.ie/publicmultinodemap.asp
https://www.irishtimes.com/transport/2022/11/19/who-runs-irelands-road-tolls-and-who-gets-the-money/
[21] Palcic et al. (2018) observe that interest rates on PPP company debt were more than 400 basis points above interest rates on Irish government bonds. This appears to reflect the perceived riskiness of investing in toll roads.
[22] https://www.tii.ie/roads-tolling/tolling-information/toll-locations-and-charges/

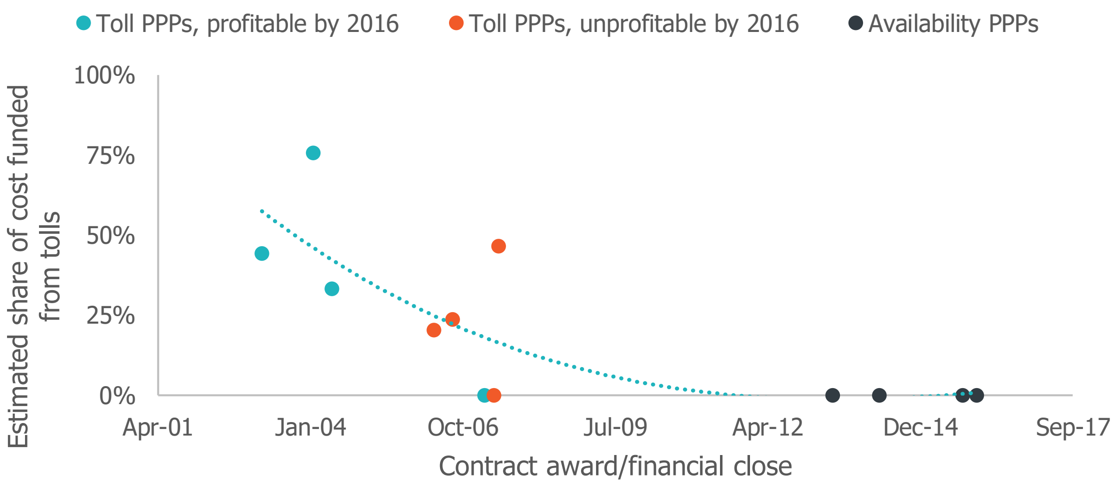
At this point, a further €422 million in future government payments had been committed by the Irish government. In spite of this, four out of the eight roads were making a financial loss for the PPP partners as of 2016, and one later underwent debt restructuring.

All up, the Irish government had provided or committed €3.1 billion to these roads, which is equivalent to 75% of the total cost to build them. Toll revenues were therefore expected to account for around one-quarter of the total cost to build the road, which is comparable to cost recovery on New Zealand toll roads with similar traffic volumes.

The Irish government contracted for four additional PPP roads between 2013 and 2016 (Sheppard & Beck, 2023). As of 2024, none of these roads are tolled. Rather than being repaid out of tolls, PPP partners for these roads are repaid for their up-front investment through 'availability payments', or payments from the government for making the roads are available to users.

Figure 13 shows that cost recovery for Irish road PPP projects declined significantly through the course of the investment programme. Early toll roads (the blue dots on the chart) averaged around 50% cost recovery. The next toll roads (the orange dots) averaged around 25% cost recovery, and private partners tended to experience financial losses. The last four PPP roads averaged 0% cost recovery, because investors would not accept repayment out of tolls and the roads were not tolled.

Figure 13: Trends in toll cost recovery for Irish PPP roads



Source: Te Waihanga adaptation of data from Tables 2, 3, and 4 in Palcic et al. (2018).

Tolls send a signal that can help to optimise new investment

Analysing potential toll revenue for new roads can help to inform choices about road investment.

If this analysis shows that toll revenues can fully fund a significant number of new roads, this is evidence that there are economic and financial benefits from increasing road investment. Moreover, the cost of the additional investment can be covered by tolls, without the need to cut back other investment, including maintenance and renewal investment.

If, on the other hand, toll revenues are insufficient to cover the cost of new roads, it is evidence that the user benefits of a new road, relative to existing roads, are not significant enough to outweigh the costs. In this case, there is not a clear case to significantly lift investment nor an incremental revenue stream to pay for that spending.

This doesn't mean that we shouldn't build more roads. It means that that they should be considered and prioritised alongside other investment needs. The benefit of toll analysis is that it can also be used to help identify those priorities. Roads where tolls can cover a larger share of their cost are more likely to be those with the greatest value to users.

The case study of Ireland, which we discussed earlier, shows that introducing price signals to investment decision-making, like the need to pay for new roads partly out of tolls, can have different impacts on investment levels depending on the context.

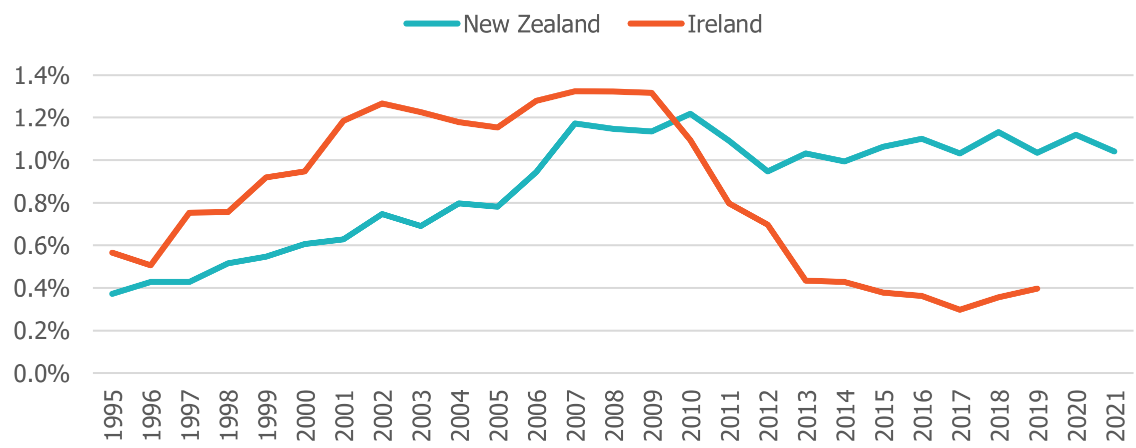
When users' willingness to pay for new infrastructure is above a certain level, as it was for the early PPP toll roads in the 2000s, this enables increased investment. But when users' willingness to pay for new infrastructure is lower, as it seemed to be for the later PPP toll roads, investment may decline due to a lack of revenues. France's toll road programme experienced similar trends towards declining cost recovery for new roads between the 1970s and 1990s, leading a system of cross-subsidisation from existing toll roads to new roads (Public-Private Infrastructure Advisory Facility, 2009).

Figure 14 shows that New Zealand and Ireland spent a similar share of GDP on road investment in the mid-1990s, but that Ireland was able to lift investment much more rapidly in the early 2000s as a result of its toll road programme.

However, after the final PPP toll road was completed in 2010, Irish road spending declined markedly. This was primarily due to the impacts of the Global Financial Crisis on the Irish economy and hence on government spending. However, declining toll revenue and declining market interest in building PPP toll roads also played a role. If users' willingness to pay tolls was higher in this period, it would have been possible to continue investing even in the face of declining government spending.

As a result, New Zealand spent an average of 1.1% of GDP on road investment over the last decade, while Ireland spent an average of around 0.4% of Gross National Income.

Figure 14: Road investment as a share of GDP or GNI in New Zealand and Ireland



Source: New Zealand road capital investment data from New Zealand Infrastructure Commission (2024); Ireland data, available to 2019, is from OECD-ITF. We compare Irish road investment to a modified Gross National Income measure, rather than GDP, to strip out the impact of globalisation effects that affect measurement of the size of the domestic Irish economy.[23]

[23] https://www.cso.ie/en/releasesandpublications/ep/p-ana/annualnationalaccounts2022/gniandde-globalisedresults/

Congestion charges: Pricing to guide usage

PwC assessed the land transport's pricing system settings as having **mixed performance against Pricing Goal 2** (see Figure 6). While transport prices are transparent to users, they sometimes under-recover the overall costs to provide transport networks, and many externalities associated with road use, like urban congestion, vehicle noise and emissions, and safety risks, are unpriced or under-priced. As a result, price signals do not incentivise optimal use of transport networks.

As outlined in Appendix 1, transport prices are intended to be set on a cost-recovery user-pays basis, but do not typically achieve this in practice. In addition, fuel excise duties and road user charges are the same everywhere in New Zealand, which means that they do not signal costs that vary according to where and when people use road networks, such as urban road congestion.[24]

In this section, we examine the impact of another type of price that could be set to address this issue: **congestion charges**. While congestion charging is not possible under current legislation, it has been investigated in recent years, leading to in-principle agreement to develop new legislation to enable it. We consider how congestion charges could incentivise different use of urban road networks and how this may affect the need for new investment.

Signaling social costs is important for good network performance

Using prices as signals to users about how to use networks most efficiently is important for several reasons.

First, the cost to provide and use infrastructure networks can vary significantly between different locations. For example, in some cases the cost to service new housing with infrastructure is several times higher in 'greenfield' locations than it is in 'brownfield' areas where existing infrastructure can be upgraded (Infrastructure Victoria, 2023; MRCagney, 2019; NSW Productivity Commission, 2023).

Second, infrastructure can get congested at peak times, meaning that each additional user imposes a cost on other network users.

Third, use or provision of infrastructure often leads to 'spillovers' or externalities for non-users. For example, noise and emissions from vehicle traffic can have a negative impact on surrounding residents and businesses.

Prices are one way to signal these costs so that users can choose how best to use infrastructure. If they don't have this information, they may choose to use networks in ways that end up increasing overall costs for all users. For instance, if councils charge the same development contributions in locations that are extremely expensive to service with infrastructure as they charge in cheaper locations, then a greater share of people may choose to live in the expensive locations. This will drive up the total cost of infrastructure provision that needs to be recovered from all users.

[24] There are also other examples of costs that vary by location or time period. This includes the impact of heavy vehicle movements on different classes of roads, which can affect decisions about use of rural roads and land, and air quality and traffic noise impacts, which are mostly an urban issue.

Congestion costs are poorly signalled to users

Congestion costs vary significantly by location and time of day

Because fuel excise duty and road user charges are set at a national level, they are not effective at signalling costs that vary significantly by location and time of use, like traffic congestion, traffic noise, and some types of vehicle emissions.[25]

Congestion is a common phenomenon in road networks, but it is only a significant problem on a small share of the network at specific times of day. In low-traffic conditions where roads are operating well below their design capacity, like most rural roads, this isn't a problem. But in high-traffic conditions, like some urban roads, congestion costs can be significant relative to the other costs of providing and using road networks.

In New Zealand, traffic congestion is most acute in Auckland. The Ministry of Transport (2023a) estimates that the annual social and economic cost of congestion is around $400 million in Auckland, $39 million in Wellington, and only $4 million in Christchurch.[26] Figure 15 shows that traffic congestion is not evenly distributed in Auckland. Congestion is worse at peak times than off-peak times, and is most severe on a relatively small proportion of Auckland's total road network, especially near the city centre and on key motorway corridors.

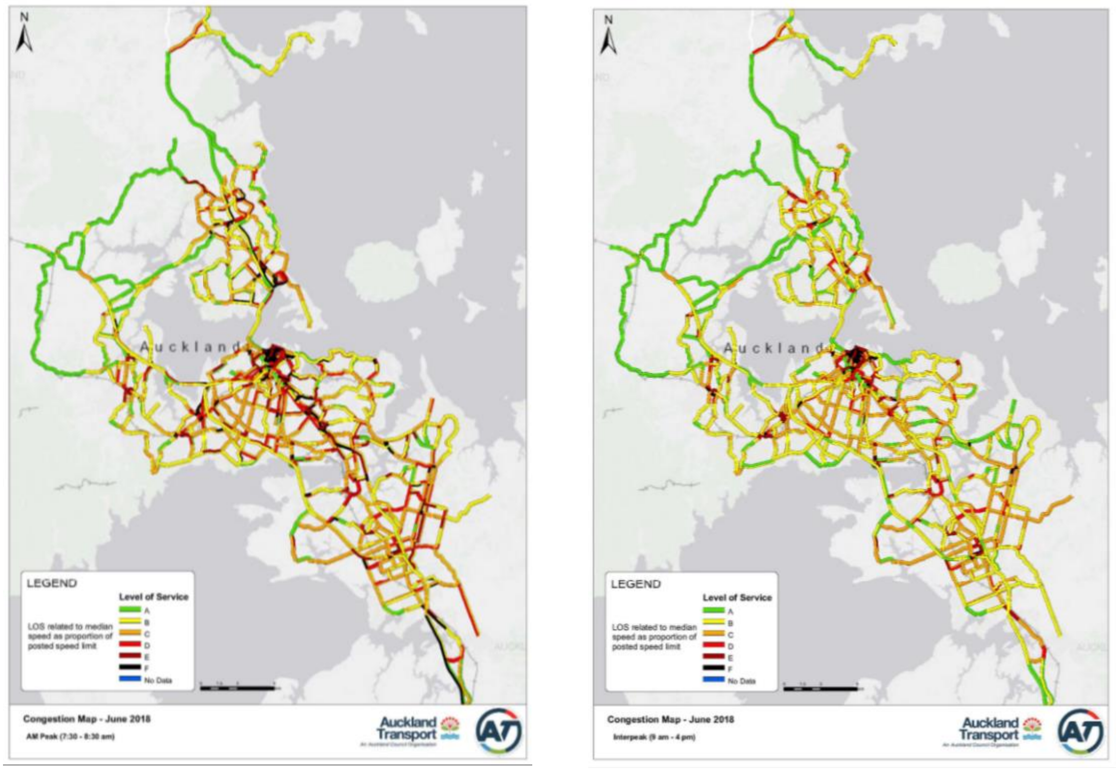
Because congestion is a highly nonlinear phenomenon, small changes in traffic in congested conditions can cause large changes to network efficiency and reliability. This means that users' experience of congestion may be worse than the conditions on the average day.

[25] In addition to carbon emissions, which have global environmental costs, petrol and diesel vehicles emit several pollutants, like fine particulate matter (PM10/PM2.5) and nitrous oxides, that damage human health. A recent New Zealand study found that the annual health costs of these transport emissions, from increased death, illness, and lost productivity, is equal to over $10 billion (Kuschel et al., 2022).

[26] This is a higher figure than Wallis and Lupton (2013) but a lower figure than NZIER (2017). All three reports used a similar concept of excess congestion (i.e., congestion that results in reductions to road throughput), but NZIER appears to report a higher figure as they accounted for some additional second-order impacts of congestion.

Figure 15: AM peak and interpeak congestion in Auckland, 2018

Panel A: AM peak congestion *Panel B: Interpeak congestion*



Source: The Congestion Question (2019).

The cost of driving does not vary by time or location

Due to the way that road use is priced, people don't consider the delays they impose on other drivers when they choose whether and when to drive.

Petrol taxes and road user charges are the same everywhere in New Zealand. They can be an effective way to recover overall costs to provide the road network. When set to fully recover costs, they signal the *average* cost of road use to users, excluding externalities.[27]

Some transport prices vary more by location. Public transport fares, which are set by regional councils, tend to vary between cities, within cities, and by time of day depending upon the cost to provide services. Similarly, development contributions for local road improvements can vary by location. However, these prices make up a small share of overall land transport funding so their signalling power is limited.

Over time, more congested parts of the network will tend to receive more investment in road capacity expansion than less congested locations (Wallis & Lupton, 2013). Because investment is mainly funded out of national-level petrol taxes and road user charges, user charges will be too high for people driving in less-congested rural locations and too low for people driving in more-congested urban locations, relative to the cost that these users impose (Infometrics, 2008).[28]

[27] We also have some mechanisms for signalling the cost of national-level externalities, like the impact of carbon emissions on climate change. However, some quantitatively important externalities, like the health impacts of air pollution caused by vehicle emissions, aren't priced at all.

[28] Similar issues can also arise due to heavy vehicle movements. For instance, the maintenance costs arising from heavy vehicle use may vary between different road categories. For instance, trucks may cause more damage to lightly-constructed rural roads than they do to urban roads.

This in turn encourages additional driving in congested places, causing excess traffic congestion.

You can spend a large amount trying to build your way out of congestion

International and local evidence shows that supply-side solutions, like building more road capacity, are not effective for reducing urban congestion. It is possible to spend a lot of money on transport infrastructure construction and end up with roads that are equally congested.

The 'fundamental law of road congestion' is that if you build more roads, more people will drive cars as a result, and congestion will remain. This is also called the 'induced traffic' effect. Several careful statistical studies demonstrate that it applies in 228 US cities over the 1983–2003 period (Duranton & Turner, 2011), 93 Japanese cities over the 1990–2005 period (Hsu & Zhang, 2014), and 545 European cities over the 1985–2005 period (Garcia-López et al., 2022). The available evidence suggests that induced traffic effects also occur in New Zealand (Byett et al., 2024).

Induced traffic effects can vary between different contexts. They tend to be larger in congested urban areas, where there is some pent-up demand for driving, and smaller on uncongested rural roads (Byett et al., 2024). Induced traffic effects appear to be smaller in places with better public transport services or road tolls (Garcia-López et al., 2022).

International evidence on congestion pricing

The basic idea of congestion pricing is to charge people more to drive on busy roads at peak times. If these charges are set to reflect the cost of the extra delay that each added driver imposes on other road users, they can encourage people to avoid creating excess congestion.[29] This will in turn maximise the overall capacity of the road network to move people and goods.

Some cities have tried congestion pricing

While many cities have tried to build their way out of congestion, with little success, some cities have taken a different approach, using congestion pricing or similar pricing policies like variable toll lanes on motorways. These schemes involve additional charges to drive on congested parts of the road network, often with variation in charges between peak and off-peak periods.

Table 4 shows that congestion pricing schemes commonly lead to a 10-20% reduction in the number of people trying to drive to the charged areas. Because these areas tend to be heavily congested, this tends to lead to a proportionately larger improvement to travel times. For instance, Singapore found that traffic volumes reduced by 13% but average road traffic speeds increased by 20%. In addition, congestion pricing schemes tend to improve the reliability of travel times.

[29] Eliminating 'excess congestion' does not mean that roads will always operate at free-flow speeds. Rather, it means that the overall number of vehicles moving through the road network is maximised. Traffic modelling suggests that this point is reached at approximately traffic level of service C, which is the point at which the trade-off between more cars on the road and slower speeds is maximised (The Congestion Question, 2019). 'Excess congestion', accounts for perhaps one-quarter to one-half of total traffic delay – the remaining delay would be economically inefficient to eliminate (Bureau of Infrastructure, Transport and Regional Economics, 2015; Wallis & Lupton, 2013).

Table 4: Observed impacts of congestion pricing in selected cities

City (date)	Scheme type	Reduction in traffic in affected areas	Change in travel times or delay in affected areas
Stockholm, Sweden (2006)	City centre cordon charge	20%	30-50% congestion reduction
Gothenburg, Sweden (2013)	City centre cordon charge	12%	Observed average travel time reduction of 9%
Singapore (1998)	Area wide scheme including expressways	13%	Road speeds increased 20%
London, UK (2003)	City centre area charge	10%	Travel times increased slightly due to exemptions from charges and other changes to transport networks
Dubai, UAE (2007)	Strategic highway charge	25% reduction on charged roads, with increase on parallel routes	50% reduction in travel time, with increases on parallel routes

Source: Most data in this table is from The Congestion Question (2020); data on Stockholm congestion reduction is from Eliasson (2014) and data on Gothenberg congestion reduction is from West and Börjesson (2020).

Stockholm shows that there are many ways to avoid paying a congestion charge

If congestion pricing discourages some people from driving in congested areas, what do they do instead? This is an important question, because it affects the feasibility of putting congestion pricing in place. If people don't have realistic alternatives to driving to a specific place, at a certain time, then pricing may not be effective.

People's ability to respond to a price signal depends in part on the availability and quality of alternatives. For instance, as our analysis of toll roads shows, if the alternative untolled route is almost as fast as the toll road, a small monetary toll will cause many people to shift to the untolled road. However, if the untolled route is much slower, fewer people will shift.

In urban areas, people often see public transport or bypass roads around congested areas as the main alternatives. As a result, some argue that congestion pricing shouldn't be implemented in places where these alternatives are seen as inadequate (Börjesson et al., 2014; Eliasson, 2014).

However, those aren't the only options. In addition to switching to another transport mode or a different route, people can choose to:

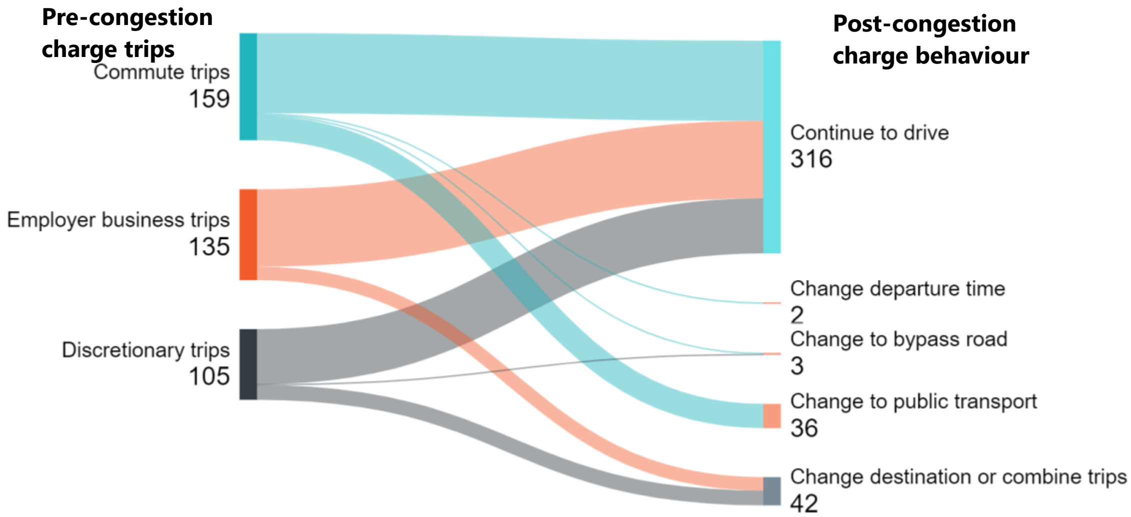
- go to another destination instead
- travel at a different time, if congestion charges are mainly applied at peak times
- combine multiple trips into one to avoid paying multiple charges
- avoid making a trip, if the value of the trip was low to them
- over time, increase housing and business development in areas that are less exposed to congestion.

The case study of Stockholm shows that, even in a location with good public transport and an unpriced bypass road, people respond to congestion pricing in many different ways. Stockholm's congestion pricing scheme reduced the number of peak car trips to the city centre by around 20%. A travel survey was carried out to find out what happened to these trips (Eliasson, 2014).

Figure 16 shows that the largest single response was for commuters to change to public transport. This accounted for 43% of the total reduction in car trips. However, an equally important response was for discretionary trips and professional trips (like trades and couriers) to change destinations or combine multiple trips into one. For instance, trades workers may have scheduled jobs to allow them to serve multiple customers in a single trip into the charging area, rather than making separate trips. This accounted for 50% of the total reduction in car trips.

What this means is that although congestion pricing is likely to be more effective in areas with good public transport, people also have other options for changing behaviour to avoid the charge.

Figure 16: Changes in peak-time trips to the Stockholm city centre after congestion pricing



Source: Adapted from Eliasson (2014). Diagram: https://sankeymatic.com/build/.

Forecasted impacts of congestion pricing in Auckland

Since 2006, a number of major reports have investigated congestion pricing for Auckland and found that it would significantly reduce excess traffic congestion in Auckland (Alternative Transport Funding Project, 2013; Auckland Transport Alignment Project, 2016a; Ministry of Transport, 2006, 2008; The Congestion Question, 2020). Moreover, congestion pricing is expected to be more effective than any other way of achieving this objective.

How to cut Auckland's traffic delay by one-third

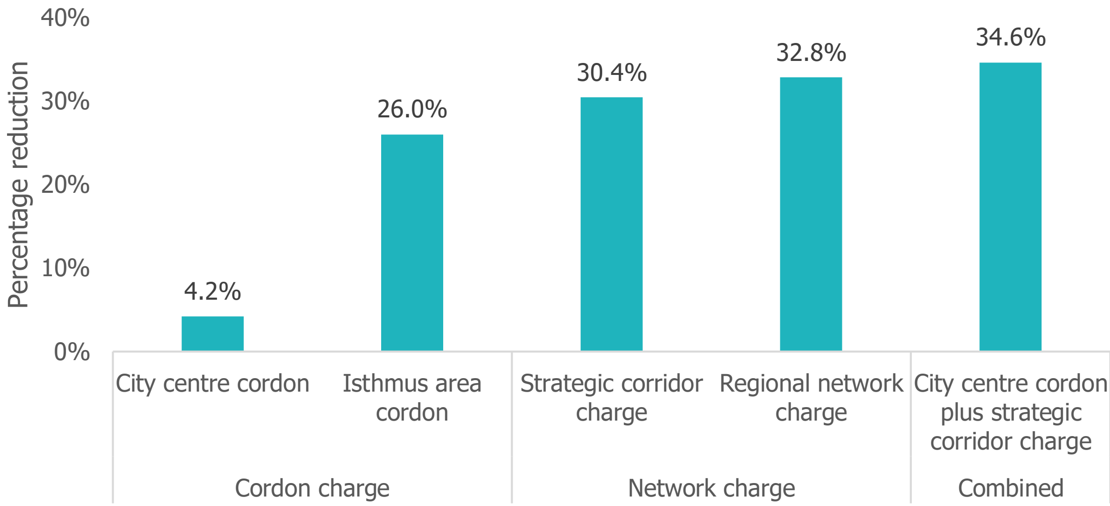
Figure 17 shows the modelled impact of five different congestion pricing schemes on excess traffic congestion in Auckland, relative to a road network that is operating at optimal capacity.[30]

The most ambitious option, a combined city centre cordon and strategic corridor charge, is expected to reduce excess traffic congestion by almost 35% on the average day. This means that this pricing scheme would 'solve' over one-third of Auckland's congestion problems. Larger

[30] Excess traffic congestion is measured relative to the level of service that maximises total throughput of the road network, rather than completely free-flow conditions. This is achieved at a level of service of around 'C'.

improvements could presumably be achieved by adjusting the level of congestion charges to local conditions, rather than setting a single charge everywhere on the network.

Figure 17: Modelled impact of congestion pricing options on excess congestion delay on Auckland's road network, 2028 morning peak period



Source: The Congestion Question (2020).

In addition to modelling changes in traffic delays, the Congestion Question (2020) also modelled impacts on total vehicle and public transport trips on the Auckland network during the morning peak period. Congestion pricing is expected to reduce total driving, increase use of public transport, and encourage people to shift car trips to off-peak periods or choose destinations where congestion charges are lower.

However, the impacts on overall travel demand are small. Because congestion is highly nonlinear, it is only necessary to shift a small share of total demand off the network to achieve a significant reduction in traffic delay.

The most ambitious option, a combined city centre cordon and strategic corridor charge, is expected to reduce total morning peak vehicle trips by a mere 1.7% and increase total public transport trips by 1.5%. This means that existing public transport capacity is likely to be sufficient to accommodate added demand, although some parts of the network may come under pressure. Fare revenues from additional trips is likely to help offset the cost of any new services or infrastructure that is needed.

How to save $10 billion in transport investment

The Congestion Question (2020) did not consider how congestion pricing would change investment needs. However, an earlier piece of analysis by the Auckland Transport Alignment Project (2016b) compares outcomes from alternative scenarios with different approaches to transport pricing and investment.

Table 5 summarises outcomes from these scenarios. A 'higher investment' scenario in which the city builds a large amount of new road and public transport capacity would lead to worsening congestion during both the peak and inter-peak periods. By contrast, an 'influence demand' scenario with congestion pricing would see local and central government spending 19% less on new infrastructure investment than in the other scenario but would also achieve large and sustained reductions in peak-time congestion.[31]

This means that congestion pricing would reduce congestion and allow the city to avoid over $10 billion in transport investment that it may otherwise need to try to respond to congestion pressures. This is an annual cost saving of $340 million that would otherwise be paid for out of transport user charges and rates.

To put this number in context, the most ambitious scheme modelled by The Congestion Question (see Figure 17) would raise annual revenues of around $260 million.[32] While these are merely indicative scenarios, they suggest that the impact of congestion pricing might be to *lower* overall transport user charges due to reduced investment needs.

Table 5: Comparing alternative approaches for addressing congestion in Auckland

Scenario	New infrastructure investment over 30 years (2023 NZD)	Congestion pricing?	Share of travel time spent in severe congestion, 2046	
			AM peak	Interpeak
2013 network performance			*27%*	*16%*
'Higher investment' scenario	$55.0 billion	No	31%	21%
'Influence demand' scenario	$44.7 billion (19% less investment)	Network-wide pricing	23%	17%

Source: Te Waihanga analysis of data from ATAP (2016b), updated to 2023 New Zealand dollars using Statistics New Zealand's Capital Goods Price Index for Civil Construction.

Congestion pricing will reduce our investment needs

In cities, our transport investment needs will change as a result of congestion pricing. Reduced congestion will allow us to defer or avoid some costly road upgrades (Anas & Xu, 1999). When we do invest, new capacity will not fill up as rapidly (Garcia-López et al., 2022).

On the other hand, congestion pricing will also increase demand in some specific parts of the network. Demand for public transport and cycling will increase, which might trigger the need for capacity improvements for those modes in some places. Car trips may re-route to different corridors or destinations, which might create the need for investment there. However, transport modelling shows that the overall impact of these changes is likely to be minor, and largely possible to accommodate within existing transport capacity.

The case study of Sweden, which we discussed earlier, shows that using transport prices to guide better use of transport networks is likely to lead to lower overall investment needs.

[31] These scenarios are likely to generate broader costs and benefits, which are not comprehensively analysed in the ATAP report. Both scenarios should be treated as indicative, as neither is likely to optimise overall value for money from Auckland's transport network. However, we note that subsequent cost benefit analysis indicates that some specific congestion charge schemes are likely to deliver benefits in excess of costs (The Congestion Question, 2020).

[32] The Congestion Question modelling report suggests that the combined city centre cordon and strategic corridor charge, which achieves the largest reduction in congestion, would raise $223 million in annual revenue. We adjusted this figure for consumer price inflation between 2020 and 2023.

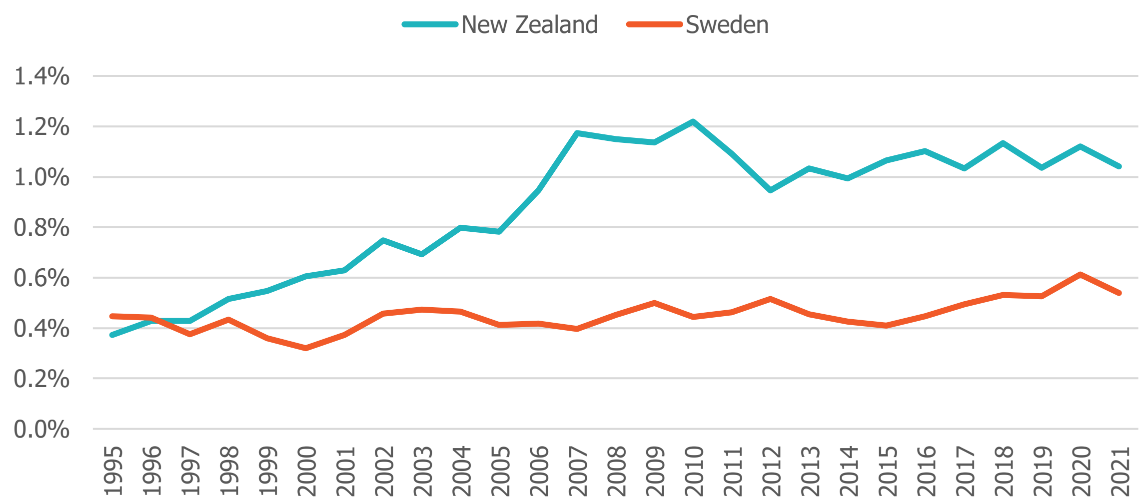
Sweden implemented congestion pricing in Stockholm, its largest city, in 2006, and in Gothenburg, its second-largest city, in 2013. These pricing changes fit into a broader Swedish pattern of using price signals to optimise use of transport networks.

Over the last three decades, Sweden has significantly increased transport prices and carbon prices to reduce carbon emissions from transport. This started in 1991 with a carbon tax on of US$30/tonne on household heating fuels and transport fuels. This caused an 11% reduction in transport carbon emissions (Andersson, 2019). A 'Green Tax Shift' starting in 2001, which included measures like increases to carbon taxes and purchase subsidies for low-emission vehicles, caused further transport carbon emission reductions of up to 20% (Koch et al., 2022). Carbon emission reductions appear to reflect a shift to more fuel-efficient vehicles and a reduction in traffic growth.

Like New Zealand, Sweden's population growth accelerated significantly between the late 1990s and late 2010s, placing upward pressure on infrastructure and housing.[33] However, unlike New Zealand, Sweden was able to accommodate accelerating population growth without such a large increase in share of GDP spent on transport infrastructure.

Figure 18 shows that New Zealand and Sweden spent a similar share of GDP on road investment in the mid-1990s but New Zealand now spends over twice as much. Over the last decade, New Zealand spent an average of 1.1% of GDP on road investment, while Sweden spent an average of 0.5%. This suggests that congestion pricing revenues were used to substitute for other transport funding sources rather than leading to higher overall investment.[34]

Figure 18: Road investment as a share of GDP in New Zealand and Sweden



Source: New Zealand road capital investment data from New Zealand Infrastructure Commission (2024); Sweden data is from OECD-ITF.

[33] https://data.worldbank.org/indicator/SP.POP.GROW?locations=TW-SE-NZ
GDP per capita growth was also comparable between the two countries: https://data.worldbank.org/indicator/NY.GDP.PCAP.KD?locations=NZ-SE
[34] Stockholm congestion charging was associated with a programme of road and public transport improvements to increase alternatives to paying the congestion charge. However, this did not lead to a noticeable increase in overall transport investment at the national level.

Pricing to help share benefits

PwC assessed the land transport's pricing system settings as having **mixed performance against pricing Goal 3** (see Figure 6). This is because efficiency improvements are more likely to result in increased investment, which may improve quality of services, rather than lower prices for users.[35] And many users have limited access to transport alternatives, preventing them from making price-quality tradeoffs.

As noted in the Introduction, infrastructure prices are often a focus for affordability and equity concerns. Due to the demand characteristics of infrastructure services, increases to infrastructure prices tend to reduce usage but also increase the share of household incomes spent on infrastructure. Because low-income households tend to spend more of their income on infrastructure services, higher prices can have a larger impact on their discretionary income.

In this section, we examine how introducing new prices and charges, namely road tolling and congestion pricing, might affect affordability for different types of households.

New Zealand households spend a lot on land transport

The average New Zealand household spent around 16% of its after-tax income on infrastructure services in 2018/19, amounting to slightly over $13,000 a year (New Zealand Infrastructure Commission, 2023a).

A total of 55% of this spending is on private transport infrastructure services, like the costs to own and operate cars, and 6% is spent on public transport infrastructure services, including public transport fares and local government rates that are used to fund public transport services. As a result, the average household spends over 10% of its after-tax income, or more than $8,000 per year, on transport infrastructure services.

Low-income households tend to spend a larger share of their income on transport

High-income households tend to spend more on transport than low-income households. They are likely to own more cars, drive more, and use public transport more frequently.

However, transport spending does not rise proportionately with income, meaning that lower-income households tend to spend a larger share of their after-tax income on transport. While these households may drive and take public transport less, they still have to pay for fixed costs like owning a car or paying taxes and rates that go towards funding transport infrastructure and public transport services.[36]

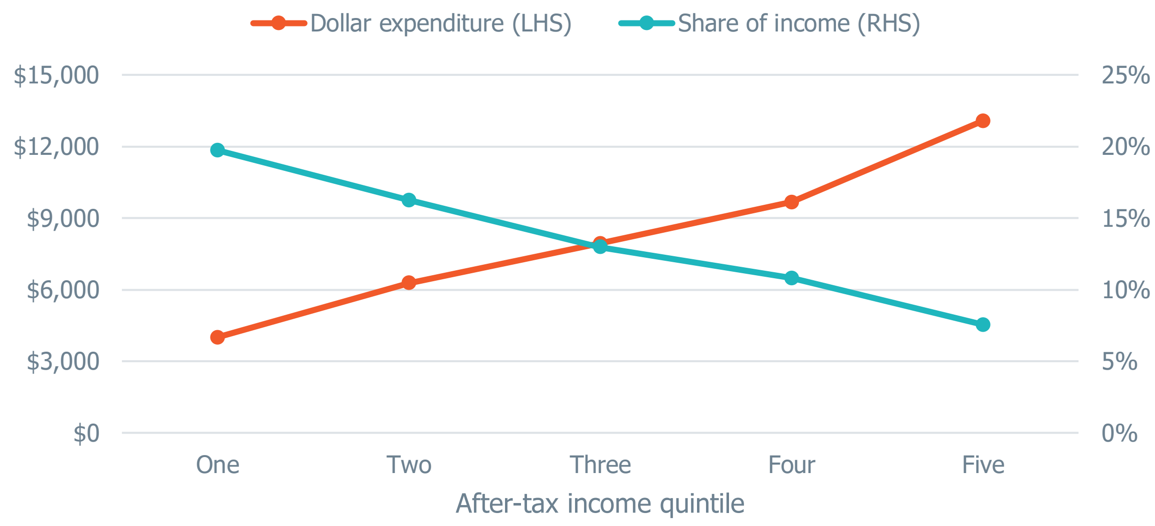
Figure 19 shows that, in 2018/19, the lowest income households spent just under 20% of their after-tax income on transport, an average of $4,700 for the year. In comparison, the highest income

[35] In recent years, there has been a trend towards rising prices for investment and maintenance activity, driven by a combination of slow productivity growth, rising input prices, and scope changes to projects (New Zealand Infrastructure Commission, 2022b, 2022a, 2023c). This is placing upward pressure on transport prices.
[36] In 2018/19, around 43% of households' overall transport spending consists of 'variable' costs that vary depending upon household use of transport networks, while 57% consists of 'fixed' costs that do not vary directly with usage. Note that, in this analysis, we estimate households' cost to own a 'basic' car. In reality, high-income households are likely to own more expensive cars than low-income households.

households spent only 7% of their after-tax income, a lower share, but higher overall at nearly $13,000 for the year.

While low-income households tend to spend a larger share of household income on transport, there can be significant variation in spending between households with similar incomes. For instance, low-income people living in the Auckland city centre tend to have much lower infrastructure spending than low-income people living in south Auckland. This can make it difficult to target assistance to households facing affordability challenges.

Figure 19: Annual household transport expenditure by after-tax income quintile in New Zealand



Source: New Zealand Infrastructure Commission (2023a).

Toll roads allow users to make price-quality tradeoffs

In the first substantive section of this report, we analysed cost recovery potential for toll roads. Under New Zealand's Land Transport Management Act 2003, tolls can be levied on new roads if a 'feasible, untolled alternative route' is available to road users.

In that section, we showed that tolls on a new road can fully cover the cost to build and maintain the road under certain conditions, but not others. Here, we consider the impacts of building new toll roads on Pricing Goal 3.

When new toll roads achieve full cost recovery, they provide choices without affordability costs

The key feature of a toll road is that people do not have to use it and pay the toll. If people cannot afford the toll, or feel that the toll is too high relative to the benefits they receive from using the road, then they do not have to pay.

When tolls can recover the full cost to build a new road, then there is no need to seek funding from non-users. In this case, toll roads have a strong positive impact on performance against Pricing Goal 3. This is because:

- The new toll road allows people who value higher quality of service, such as a faster or more comfortable road, to pay to obtain it.

- People who are not willing or able to pay to use the road, such as low-income households, do not need to pay more and hence do not face additional affordability challenges.
- People who are not ordinarily willing to pay the toll still benefit from the option to use the road, for instance if they need to get somewhere faster due to a family emergency (Cook & Li, 2023).

When new toll roads are partly subsidised by non-users, impacts are harder to assess

The distributional impacts of new toll roads are harder to assess when tolls only cover part of the cost to build the road. In this case, it is necessary to pay for the rest of the cost out of transport charges levied on all road users, like fuel excise duty and road user charges.

Most of the benefits of a new road accrue directly to people who use the road (see Table 3). As a result, people who are not willing or able to pay the toll, but who pay other transport charges that are used to help fund the new road, end up subsidising benefits for users of the toll road.[37] In this scenario, tolling results in more mixed performance against Pricing Goal 3. This is because:

- The new toll road allows people who value higher quality of service, such as a faster or more comfortable road, to pay more to obtain it.
- People who are not willing or able to pay to use the road, such as low-income households, may still face increased transport charges to help to pay for the road, which may reduce the affordability of transport for them.

Understanding the distributional impacts of a road that is partly paid for by tolls requires us to understand how changing other transport prices, like fuel excise duty or vehicle registration fees, affects different types of households.

Congestion charges distribute costs to people who use networks more

The PwC study includes a quantitative exploration of the distributional impacts of different types of infrastructure prices, including fixed charges levied on all users, variable charges that vary according to frequency or volume of use, and congestion charges (PwC NZ, 2024b). They used household expenditure data to analyse impacts on households of different size, with different income levels, living in different types of places.

PwC compared the impacts of raising a set amount of money (e.g. $250 million per annum) by increasing different types of charges, including fixed charges like vehicle registration fees, variable charges like fuel excise duty, and a congestion charge levied on Auckland roads.

Because high-income households travel more, they pay more through variable charges or congestion charges

Higher-income households generally use infrastructure more than lower-income households. They tend to drive more, use more water, and use more electricity. When we price infrastructure based on usage, higher-income households tend to pay more as a result, although outcomes can vary significantly between individual households.

[37] There may be a case to provide such a subsidy, for instance if the new toll road provides meaningful benefits to users on other parts of the road network.

However, most households, regardless of income, are connected to infrastructure networks. They generally own a car and a telephone and live in a home that is connected to water and electricity networks. When we charge everybody who is connected to infrastructure networks, low-income and high-income households tend to pay a similar amount.

Comparing the distributional impacts of different types of transport prices

PwC used household expenditure survey data to estimate the impacts of raising the same amount of money by either increasing vehicle registration fees or increasing fuel excise duty and road user charges at a national level. They then compared these results with a previous analysis of the household impacts of options for an Auckland congestion pricing scheme (Covec & MRCagney, 2018).[38] PwC focused on the 'Strategic Corridors' scenario, which charges people travelling along major arterial roads and motorways at peak times (see Figure 17 in previous section).

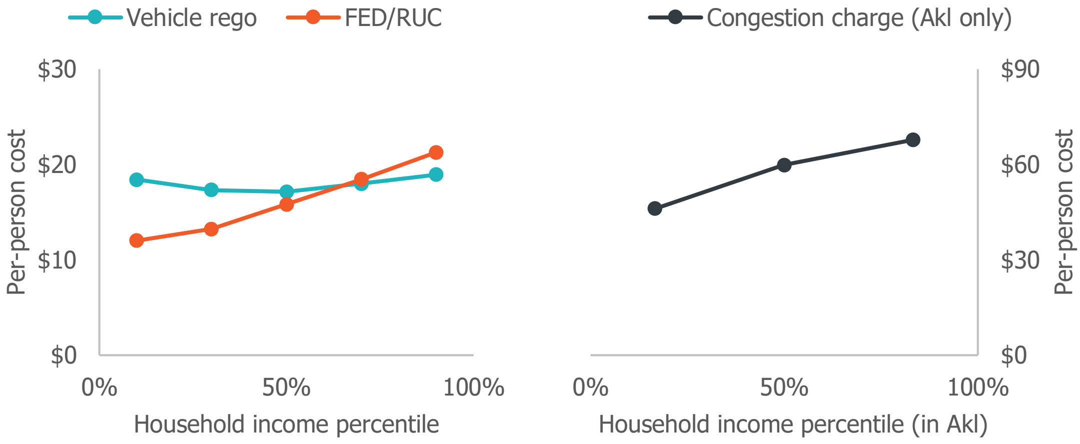
These results are not perfectly comparable. A key difference is that PwC's analysis examined the impact of increasing infrastructure charges at a national level, while Covec and MRCagney examined impacts of a charge that primarily affects Auckland households. This results in higher per-household charges within Auckland, but very little impact on non-Auckland households.

Figure 20 compares the financial impacts of these price increases for urban households with different income levels. This shows that:

- Increasing vehicle registration costs (a fixed charge) is expected to have similar financial impacts on both low-income and high-income households. People in the top income quintile are estimated to pay 5% less than people in the bottom quintile.
- Increasing fuel excise duty and road user charges (variable charges) is expected to place more of the cost on high-income households, as they tend to drive more. People in the top income quintile would end up paying 60% more than people in the bottom quintile.
- Introducing a congestion charge is expected to result in higher costs for high-income Auckland households, compared with low-income Auckland households. This is because high-income households tend to drive more at peak times. People in the top third of incomes would end up paying 15% to 30% more than people in the bottom third.[39]

[38] In addition to its analysis of household impacts, The Congestion Question also conducted a separate analysis of impacts on different types of businesses (Covec & MRCagney, 2019).
[39] Auckland households tend to have higher incomes than households elsewhere in New Zealand, so the overall effect is likely to be larger at a national level. If congestion charges are used to address urban transport issues that would otherwise attract cross-subsidies from road users in other regions, they will also improve spatial fairness.

Figure 20: Estimated annual costs of increasing transport prices on households with different income levels



Note: Te Waihanga re-analysis of data in Table C7 of PwC (2024b) (impacts on metro area households) and Table ES5 in Covec and MRCagney (2018) (all Auckland households). The vertical axis for the graph showing impacts of an Auckland congestion charge is scaled to reflect the fact that roughly one-third of the country's population lives in Auckland.

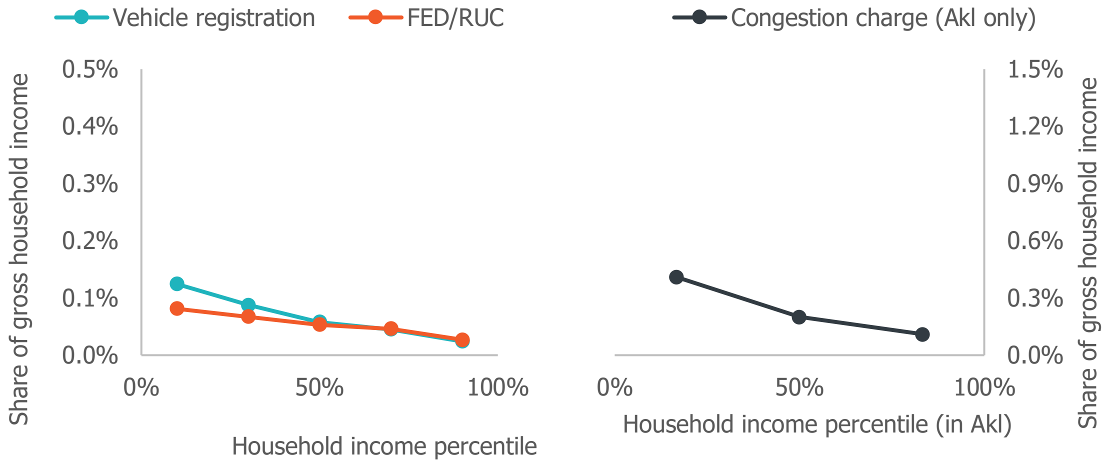
Transport prices have larger impacts on low-income households

Figure 21 shows the financial impacts of these price increases as a share of income for urban households with different income levels.

Relative to household incomes, all three types of charges have a larger impact on low-income households than on high-income households. This is because infrastructure use tends to be income-inelastic, meaning that households with higher income use networks a bit more, but not a lot more, than low-income households.

Increasing variable charges like fuel excise duty and road user charges is expected to have a slightly smaller impact on low-income households. The impacts of congestion charges are harder to assess as Auckland households tend to have higher incomes in general. However, these differences are small, meaning that reducing some infrastructure prices and increasing others is unlikely to have large net benefits for low-income households.

Figure 21: Estimated impacts of increasing transport prices on households with different income levels, relative to gross (pre-tax) household income



Note: Te Waihanga re-analysis of data in Table C8 of PwC (2024b) (impacts on metro area households) and Table ES6 in Covec and MRCagney (2018) (all Auckland households). Re-stating of estimates in the PwC report as a share of gross household income rather than disposable household income was needed to produce comparable measures. The vertical axis for the graph showing impacts of an Auckland congestion charge is scaled to reflect the fact that roughly one-third of the country's population lives in Auckland.

Affordability challenges are hard to fix by adjusting prices

Problems related to the affordability of infrastructure are hard to address through broad changes to prices. While the stated purpose of reducing transport user charges is often to improve affordability for low-income users (Ministry of Transport, 2023b), actual outcomes can differ.

This is because, unless transport investment is *also* reduced, it will be necessary to increase other transport charges, or increase taxes or rates to make up the difference. As long as the total amount of money that is spent on transport infrastructure remains the same, changing how this money is gathered will neither increase nor decrease affordability for the average household.

The distributional impacts of these changes – which types of households win and lose – are not always obvious. For instance, reducing fuel excise duty and increasing other charges like vehicle registration fees seems likely to increase, not decrease, costs for low-income households.[40]

Broad-brush price reductions can have unintended consequences for infrastructure investment. For instance, lowering the cost of driving by cutting fuel excise duties may incentivise increased use of road networks, leading to higher road maintenance costs and increased urban congestion. This might cause the need for increased investment in the future, which would place upward pressure on user charges and taxes.

In the context of a cost-recovery user-pays transport funding model, the best way to address affordability concerns is to improve the efficiency of building new infrastructure and using and maintaining existing infrastructure, and pass these cost savings on to users through lower prices.

[40] Subsidising infrastructure user charges out of income taxes is more likely to be distributionally progressive, as income tax rates are higher for higher-income people (Heatley & Sweet, 2024). This approach would not align well with the first and second goals of infrastructure pricing. However, targeted tax-funded subsidies to address specific distributional problems could be consistent with best practice infrastructure pricing principles.

The distributional impact of changes to transport prices, such as the introduction of road tolls or congestion pricing, should be assessed in this context. As shown in previous sections, these pricing tools can help to optimise new infrastructure investment by prioritising the most valuable network upgrades, and optimise use of existing urban road networks by incentivising users to avoid heavily congested parts of the network.

If these pricing tools help to optimise the total amount of transport investment that is needed, then they can improve affordability for low-income households on balance even if they seem to result in some additional costs in the short run.

Conclusion

We conclude by outlining the key findings from our analysis in this *Research Insights* paper and implications for how we assess our current and future infrastructure investment needs.

Prices provide information to guide investment and usage

While we usually think of prices as a way of raising revenue to pay for investment, they also provide **information** that can be used to inform decisions.

Information from prices is important for infrastructure providers, because it can give them a signal of users' willingness to pay for maintaining and improving infrastructure. Price signals can help to optimise the level, mix, and timing of investment.

Information from prices is also important for infrastructure users. Well-designed prices can help to signal where and when the overall economic, social, and environmental cost to use infrastructure networks is higher. They incentivise people to use networks in ways that avoid creating excessive costs for society.

We would expect infrastructure sectors that are less aligned with best practice pricing, such as land transport and water, to find it more difficult to raise the right amount of money to maintain and improve their assets. In the absence of good price signals, we would expect them to face greater challenges identifying the highest-value areas for investment. We would also expect their networks to operate less efficiently, as users lack good information and incentives to optimise their use. This will in turn create pressure for more funding from central and local government.

Using prices to guide investment can help to optimise new infrastructure

To understand how prices can help to optimise new infrastructure investment, we provide a quantitative case study of toll roads.

Tolls raise revenue to help pay for new roads, but they also provide information about the value that users place on significant improvements to the existing road network.

If toll revenues can fully fund new roads, this is evidence that there are economic and financial benefits from increasing road investment. Moreover, the cost of the additional investment can be covered by tolls, without the need to reduce spending on other parts of the network or increasing overall transport user charges.

If, on the other hand, toll revenues are insufficient to cover the cost of new roads, this means that they must be funded within existing budget constraints. We know, from past research, that New Zealanders have been willing to spend an average of around 5.8% of GDP on all types of infrastructure investment over the last 20 years, a figure that has not significantly increased or decreased over time (New Zealand Infrastructure Commission, 2024).

In this context, increasing investment in one area, like new roads, needs to be considered and prioritised alongside other investment needs such as road maintenance or hospital and school construction. Toll analysis can be used to help prioritise within existing budget constraints, as roads with a higher share of their cost paid for by tolls are more likely to be those with the greatest value to users.

Using prices to guide usage can raise the value we achieve from existing networks

To understand how prices can help to optimise the value we receive from existing infrastructure networks, we provide a quantitative case study of congestion charging.

Congestion charging uses time- and location-varying charges to encourage people to avoid congested parts of an urban road network at peak times.

Congestion is only a problem on a small part of the national road network at specific times. Because transport prices like fuel excise duty and road user charges are set at a national level, they do not signal location-specific congestion costs to users. Transport user charges are too high for people driving in less-congested rural locations and too low for people driving in more-congested urban locations, relative to the cost that these users impose on the network.

This in turn encourages additional driving in congested urban areas, leading to excess traffic congestion, and, in the long run, pressure for higher spending on urban transport networks.

Congestion pricing has been shown to reduce traffic volumes and congestion delays in places where it has been tried. In Auckland, New Zealand's largest and most congested city, one option for congestion pricing is expected to reduce excess traffic delay by 35%. Transport modelling shows that congestion pricing would enable the city to substantially improve congestion while spending 19% less on new infrastructure than an alternative scenario.

While congestion pricing will increase demand for public transport services and less-congested parts of the road network, these effects are unlikely to be large enough to result in a large increase in investment requirements. As a result, congestion pricing is likely to reduce overall investment needs by optimising existing networks.

Affordability challenges are best addressed through efficiency

In dollar terms, high-income households tend to spend more on transport than low-income households. They are likely to own more cars, drive more, and use public transport more frequently. However, lower-income households tend to spend a larger *share* of their after-tax income on transport.

This can drive concerns about the affordability of transport prices for low-income households or other vulnerable households.

However, it is hard to improve affordability for low-income households by changing transport prices. If one transport price is reduced without matching cuts to transport investment, it will be necessary to increase other transport prices or raise taxes or rates to make up the difference. While people may not perceive these impacts, the overall effects of these changes can be small and there is the potential for unintended affordability costs.

In the context of a user-pays cost recovery funding model, the best way to address affordability concerns for low-income households over the long term is to improve the efficiency of infrastructure provision and pass on these cost savings through lower prices. Any remaining affordability impacts are best addressed with targeted assistance for vulnerable groups.

Pricing tools like tolling and congestion charges can help to optimise new investment decisions and improve the performance of existing infrastructure networks. These tools can have indirect benefits for affordability even if they seem to result in some additional costs in the short run.

It's unclear whether New Zealand has a transport investment deficit, or a pricing problem

The analysis in this paper helps us to critically reflect on the idea that New Zealand has a large infrastructure deficit.

An infrastructure deficit can be thought of as a shortfall of infrastructure relative to what we want or need. However, our wants and needs are in turn a function of how things are priced.

As an analogy, think about how people tend to act at a party where the hosts are offering free pizza. People often tend to eat until they're full – and then go back for another slice. When the pizza's free, people will happily consume until they can't eat another bite. And people who turn up late to the party may not get any pizza.

People behave differently when they have to pay for pizza by the slice, say at a pizzeria. Rather than eating half a pizza, they may only have a slice or two. Are they experiencing a 'pizza deficit' as a result? Probably not. Instead, they're simply choosing an amount that reflects their true willingness to pay for pizza.

There are obviously many differences between pizza and infrastructure. However, the basics of human psychology are similar in many circumstances. When we don't pay for things, or when it's not obvious how we're paying, we often respond by consuming more than we otherwise would.

Likewise, when infrastructure providers can't see what we're actually willing to pay for infrastructure, they may struggle to make the right investments. As an analogy, someone who carefully studies how much free pizza people eat at parties before opening up a pizzeria might be surprised (and disappointed) when the average customer doesn't buy and eat half a pizza every time they visit.

Our two international case studies show how improving transport pricing can optimise investment and ensure that our needs are met.

Ireland shows the impact of price signals for new transport investment. When they introduced the need to pay for new roads partly out of tolls, it enabled them to increase investment when users' willingness to pay for new infrastructure was above a certain level. Investment later declined as the financial viability of toll roads, which is a signal of the value that users place on the road, declined.

Sweden shows the impact of price signals for transport users. Sweden implemented congestion pricing in Stockholm, its largest city, in 2006, and in Gothenburg, its second-largest city, in 2013. Congestion pricing resulted in significant reductions in traffic volumes and traffic delays in city centre areas. This appears to have helped to moderate demand for new investment: while Sweden's population growth rates have accelerated in recent decades, road investment has remained stable as a share of GDP over this time.

Appendix 1: A brief overview of land transport investment and pricing

This Appendix outlines the key elements of New Zealand's land transport investment and pricing system, focusing mainly on the road network.

New Zealand's land transport sector includes the road, rail and public transport networks. It is mainly publicly owned and operated, with responsibility for governance, planning, operations and maintenance spread across various central and local government agencies.

Land transport funding was designed as a cost-recovery user-pays model

Land transport funding is built around the concept of a cost-recovery user-pays model. User charges of various types are intended to cover the cost to build, maintain, and operate transport infrastructure and services. User charges include both:

- **Variable charges** that reflect how much people use infrastructure. These include fuel excise duty and road user charges, parking charges, road tolls, public transport fares, and rail track access charges.
- **Fixed charges** that are charged for access to the network, rather than volume of use. These include vehicle registration and licensing fees, local government rates and targeted rates, and development contributions for new housing.

Much land transport investment is done through pay-as-you-go financing, meaning that current revenues are used to pay for current investment. However, some investment is debt-financed, including some local government investment and major investments by central government that cannot be funded out of current revenues.

The National Land Transport Fund is the primary mechanism for allocating these funds

For the most part, central government spending on roads and public transport, which comprise the majority of its land transport investment, is done through the National Land Transport Fund (NLTF). This is intended to be a 'ring-fenced' fund that takes in revenues from land transport users (through fuel excise duty, road user charges, and vehicle registration and licensing fees) and spends it on transport investment and services. It is allocated by the New Zealand Transport Agency / Waka Kotahi (NZTA).

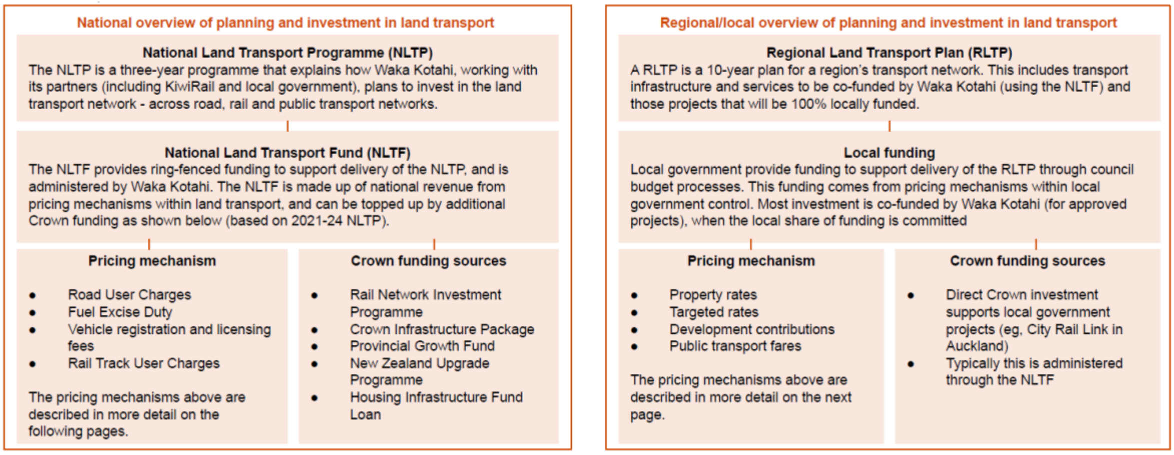
For the most part, the NLTF is spent on:

- Building and maintaining state highways, which are provided by NZTA and funded entirely by the NLTF
- Building and maintaining local roads and transport infrastructure, which are partly funded by the NLTF and partly funded by local governments out of rates and other charges

- Providing public transport services, which are funded through a mix of public transport fares, NLTF funds, and local government rates.[41]

Figure 22 shows the overall structure of the land transport funding system as of late 2023.

Figure 22: The structure of planning and investment in land transport



Source: PwC (2024a).

How investment is determined

Elected members have always played a role in determining the level of land transport investment and the desired outcomes from investment. However, the way that they have provided direction on investment has changed over time.

The land transport funding and investment system underwent reforms in 2008

The land transport system has undergone several significant reforms in recent decades, with the most recent major reforms in 2008.

The 1989 Transit New Zealand Act restructured the land transport sector It established Transit New Zealand to operate and invest in the state highway network and allocate the National Land Transport Fund. The NLTF was in turn used to fund state highways and provide funding assistance for local government's road and public transport spending. This Act established a principle of allocating funds based on cost benefit analysis (see below), with some exceptions. In practice, road maintenance funding tended to be the first priority. There were some further structural changes in the 1990s, such as a 1996 split between the state highway network operator (Transit NZ) and the fund allocator (Transfund NZ, later renamed Land Transport NZ).

The 2003 Land Transport Management Act replaced the singular focus on cost benefit analysis with a broader set of funding criteria and gave the Transport Minister more ability to direct funding levels for different activity classes. The annual central government Budget was used to set performance measures for Transfund NZ/Land Transport NZ, such as targets for pavement quality

[41] Public transport is cross-subsidised from fuel excise duties/road user charges and local government rates. This reflects the fact that public transport use generates significant non-user benefits, such as reduced road congestion. Empirical research and modelling suggests that these non-user benefits are large enough to justify operating cost subsidies of 50% or more (Adler & van Ommeren, 2016; Australian Productivity Commission, 2021; Parry & Small, 2009; Proost & Dender, 2008).

and the cost-effectiveness of road maintenance spending.[42] These targets then informed funding allocation.

In 2008, three key changes were made. First, Land Transport NZ and Transit NZ were merged to create the New Zealand Transport Agency, which is responsible for both operating and investing in the state highway network and allocating NLTF funding for state highways, local roads, and local public transport services.

Second, a new policy mechanism, the Government Policy Statement on Land Transport (GPS-LT) was put in place to direct how land transport funds are spent. The GPS-LT allows the Minister of Transport to set objectives and priorities for land transport spending and define funding ranges for individual categories of investment. It is updated every three years. The GPS-LT funding ranges set the minimum and maximum that can be spent on each transport activity class every year over a 10-year forecast period.

Third, fuel excise duties were fully hypothecated to the land transport fund, meaning that all of the main central government taxes and charges on road users were ring-fenced to pay for transport investment and services. We discuss this change further below.

The GPS on Land Transport determines how the National Land Transport Fund is spent

Since the release of the first GPS-LT in 2009, GPS-LT funding ranges have played a strong role in determining how the NLTF is spent. When funding ranges increase, spending in that activity class generally increases, and vice versa.

NZTA has some discretion about how to implement the direction in the GPS-LT. Funding ranges can be quite wide, and spending at the top of the range in all activity classes would over-allocate the NLTF. As a result, NZTA sets more specific annual spending targets for each activity class. For instance, the 2021 GPS-LT set a funding range of $800 million to $1.25 billion for state highway improvements in 2022. NZTA set a spending target/budget of $991 million for 2022 and ended up actually spending $1.034 billion.[43]

Funding ranges can change substantially across GPS-LT updates, even when there have been few changes to underlying travel demands or maintenance requirements. For example, Table 6 shows changes to the funding range for state highway maintenance, operation and renewals.

Table 6: Changes to GPS-LT funding ranges for state highway maintenance, operations, and renewals

GPS period	Years covered	Lower bound (nominal $m)	Upper bound (nominal $m)	Change to midpoint of range
2009 GPS-LT	2010-2012	$1,410	$1,725	
2012 GPS-LT	2013-2015	$1,305	$1,660	-5%
2015 GPS-LT	2016-2018	$1,350	$1,810	+7%
2018 GPS-LT	2019-2021	$1,810	$2,130	+25%
2021 GPS-LT	2022-2024	$2,260	$2,940	+32%

Source: Te Waihanga analysis of Ministry of Transport data.

[42] https://www.treasury.govt.nz/sites/default/files/2008-03/est01trans.pdf
[43] https://www.nzta.govt.nz/assets/resources/annual-report-nzta/2021-22/nltf-annual-report-2021-22-section-b.pdf

Figure 23 shows how actual spending from the National Land Transport Fund compares with GPS-LT funding ranges. These comparisons help us understand how policy affects investment choices.

Panel A shows state highway maintenance, operations, and renewal spending. Actual spending declined during the periods covered by the 2012 and 2015 GPS-LT, which reduced the funding range for this activity. They increased in 2018, reflecting an increased funding range in the 2018 GPS-LT, and increased further following the 2021 GPS-LT. An additional point to note is that, while planned work stayed within GPS-LT funding ranges, the 2016 Kaikoura Earthquake and the 2023 North Island Weather Events resulted in emergency works that exceeded the GPS-LT funding range.[44]

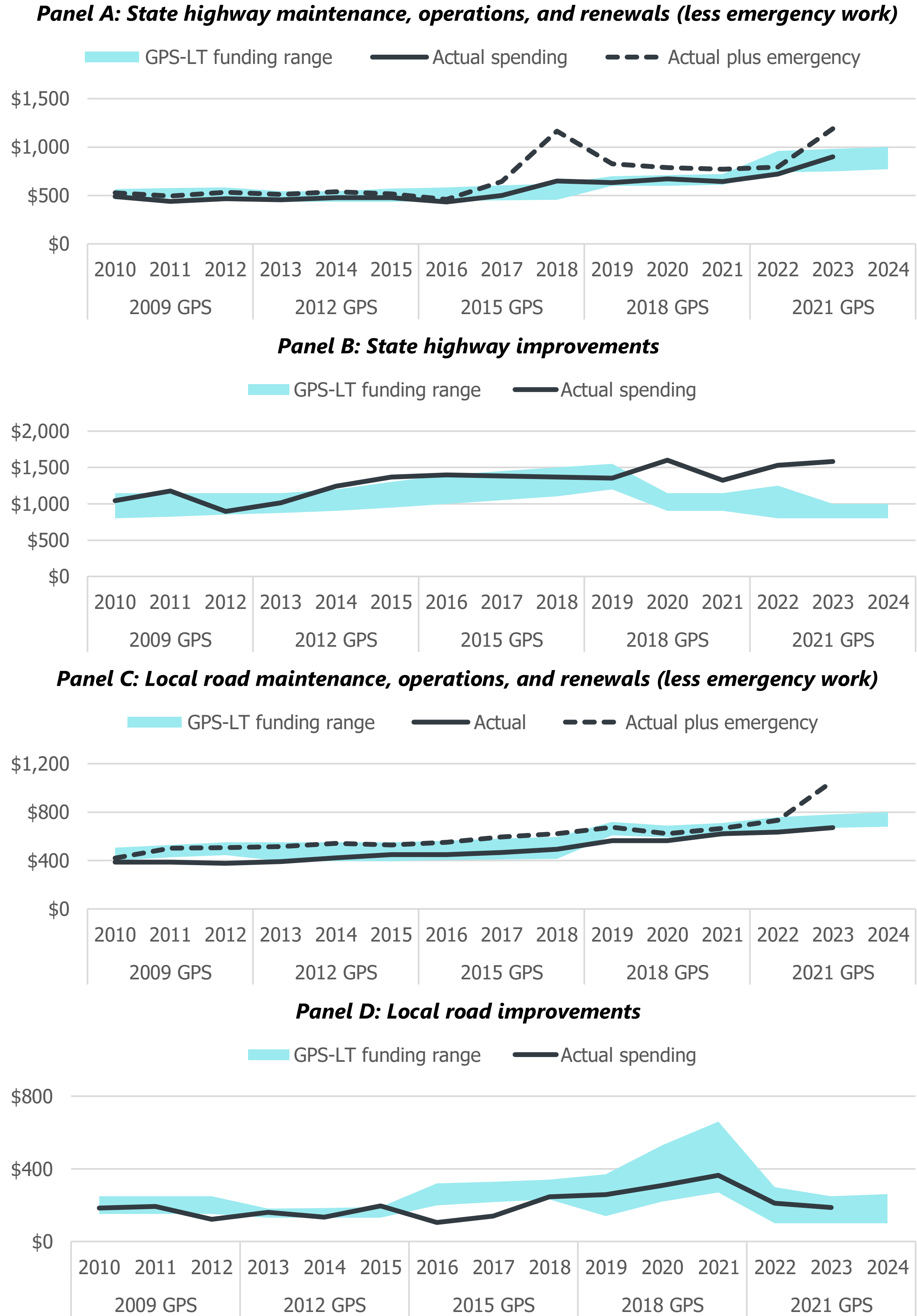
Panel B shows state highway improvement spending, which is the largest single category of NLTF spending. From 2010 to 2019, actual spending generally tracked the upper end of the GPS-LT funding range, and occasionally exceeded it. From 2020 to 2023, the GPS-LT funding range declined, but actual spending did not decline as a result. This resulted in actual spending that considerably exceeded the GPS-LT funding range. It is unclear what was driving this. It may reflect NZTA's continued prioritisation of network improvements, or other factors like Crown injections of funds to pay for specific road improvements (see Table 7 below).

Panel C shows local road maintenance, operations, and renewal spending, which follows the same pattern as state highway maintenance spending. Actual spending declined during the periods covered by the 2012 and 2015 GPS-LT, which reduced funding ranges, and increased following the 2018 GPS-LT, which increased funding. As in the case of state highways, emergency works caused total maintenance spending to exceed the funding range following the 2023 North Island Weather Events.

Panel D shows local road improvement spending, which is more volatile than the other activity classes pictured here. Actual spending fell near the bottom of the funding range in the 2009 GPS-LT, and the funding range was reduced accordingly in the 2012 GPS-LT. When the funding range was increased in the 2015 GPS-LT and 2018 GPS-LT, spending subsequently increased. When the funding range was decreased in the 2021 GPS-LT, spending decreased significantly.

[44] In both cases, the Crown provided additional funding for emergency works. This suggests that GPS-LT funding ranges may be too low to accommodate natural disaster recovery. This is a further challenge to the concept of the NLTF as a cost-recovery user-pays mechanism.

Figure 23: Actual NLTF spending compared with GPS-LT funding ranges, 2010-2024



Source: Te Waihanga analysis of data from NZTA, Ministry of Transport. Actual NLTF spending excludes local government share of funding for local roads.

Cost-benefit analysis is used as an input to investment decision-making

NZTA, like its predecessor agencies, has some autonomy to select which projects to fund within the investment ranges set by policy. In the present system, NZTA has discretion about how to prioritise potential investments within each activity class, unless otherwise directed by the GPS-LT. However, investment prioritisation is only done *within* activity classes. In some cases, this can constrain NZTA from allocating funds to the highest-value project, if that project sits within an activity class that is already fully committed.

Processes for prioritising potential investments have changed over time. Starting in the early 1980s, cost benefit analysis has been used to help select and prioritise projects for investment (Douglas et al., 2013). Cost benefit analysis involves comparing the overall social benefits of a project, including non-monetary benefits accruing to users and non-users, with the social costs of that project. Cost benefit analysis procedures have been periodically updated and extended, to capture a wider set of social, economic, and environmental benefits. Current evaluation procedures are described in NZTA / Waka Kotahi's (2023) *Monetary Benefits and Costs Manual*.

The GPS-LT system introduced additional factors to guide investment prioritisation, such as the need to achieve 'strategic fit' with government policy objectives. This reduced the role of cost benefit analysis.

This change coincided with declining value for money from investment (Pickford, 2013). Prior to this, projects were typically expected to pass a benefit-cost ratio threshold of 4 (Douglas et al., 2013).[45] Figure 17 shows that benefit-cost ratios for new investment declined sharply from an average of nearly four between 2005/06 and 2007/08 to an average of around two between 2008/09 and 2011/12.

Subsequent analysis by the Ministry of Transport (2014) showed that lower value for money was due in significant part to constraints driven by the GPS-LT funding ranges, as well as 'strategic fit' objectives that prioritised lower-value projects.[46] However, longer-term trends in benefit-cost ratios are hard to identify due to the impact of various changes to the transport cost benefit analysis manual.[47]

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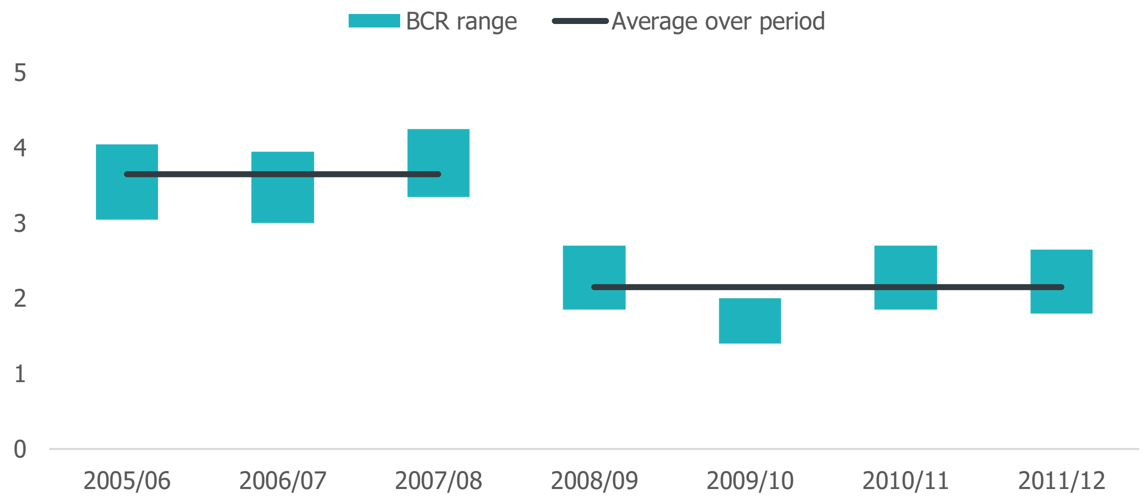
[45] This level of BCR threshold implies a degree of 'underinvestment' due to funding constraints, an issue that was noted as a concern in several reviews of land transport investment from the 1980s onwards.

[46] The Ministry of Transport (2014) states that: 'These constraints might include: the requirement on the NZ Transport Agency to spend within particular ranges each year, reducing the Agency's flexibility to retain funding for higher priority projects in later years; the NZ Transport Agency spending on large projects with lower priority scores that ties up funding into future years and future NLTPs, reducing the amount of funding available to higher priority projects; higher priority projects not being ready to go when funding is available so that the NZ Transport Agency undertakes lower priority projects instead.' They conclude that: 'the net benefit of new and improved state highways would improve by about 38% if constraints could be eliminated, and a further 60% by focussing only on efficiency [benefit-cost ratios]. Overall, the net benefit of this spending would increase by about 122%.'

[47] Douglas et al. (2013) note major updates to the cost benefit analysis manual in 1986 (the first version), 1991, 1997, 2002, and 2006. This was followed by further major updates in 2013, 2020, and 2023. The scope of benefits included in appraisal, parameters used to value those benefits, assumptions about background traffic growth conditions, and period over which to value benefits and costs have changed significantly over this time. Appraisals undertaken under different evaluation manuals are often not directly comparable. As the BCRs summarised in Figure 24 were prepared under the same evaluation manual, they are more likely to be comparable.

Figure 24: Benefit-cost ratios for new and improved state highway projects, 2005/06 to 2011/12



Source: Ministry of Transport (2014).

Since the early 2010s, policy changes appear to have limited funding for maintenance and renewal.[48] In our previous research, we showed that reduced spending on state highway and local road maintenance and renewal caused pavement resealing rates to be reduced to below the level that would be required to maintain pavement condition (New Zealand Infrastructure Commission, 2024). Reduced resealing activity has led to modest but measurable reductions in the quality of road surfaces, especially for roads with lower traffic volumes or low strategic importance.

How transport prices are set

Key land transport prices

Fuel excise duty and road user charges make up the largest share of overall land transport revenue. Other types of user charges include vehicle registration fees, tolls, local government rates and development contributions, public transport fares, parking charges, and rail track user charges.

Fuel excise duty is set as a charge on every litre of petrol, liquefied petroleum gas (LPG) or compressed natural gas (CNG) sold to retail customers. Petrol duty, which accounts for the vast majority of total revenue, is currently levied at a rate of 70.024 cents per litre (excluding GST), which is bundled into the total retail price of petrol. Based on the average fuel consumption of New Zealand's petrol light vehicle fleet (9.4 litres per 100km at the last increase in FED, with a declining trend since then), the average light vehicle user will pay $66 in fuel excise duty for every 1000 kilometres they travel, excluding GST. More fuel-efficient vehicles pay a bit less, while less fuel-efficient vehicles pay more.

Road user charges are set as a charge on road distance travelled by diesel vehicles and (starting in April 2024) electric vehicles.[49] Different charges are set for different types of diesel vehicles, depending upon their relative impact on the cost of providing and maintaining the road network.

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[48] Glaeser and Poterba (2021): 'Microeconomists approach infrastructure spending project by project with the well-worked tools of cost-benefit analysis. [...] This approach typically yields only modest returns for most new large-scale infrastructure projects. Returns for maintenance of existing infrastructure are typically much higher.'

[49] A large amount of diesel is used for agricultural and fishing vehicles, which do not use the road network and hence do not pay road user charges.

Road user charges for light diesel vehicles and fuel excise duties paid by an average petrol vehicle are intended to be similar. Heavier diesel vehicles, such as freight vehicles, are charged more to reflect the fact that they do more damage to roads and hence contribute more to the cost to maintain and renew roads.[50] For instance, a light diesel vehicle or electric vehicle (type 1, less than 3.5 tonnes) is charged $76 per 1000 kilometres, including GST, while a nine-axle combination truck and trailer (type H91, not more than 50 tonnes) is charged $389 per 1000 kilometres, including GST.[51] Excluding GST, light diesel vehicles or electric vehicles pay $66 per 1000 kilometres, which was the same as average FED rates for light petrol vehicles as of 2020.

Since 2008, fuel excise duties and road user charges have both been fully hypothecated to the NLTF, meaning that all of the revenue that central government raises from these sources is used to pay for land transport infrastructure and services rather than other categories of government spending. Prior to 2008, road user charges were fully hypothecated to the NLTF, but fuel excise duties were only partly hypothecated to land transport.[52] The remainder was allocated as general central government revenue and used to pay for other public services, like education and health (Figure 25).

A Cost Allocation Model is used to inform decisions about transport user charges

Fuel excise duty and road user charges are a **cost recovery mechanism** for planned land transport spending. Under this approach, annual planned expenditure, by activity class, is projected and then allocated across road users.

A Cost Allocation Model is used to identify a set of prices that allocate planned spending to different road users in proportion to their relative impact on network costs. It does so by applying a set of engineering calculations about the relative impact of different types of heavy and light diesel vehicles on road maintenance and investment costs.

User charges vary by vehicle type but **do not vary depending on location or time of use**. In addition, they do **not signal the social cost of externalities**, such as urban traffic congestion or vehicle noise and emissions, to users.[53] Past reviews have highlighted that there is a rationale to augment these user charges with congestion pricing to the short-run cost of traffic congestion to users.

While price-setting is informed by the Cost Allocation Model, fuel excise duty and road user charges are ultimately set by elected members through regulations. The actual prices that are charged are chosen based on a range of considerations, including how much money is needed to fund planned transport spending and perceived affordability constraints for users.

Road transport prices are currently declining relative to economy-wide inflation

Because land transport spending makes up a significant share of household budgets, transport pricing is sometimes seen as contributing to affordability and cost of living challenges.

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[50] The amount of road damage done by different types of vehicles is approximated based on the fourth power of axle weight (Infometrics, 2008; Ministry of Transport, 2022).

[51] https://www.nzta.govt.nz/vehicles/road-user-charges/ruc-rates-and-transaction-fees/

[52] https://www.scoop.co.nz/stories/PA0707/S00406/fuel-tax-will-go-to-road-users-activities.htm

[53] Some externalities are partly addressed by other charging mechanisms. For instance, Accident Compensation Corporation levies cover some of the social costs of road crashes, while Emissions Trading Scheme prices cover some of the social cost of carbon emissions.

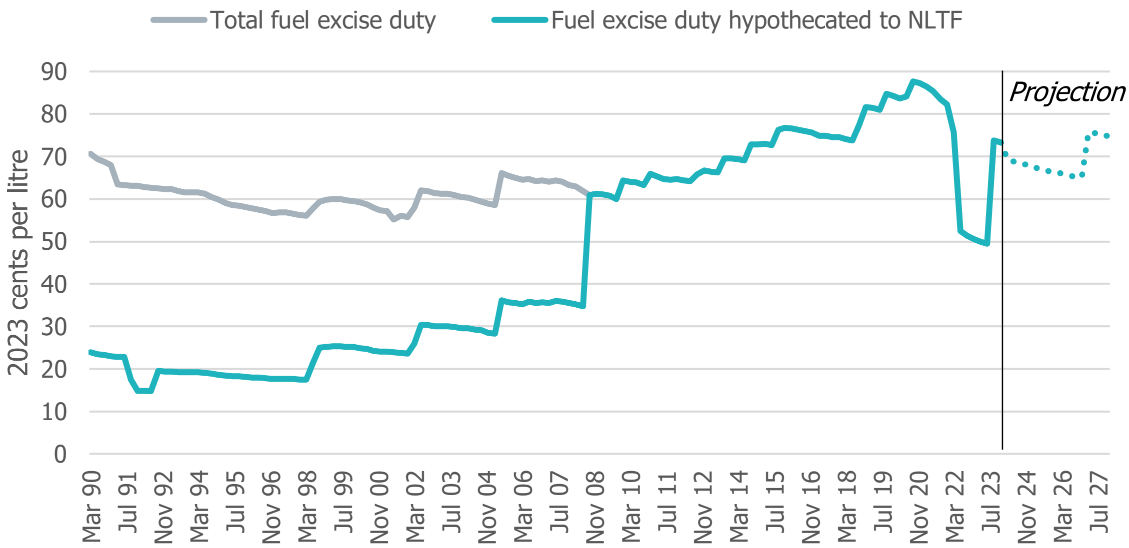
In recent years, policymakers appear to have responded to affordability concerns in part by cutting transport prices that are set by policy – principally fuel excise duty, road user charges, and public transport fares – or holding them constant for multi-year periods.

Figure 25 shows inflation-adjusted fuel excise duty charges from 1990 to 2027.[54] While prices have risen significantly since 1990, enabling an increase in overall land transport investment, there have also been a number of periods where prices have been allowed to decline in inflation-adjusted terms. Over the last decade, this has included:

- A freeze on fuel excise duty from September 2015 to September 2018, resulting in a 3% decline in inflation-adjusted funding
- A freeze in fuel excise duty from September 2020 to March 2022, during the period of the Covid-19 pandemic, resulting in a 6% decline in inflation-adjusted funding
- A 25 cent per litre cut in fuel excise duty between March 2022 and June 2023
- A commitment to suspend further fuel excise duty increases until the next programmed increase in January 2027, as well as ending the Auckland regional fuel tax.[55]

As a result of these changes, inflation-adjusted fuel excise duties in the December 2023 quarter were at the lowest level since 2015. By the end of 2026, they are projected to decline to the lowest level since 2012 before recovering slightly due to a planned increase in 2027.

Figure 25: Inflation-adjusted fuel excise duty, 1990-2027



Source: MBIE energy price data; SNZ CPI data; Treasury HYEFU December 2023. Fuel excise duty includes an allowance for the Auckland regional fuel tax, which was in force between June 2018 and early 2024. The grey line (pre-2008) shows total fuel excise duties, while the blue line shows the portion that was hypothecated to the NLTF. Since 2008 all fuel excise duty has been hypothecated to the NLTF.

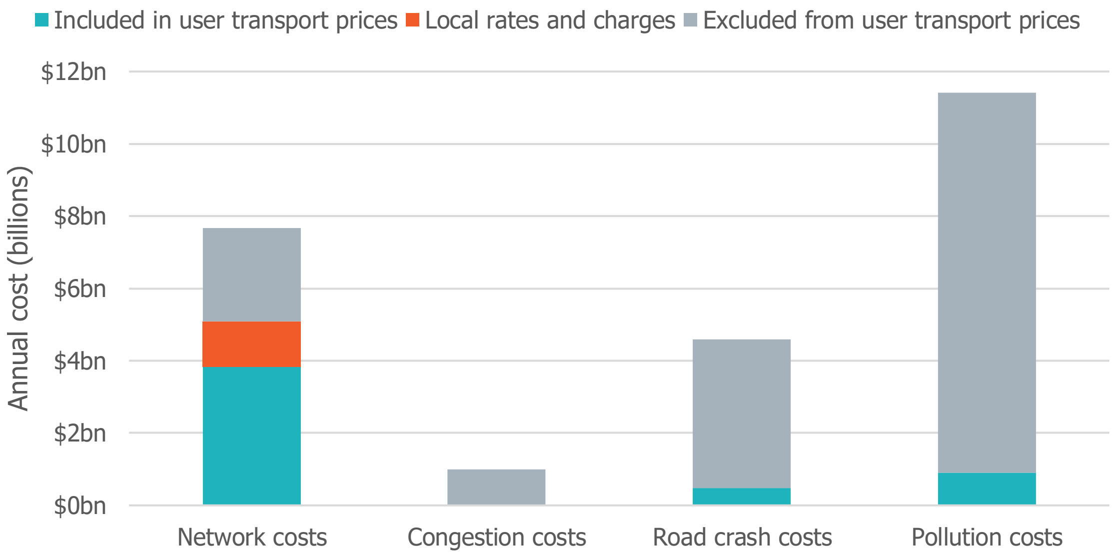
Externalities associated with road network use are only partly priced

Setting prices that send good signals to users is particularly challenging for land transport, as there are many externalities, or spillovers, from building and using transport infrastructure. Negative externalities include things like traffic congestion, the social cost of vehicle crashes, and health and

[54] A similar time series of road user charges levied on diesel vehicles is not available. However, road user charges are likely to follow a broadly similar path as light vehicle road user charges are intended to be similar to fuel excise duty for an average petrol vehicle.
[55] https://www.rnz.co.nz/news/political/510815/transport-minister-proposes-fuel-tax-increase-for-2027

environmental damage caused by vehicle noise and emissions.[56] Positive externalities include things like agglomeration benefits from enabling cities to be larger, denser, or better connected. As Figure 20 shows, many negative externalities are not fully internalised in prices.

Figure 26: Pricing of negative externalities associated with road use



Source: Te Waihanga analysis of land transport funding data (see Table 7); cost of congestion estimates from NZIER (2017) and Ministry of Transport (2023a); total social cost of road crashes from Ministry of Transport (2021) and ACC levy costs for road users from ACC data; pollution costs include carbon emissions (priced through the ETS, and estimated based on MBIE land transport fuel use and energy price monitoring data) and the local health impacts of other transport emissions quantified in the HAPINZ study (Kuschel et al., 2022).

Importantly, the private and social costs of land transport use can vary significantly depending upon where or when people are travelling. This is especially important for congestion costs and health costs of vehicle noise and emissions, which tend to be a greater problem in higher-density urban areas than in small towns or rural areas. We discuss the case of traffic congestion in more depth in the body of the report, but note that the health impacts of vehicle emissions on human health are potentially much more consequential and that they are not even partly priced in.

How the costs of land transport are funded

Although land transport funding is intended to be based on cost-recovery user-pays model, user charges do not cover the full cost of providing road and public transport networks. At a broad level, this is because planned investment has tended to exceed current user revenues. The gap has been filled by Crown loans, other forms of debt like public-private partnerships, and Crown grants.

User charges do not fully fund road or rail investment

Table 6 below summarises available data on sources of road, public transport, and rail funding from 2008/09 to 2023/24. This appears to be an under-estimate of local government road and public transport spending, as it does not capture information on local government transport spending that did not attract funding assistance from the NLTF (including

[56] As previously noted, negative externalities arising from private vehicle use create a rationale to tax private vehicle use and/or cross-subsidise competing alternatives like public transport and walking and cycling.

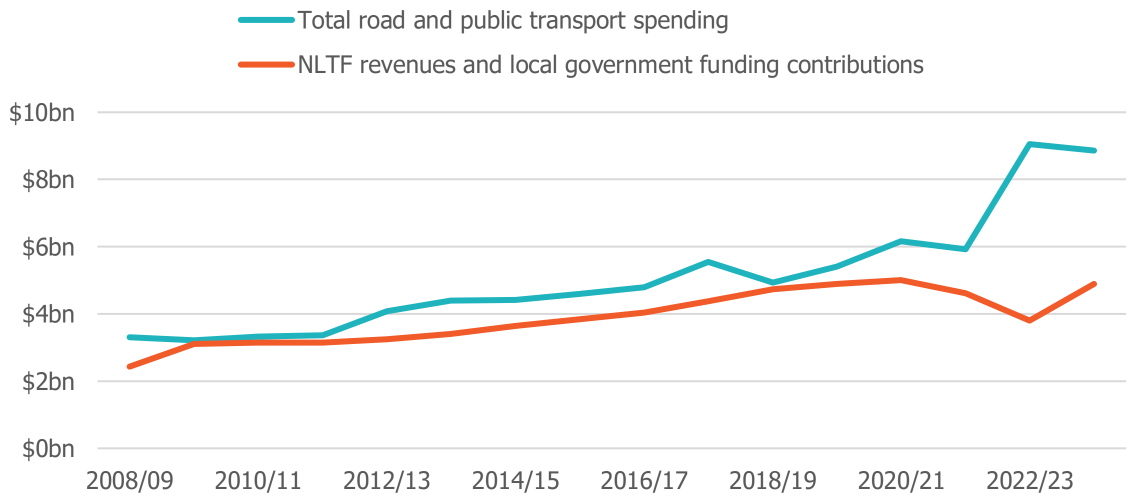
Auckland Council's City Rail Link contribution). It also appears to exclude public transport fare revenue.[57]

Over this period, 59% of road and public transport spending was funded from user charges paid into the NLTF. A further 20% was funded by local government, out of rates and development contributions. 10% was financed by Crown loans for road projects, and 11% was funded by Crown grants for road and public transport projects. The rail network also attracted significant Crown grants, with Crown grants being roughly equal to other Kiwirail revenues.

Direct Crown funding includes spending on specific projects like the City Rail Link and programmes like the New Zealand Upgrade Programme, Rail Network Investment Programme and Provincial Growth Fund, and ongoing Crown loans and grants to the National Land Transport Fund. This has included substantial Crown funding for natural disaster recovery.

Figure 27 shows that there has been a consistent gap between NLTF revenues and local government funding contributions and total road and public transport spending since the mid-2010s. This gap has increased significantly in recent years. It has been filled with Crown loans and grants. The 2024 Budget indicated an intention to continue significant Crown loans and grants for road projects.

Figure 27: Road and public transport spending funded from current user charges, 2008/09-2023/24



Source: Te Waihanga analysis of Treasury annual Budget statements and NZTA NLTF reporting. 2023/24 local government funding contributions are not yet available and hence are imputed using 2022/23 data.

Long-term liabilities on the NLTF balance sheet have also increased

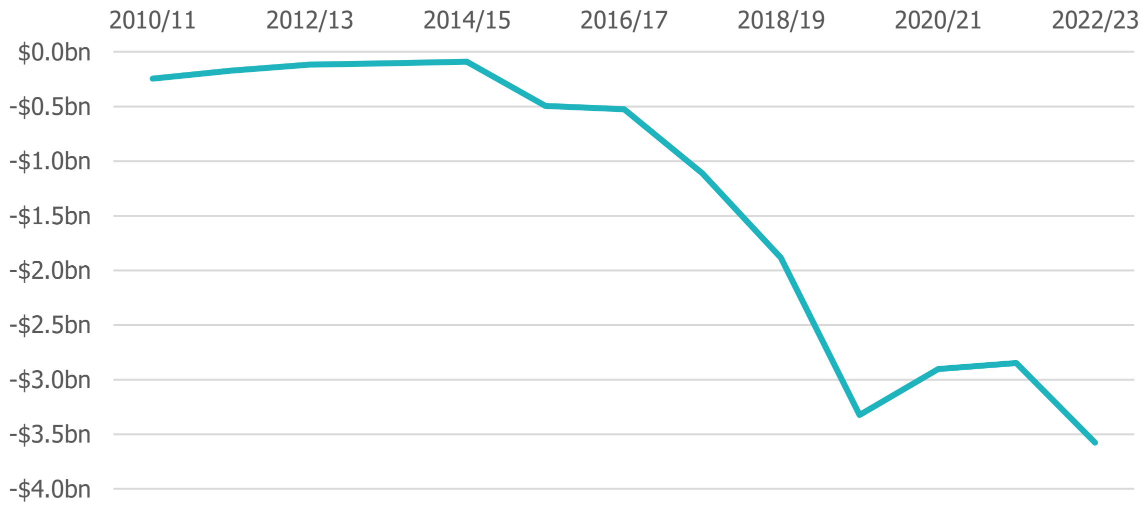
Figure 28 shows that the NLTF began to accrue significant long-term liabilities, such as debt and commitments related to public private partnerships roads, starting in the mid-2010s. Prior to this the NLTF was operating largely as a pay-as-you-go system. Since 2019, the net closing balance of the NLTF has been in the range of negative $3 billion to negative $3.5 billion.

Some, but not most, of these long-term liabilities are linked to additional revenue streams that can be used to repay debt without constraining future NLTF spending. For instance, toll revenues are

[57] By comparison, the Office of the Auditor-General (2023) provides a broader breakdown of transport funding sources and uses of funds at a single point in time (see page 22 in their report). They note that there is no single data source that covers all funding sources in a consistent way.

expected to repay the $107 million liability associated with the Tauranga Eastern Link. However, the two PPP roads (the Transmission Gully and Puhoi to Warkworth motorways), which are associated with $2 billion in long-term liabilities, are not tolled and hence do not generate any direct revenues that could be used to meet future payments.

Figure 28: NLTF general funds closing balance, 2010/11 to 2022/23



Source: Te Waihanga analysis of data from NZTA National Land Transport Fund annual reports. The closing balance for the NLTF reflects the net position of the fund, taking into account current assets and long-term liabilities, including debt and other commitments like public private partnerships.

Table 7: Sources of land transport funding, 2008/09 to 2023/24 financial years (nominal $m)

Financial year	Road and public transport network spending (NLTF plus other Crown spending)					Rail network spending		
	National Land Transport Fund revenues	Crown loans for road projects	Crown grants for road projects	Crown grants for emission reduction projects	Local government contributions to NLTF co-funded projects	Kiwirail revenues	Crown grants for rail projects (incl CRL)	Local government contributions (incl CRL)
2008/09	$1,714	$0	$868	$0	$717	$539	$8	
2009/10	$2,392	$0	$104	$0	$718	$647	$798	
2010/11	$2,413	$110	$68	$0	$740	$667	$692	
2011/12	$2,369	$170	$52	$0	$781	$716	$877	
2012/13	$2,426	$750	$73	$0	$825	$501	$979	
2013/14	$2,629	$970	$28	$0	$776	$741	$286	
2014/15	$2,840	$767	$11	$0	$801	$721	$313	
2015/16	$3,053	$750	$0	$0	$793	$694	$8	
2016/17	$3,169	$750	$0	$0	$873	$595	$7	
2017/18	$3,359	$622	$541	$0	$1,022	$616	$1,059	
2018/19	$3,616	$35	$166	$0	$1,114	$683	$707	
2019/20	$3,662	$384	$138	$0	$1,230	$639	$1,058	
2020/21	$3,738	$205	$953	$0	$1,268	$710	$1,322	
2021/22	$3,340	$239	$941	$126	$1,281	$851	$1,583	
2022/23	$2,367	$1,571	$3,089	$595	$1,430	$993	$2,154	
2023/24	$3,472	$1,860	$1,462	$629	Not available	Not available	$2,227	Not available
Total (2008/09 to 2022/23)	**$43,087**	**$7,323**	**$7,032**	**$721**	**$14,370**	**$10,311**	**$11,851**	**Not available**
Share of total	46%	8%	7%	1%	15%	11%	13%	Not available
Share of road and PT spending	59%	10%	10%	1%	20%			

Source: Te Waihanga analysis of data from Treasury annual Budget statements, NZTA NLTF reporting, and Kiwirail annual reports.

Appendix 2: Analysing cost recovery potential for toll roads

This Appendix describes our simple model of cost recovery potential for toll roads. This model, which is implemented in Microsoft Excel, incorporates two key elements.

First, it models light vehicle users' willingness to pay tolls, which depends upon how large the benefits that users receive from using the new road rather than the existing untolled road. This results in a set of revenue-maximising toll prices that vary depending upon the size of the travel time savings from the new road.

Second, it estimates the tolls that would need to be charged in order to pay for the whole cost to build the road. This is done using a simple cost-recovery model in which the whole-of-life costs to build and maintain the road are spread over current and future road users over a defined tolling period. In this model, required tolls vary based on the cost to build the road and current and future traffic volumes. They also reflect the forecast tolling period and the discount rate on public funds, which is a proxy for debt servicing costs.

We compare results from the first and second models to estimate cost recovery potential for toll roads with varying travel time savings, traffic volumes, and construction costs.

We then present several model extensions and a set of sensitivity tests for a single benchmark model. This shows that our broad results are not sensitive to model assumptions.

Finally, we include some further information on several currently operating or proposed toll roads in New Zealand that we use to sense-check the model.

Modelling users' willingness to pay tolls

We modelled the share of users who choose to use the new toll road, as opposed to the existing untolled route, using a simple logit model. The logit model is a standard discrete-choice model that is widely used in transport modelling and analysis of consumer choice (McFadden, 1974; Small & Verhoef, 2007; Train, 2009). It assumes that users choose between different options based on the utility that those choices offer them. Users are more likely to choose an alternative that offers a higher level of utility.

In the case of transport route choice, we assume that all users choose between travelling on the existing untolled route or the new tolled route. This is a slight simplification, as in some cases users will also have other alternatives. For instance, a new road that runs parallel to a train line may divert some users from the train as well as from the existing untolled road. However, in rural areas without public transport this is a defensible assumption.

As is standard in transport economics, we assume that time and money spend travelling results in disutility (i.e., negative benefits) for users. More specifically, the utility that a representative user achieves by travelling to their destination by route *I* can be defined as follows:

$$U_i = D - VOT * T_i - P_i$$

Where D is the utility they achieve from reaching the destination (which doesn't depend upon how they got there), VOT is the (monetary) value they place on time spent travelling, T_i is the time required to travel on route I, and P_i is the monetary cost (including petrol and tolls) of travelling on route i.

Faced with a choice between two routes i and j that both take them to the same destination, users choose the route that offers them the highest utility. Importantly, rather than assuming that everyone makes the same choice, the model assumes that there is some (random) variation in preferences between individuals. Based on some standard assumptions about variation in preferences that are outlined in Train (2008), we therefore calculate the share of people who use route i as follows:

$$S_i = \frac{\exp{(D - VOT * T_i - P_i)}}{\exp(D - VOT * T_i - P_i) + \exp{(D - VOT * T_j - P_j)}}$$

We can simplify and rearrange this equation. If we define ΔT_i as the change in travel time achieved by using route i, and ΔP_i as the difference in price on route i (ie, the toll charged on that route), then we can divide the top and bottom of the fraction by $\exp{(D - VOT * T_j - P_j)}$ and obtain the following, simpler expression for the share of users on route i. A useful feature of this equation is that it only requires us to know how much time the new route saves ,and how large the toll is, in order to predict the share of people using it:

$$S_i = \frac{\exp{(-VOT * \Delta T_i - \Delta P_i)}}{\exp(-VOT * \Delta T_i - \Delta P_i) + 1}$$

As shown in Table 8, we have sourced estimates of the value of travel time savings for light vehicles and heavy vehicles from NZTA's (2023) *Monetised Costs and Benefits Manual*.

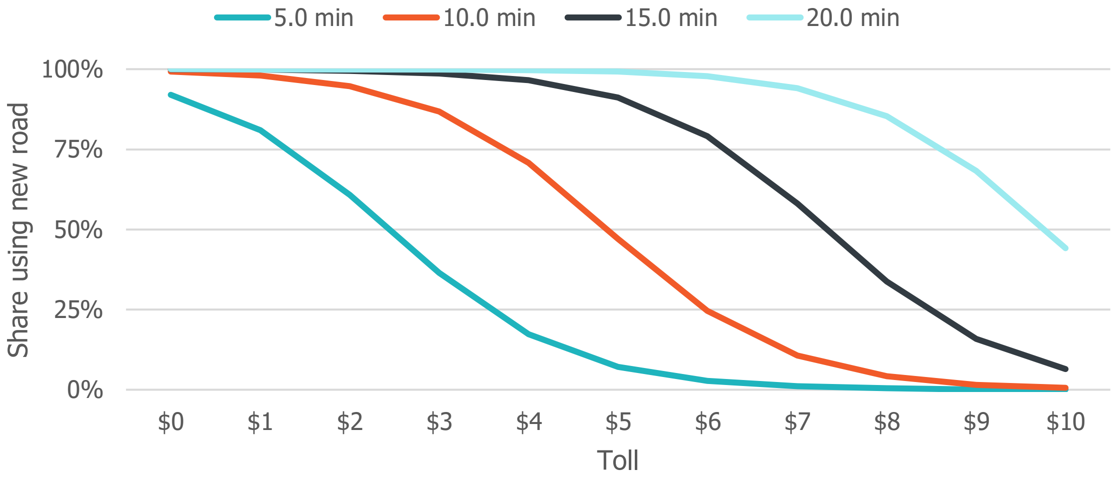
Table 8: Value of travel time parameters for light and heavy vehicle users

Vehicle type	Share of traffic	Value of travel time ($/veh/hr)	Value of travel time ($/veh/ min)	FED/RUC paid per km ($/km)
Light vehicle	*91.5%*	$29.30	*$0.49*	$0.07
Heavy vehicle	8.5%	$79.84	*$1.33*	$0.17

Source: Adapted from Waka Kotahi NZ Transport Agency (2023). Notes for light vehicles: VOT estimated using MBCM Table 14 value for commuting, multiplied by average vehicle occupancy of 1.5 (Table A50). FED per km estimated based on petrol car average fuel economy (9.5L/100km) multiplied by petrol tax rate of 70.024c/L. Notes for heavy vehicles: VOT estimated using MBCM Table 15 value for HCV1 vehicle, freight, and occupant VOT. MCV/HCV share estimated using MBCM Table A47 average of urban arterial, all periods (5%) and rural strategic, all periods (12%). RUC per km estimated based on average RUC paid per kilometre for heavy diesel vehicles.

Figure 29 shows the share of light vehicles that are predicted to use the new tolled road, rather than the existing untolled road, under a range of scenarios for travel time savings and toll prices. What this shows is that the share of vehicles using the new road will fall off quite rapidly once tolls hit a certain point, and that willingness to pay the toll is higher when travel time savings are larger.

Figure 29: Predicted share of light vehicles using a new road under different travel time saving and toll scenarios



Source: Te Waihanga analysis

After deriving an expression for the share of traffic using the new tolled road as a function of travel time savings and toll price, we derive an expression for revenue-maximising toll. To do so, we observe that total annual toll revenue for a new toll road estimated by multiplying annual traffic volumes (N) by the per-car toll (ΔP_i) and the share of vehicles choosing to use the new road (S_i):

$$R = N * \Delta P_i * \frac{\exp\left(-VOT * \Delta T_i - \Delta P_i\right)}{\exp(-VOT * \Delta T_i - \Delta P_i) + 1}$$

Following standard optimisation processes, total toll revenue is maximised when the first derivative of this function is equal to zero ($\frac{dR}{d\Delta P_i} = 0$). (Maximisation also requires that the second derivative is negative, which is always true as this is a concave function in ΔP_i.)

After differentiating R with respect to ΔP_i and rearranging and simplifying, I obtain the following expression for revenue-maximising toll:

$$\exp(\Delta P_i) * (\Delta P_i - 1) = \exp\left(VOT * \Delta T_i\right)$$

There is no analytical solution to this, but it is straightforward to solve numerically using Excel's Goal Seek function. This results in a schedule of revenue-maximising tolls based on users' average value of travel time and the quantity of time savings from the new road.

We then substitute the revenue-maximising toll back into the equation for the share of users using the new route in order to calculate how many people use the new road as opposed to the existing untolled route, and from there to calculate the maximum total amount of revenue that can be raised through these tolls.

Table 9 summarises the key results from this model, under baseline assumptions for value of travel time savings. It also calculates the expected amount of revenue per vehicle travelling on this route, after accounting for diversion to the untolled route.

Table 9: Modelled revenue-maximising tolls as a function of travel time savings from new road

Travel time saving from new road	Revenue-maximising light-vehicle toll	Share of light vehicles using new toll road	Share of light vehicles using untolled road	Total revenue per vehicle travelling on this route (accounting for diversion)
1	$1.40	29%	71%	$0.40
2	$1.60	36%	64%	$0.60
3	$1.80	43%	57%	$0.80
4	$2.00	49%	51%	$1.00
5	$2.20	55%	45%	$1.20
6	$2.50	60%	40%	$1.50
7	$2.80	65%	35%	$1.80
8	$3.10	68%	32%	$2.10
9	$3.50	71%	29%	$2.50
10	$3.80	74%	26%	$2.80
11	$4.20	76%	24%	$3.20
12	$4.60	78%	22%	$3.60
13	$5.00	80%	20%	$4.00
14	$5.40	81%	19%	$4.40
15	$5.80	83%	17%	$4.80
16	$6.20	84%	16%	$5.20
17	$6.60	85%	15%	$5.60
18	$7.00	86%	14%	$6.00
19	$7.40	87%	13%	$6.40
20	$7.80	87%	13%	$6.80

Source: Te Waihanga analysis. All tolls are rounded to the nearest 10 cents.

Modelling the tolls that would be needed for full cost-recovery

We estimated required tolls as follows:

- First, we calculated the discounted present value of whole-of-life costs to build and maintain new roads of varying types
- Second, using the same discount rate and tolling period, we calculated the discounted present value from charging a representative $1 toll to a car that uses the route once per day, adjusting for projected future growth in traffic volumes
- Third, we multiplied the value in the second step by average daily traffic volumes in the first year of the road's operation to calculate the discounted present value of revenue from a representative $1 toll on all cars using the route. (Adjusting for the assumed share of heavy vehicles, who pay a toll that's twice as high.)
- Fourth, we divided the present value of whole-of-life project costs by the present value of the revenue stream from a representative $1 toll to calculate the per-vehicle tolls that would be required to fully recover the costs to provide the new road.
- Finally, we multiply by 1.15 to account for GST on tolls, which users must pay but which does not accrue to the road operator.

More specifically, we estimate required toll costs ($\hat{P}$) by setting expected future toll revenues (in discounted/present value terms) equal to the whole-of-life cost to build and maintain the road (in discounted/present value terms). Discounting adjusts for the fact that it will be necessary to take out a loan and repay it with interest. This results in the following equation:

$$\sum_{t=1}^{n} \frac{(\hat{P} - A)T_o g_t}{(1+\delta)^t} = C + \sum_{t=1}^{n} \frac{M}{(1+\delta)^t}$$

Where A are toll administration costs (stated in terms of cost per transaction), T_o is the starting traffic volume on the road (in year 0), g_t is the ratio of traffic in year t to traffic in year 0 (e.g., if $g_5 = 1.1$, it means that traffic volumes have risen 10% in the first five years), C is the cost to construct the road, and M is the annual maintenance cost of the road. δ is the discount rate, which should reflect the financing costs of the road, and n is the length of the tolling period.

After some rearranging, this allows us to estimate the toll price that would be required to achieve full cost recovery as follows:

$$\hat{P} = \left(\frac{C + \sum_{t=1}^{n} \frac{M}{(1+\delta)^t}}{\sum_{t=1}^{n} \frac{T_o g_t}{(1+\delta)^t}} + A \right) * 1.15$$

We can adjust the denominator of the fraction to account for the fact that a share of traffic consists of heavy vehicles (S_H) that pay a higher toll rate than light vehicles (R_H, where this reflects the ratio of heavy vehicle tolls to light vehicle tolls):

$$\hat{P} = \left(\frac{C + \sum_{t=1}^{n} \frac{M}{(1+\delta)^t}}{(1 + S_H(R_H - 1)) * \sum_{t=1}^{n} \frac{T_o g_t}{(1+\delta)^t}} + A \right) * 1.15$$

All values are stated in real (inflation-adjusted) terms.

Table 10, Table 11, and Table 12 show key parameters and input assumptions to this model. The model is set up to enable sensitivity testing of all key parameters. The baseline calibration of the model assumes that traffic grows in line with national population growth, that tolls are applied for a 25-year period, and that future cashflows are discounted using a 5% real discount rate. It also assumes 8.5% of traffic is heavy vehicles that pay twice as high a toll as light vehicles, in line with prices on current toll roads.

Table 10: Baseline assumptions for required toll cost analysis

Parameter	Default value	Note
Real discount rate	5%	Treasury real discount rate for transport infrastructure[58]
Number of years toll is in place	25	Based on tolling periods for existing or historical schemes. Tolling period can be sensitivity tested between 10 and 50 years.
Population growth scenario	50th percentile (median)	SNZ national population projections. Population growth is assumed to drive traffic volume growth.

[58] https://www.treasury.govt.nz/information-and-services/state-sector-leadership/guidance/reporting-financial/discount-rates

Income growth scenario	0.8% per annum	Treasury Long Term Fiscal Model long-term GDP per capita projections
Income elasticity of transport use	0	Allows traffic growth to scale up with income growth as well as population growth. Set to 0 in the baseline model and sensitivity tested later. Suggested sensitivity test range of 0.2 to 1.1, based on income elasticity range for land transport reported in National Infrastructure Commission (2018).
Days per year	365	

Table 11: Road construction cost assumptions

Road type	**Construction cost per lane-km (2023 $m)**	**Road length (km)**	**Total construction cost**	**Average speed (travel time)**
Low cost motorway, 20km	$8.1m	20	$649.6m	100km/hr (12 min)
High cost motorway, 20km	$23.3m	20	$1,867.2m	100km/hr (12 min)
Road tunnel, 5km	$152.2m	5	$3,044.0m	80km/hr (4 min)

Source: Data from New Zealand Infrastructure Commission (2022b), updated to 2023 NZD using Statistics New Zealand's Capital Goods Price Index for Civil Construction. Low cost motorway based on 20th percentile of motorway project costs since 2017 (similar to Chch Southern Motorway Stage 2). High cost motorway based on 80th percentile of motorway project costs since 2017 (similar to Takitumu North Link Stage 2). Road tunnel based on average of 4 road tunnel projects (2 complete; 2 proposed).

Table 12: Road operation/maintenance assumptions

Cost	**Value**	**Note**
Toll administration cost ($/trip)	$0.80	Based on data reported by NZTA[59]
GST	15%	Netted off from revenues accruing to the transport agency.
Fixed ratio of heavy vehicle/light vehicle tolls	2	Based on existing NZ toll roads. Heavy vehicles are assumed to be 8.5% of traffic volumes, in line with national averages. This is slightly lower than the ratio of heavy vehicle value of travel time to light vehicle value of travel time.
Annual road maintenance cost as share of capital value	0%	Excluded from baseline model but included in sensitivity tests.

Table 13 summarises the key results from this model, under baseline assumptions for all inputs and varying road construction cost and traffic volume assumptions.

[59] https://www.nzta.govt.nz/roads-and-rail/toll-roads/toll-road-information/frequently-asked-questions/general/#breakdown

Table 13: Modelled tolls that would be required to achieve full cost recovery

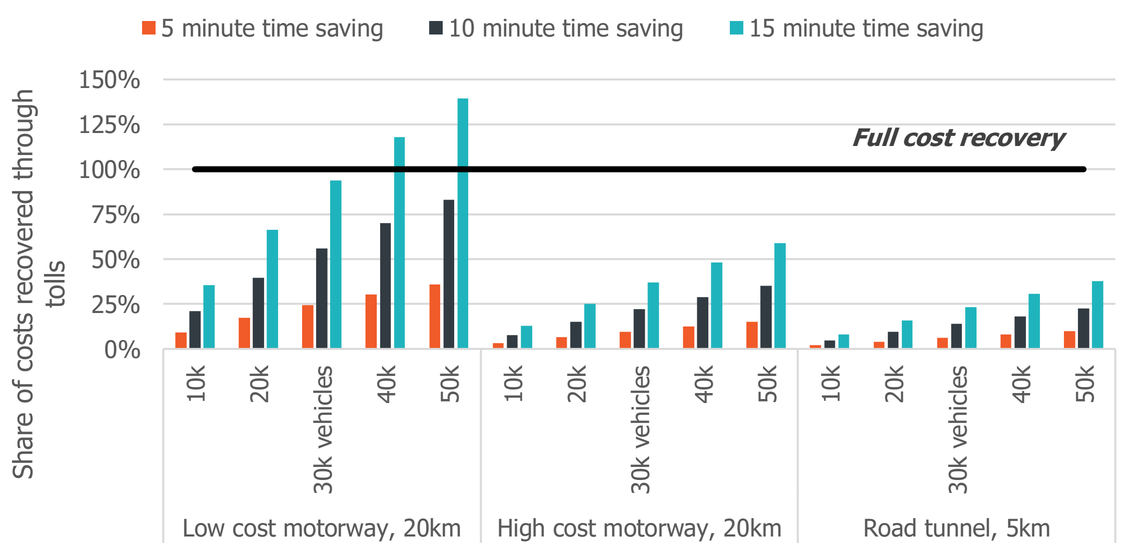
Road type	Daily traffic volume in first year	Tolls required for full cost recovery	
		Required light vehicle toll	Required heavy vehicle toll
Low cost motorway, 20km	10,000	$13.40	$26.80
	20,000	$7.20	$14.30
	30,000	$5.10	$10.20
	40,000	$4.00	$8.10
	50,000	$3.40	$6.80
High cost motorway, 20km	10,000	$36.90	$73.70
	20,000	$18.90	$37.80
	30,000	$12.90	$25.80
	40,000	$9.90	$19.80
	50,000	$8.10	$16.20
Road tunnel, 5km	10,000	$59.50	$119.00
	20,000	$30.20	$60.40
	30,000	$20.40	$40.90
	40,000	$15.60	$31.10
	50,000	$12.60	$25.30

Source: Te Waihanga analysis. All tolls are rounded to the nearest 10 cents.

Estimating cost recovery potential for new roads

Figure 30 combines information from Table 9 and Table 13 into a single picture of cost recovery potential for new roads that vary in terms of travel time savings, traffic volumes, and construction costs. It calculates cost recovery potential by dividing the maximum achievable toll revenue for a road that offers a given level of travel time saving (from the final column of Table 9) by the required light-vehicle toll (from the third column of Table 13). For instance, a high-cost motorway serving a route with 20,000 vehicles per day would *need* to charge a light vehicle toll of $18.90, but if it offered 10 minutes of travel time savings, it would only be *able* to realise toll revenue of $2.80 per car (after accounting for traffic diversion). As a result, it would have cost recovery potential of around 15%.

Figure 30: Estimated cost recovery potential for new roads (baseline model)



Source: Te Waihanga analysis.

Model extensions and sensitivity testing

In addition to the 'baseline' model above, we report several model extensions and a number of sensitivity tests on model inputs. The purpose of these extensions and sensitivity tests is to understand whether our broad conclusions are robust to alternative modelling assumptions.

Model extension 1: Accounting for induced traffic

Our first model extension is to account for potential induced traffic due to the new road. As discussed in the body of the report, new roads often induce additional traffic, while tolls can moderate this effect somewhat. We would expect induced traffic to increase cost-recovery for a new toll road, as it means more usage of the road.

To model the potential effects, we nest the route choice logit model described above within a simple elasticity-based model of travel demand. The elasticity model simply scales up (or down) total traffic on both the tolled and untolled route based on the change in the average generalised travel cost (time and money costs of travel) across the two routes.

To do so, we need to make some additional assumptions about the total travel time on the existing and new roads, rather than just the change in travel time. We estimate the travel time on the new road using assumed travel speeds in Table 11, and estimate the speed of the existing road by adding the travel time saving offered by the new road.

We estimate induced traffic effects using a generalised travel cost elasticity approach. Byett et al. (2024) report New Zealand-specific long-run generalised cost elasticity estimates ranging from -0.4 to -1.0, depending upon context (see Table B.6). We use the largest elasticity estimate available, i.e., $\varepsilon = -1.0$.

The following formula summarises this elasticity approach. Following the notation in the previous section, ΔP_i is the optimal toll charged on the new road, ΔT_i is the travel time saving for the new road, VOT is the value of travel time savings, and S_i is the share of people choosing to use the new road given optimal tolls. The total travel time of the new road is T_i and the total travel time of the untolled road is therefore $T_i + \Delta T_i$. We disregard vehicle operating costs for a simple analysis, as they are unlikely to vary enough to make a meaningful difference.

Based on these parameters, the generalised travel costs to use the existing road and the new toll road, and the weighted average across the two roads, are given by:

$$GTC_{existing} = VOT * (T_i + \Delta T_i)$$
$$GTC_{new} = VOT * T_i + \Delta P_i$$
$$GTC_{average} = S_i * GTC_{new} + (1 - S_i) * GTC_{existing}$$

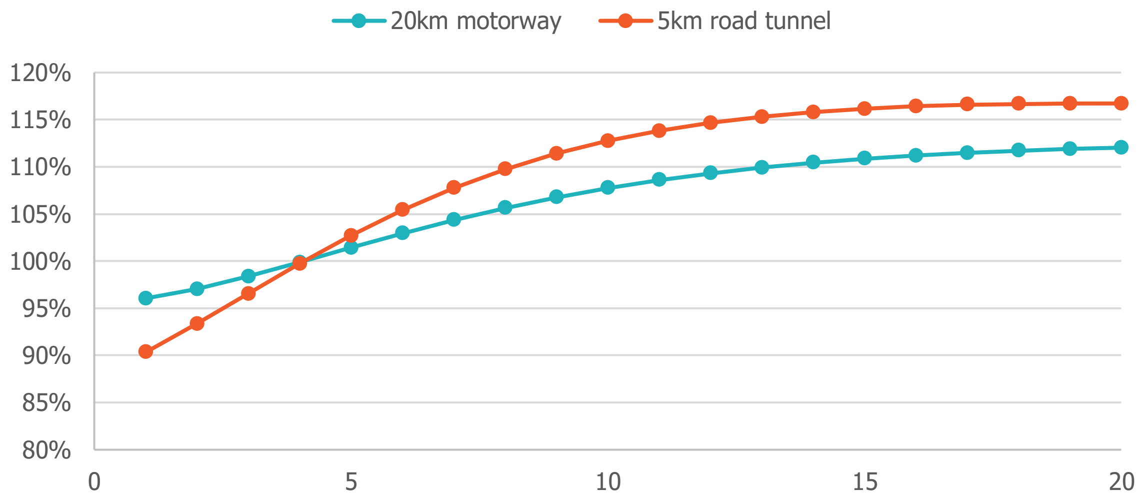
Additional revenue gained due to induced traffic effects can therefore be estimated with the following revenue multiplier:

$$\left(\frac{GTC_{average}}{GTC_{existing}}\right)^{\varepsilon}$$

Induced demand effects vary slightly depending upon travel times on the new and existing road. A new road that makes a very large reduction in travel times relative to a relatively short existing route will cause more induced traffic. As predicted, charging a toll on the new road moderates induced traffic effects but not to zero.

Figure 31 shows the resulting induced traffic toll revenue multipliers. Induced traffic effects are estimated to increase toll revenue by 17% at most. In some situations, such as toll roads that offer very small travel time savings, induced traffic effects could even be slightly negative.

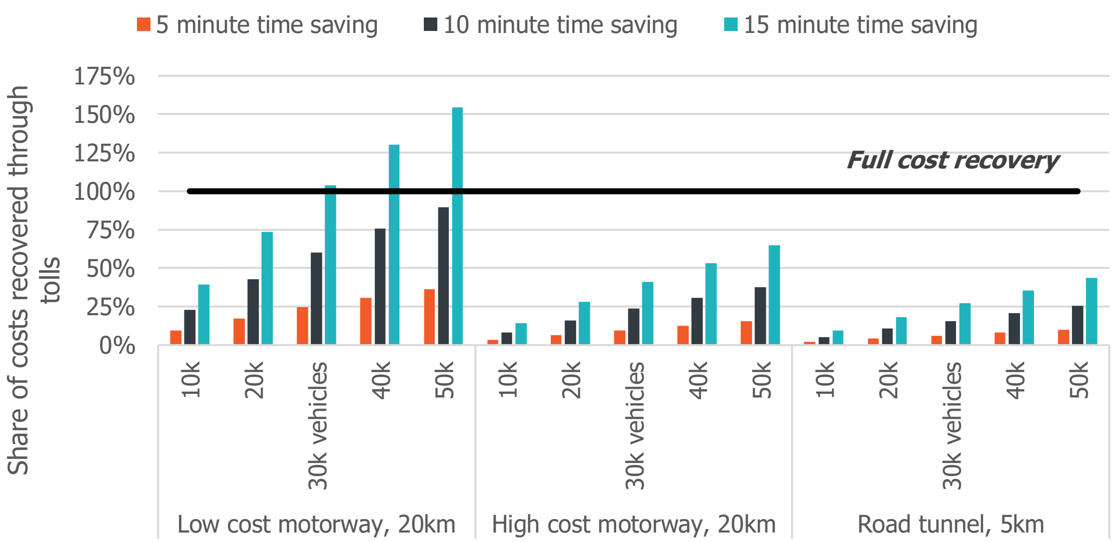
Figure 31: Induced traffic toll revenue multipliers for new toll roads



Source: Te Waihanga analysis.

We use these ratios to adjust up toll revenue in our model above, resulting in the following estimates for cost recovery potential. As predicted, cost recovery potential rises slightly, especially for roads that offer larger travel time savings. However, the effects are not large enough to materially change the key results.

Figure 32: Estimated cost recovery potential for new roads (model extension with induced traffic)



Source: Te Waihanga analysis.

Model extension 2: Rebating FED and RUC revenue to the new toll road

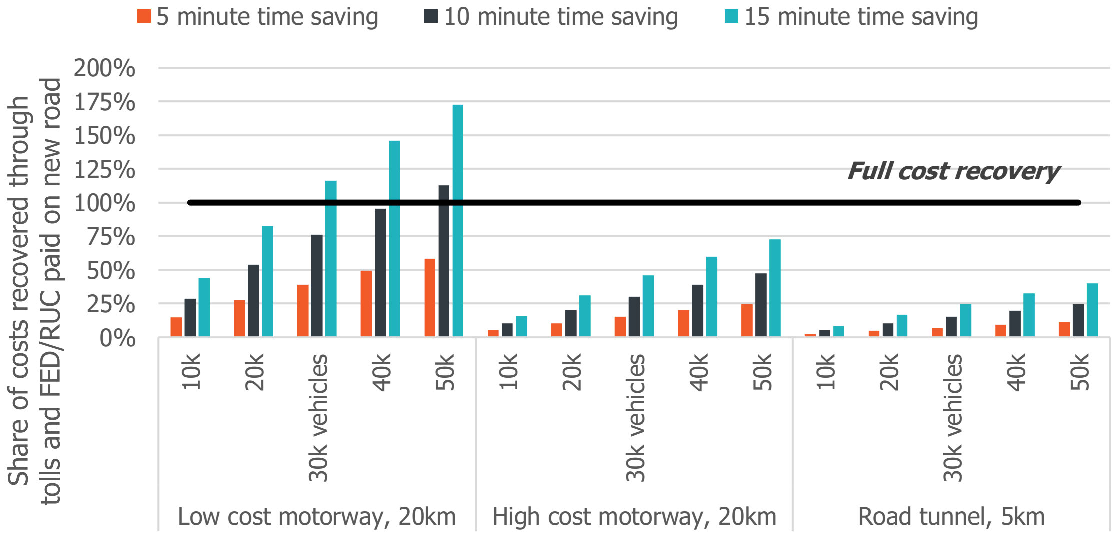
Our second model extension is to consider how cost recovery for toll roads might change if fuel excise duty and road user charges paid by vehicles while they were travelling on the new roads was hypothecated or rebated to pay for those roads.

Unlike tolls, this is not likely to be new revenue for the land transport system, as most of the people driving on the toll roads would have been driving on other roads and paying road user charges on those roads instead. However, it may be justifiable on the basis that FED and RUC recovers average costs associated with maintenance and upgrades, and that distance travelled on the new toll road may result in a maintenance or upgrade liability for the NLTF.

To do this, we simply adjust up revenue earned from toll road users to account for estimated FED and RUC paid while driving on the new toll road. We use average FED/RUC paid per kilometre by light and heavy vehicles (from Table 8) and toll road length (from Table 11). For instance, based on the average FED rate of $0.07/km, a light vehicle driving on a 20km motorway would pay around $1.33 in the process.

This results in the following estimates for cost recovery. FED/RUC rebating to the new road results in larger increases in cost recovery from users of the new road than the previous model extension. However, the broad conclusions of the model, which that full cost recovery is only possible in limited circumstances, remain the same.

Figure 33: Estimated cost recovery potential for new roads (model extension with FED/RUC rebating to new road)



Source: Te Waihanga analysis.

Sensitivity testing of model assumptions

Table 14 summarises sensitivity testing of key model assumptions for a single hypothetical case of a high-cost motorway that serves a route with 20,000 vehicles per day and offers travel time savings of 10 minutes. We examine the impact of individual model assumptions.

We find that:

- Varying any single assumption, within a plausible range, does not result in transformational increases in cost recovery rates
- The two model extensions modestly increase cost recovery for the benchmark road modelled here
- Cost recovery is not particularly sensitive to population and traffic growth projections
- Cost recovery is most sensitive to the parameter for users' value of travel time savings
- Increasing the tolling period and reducing the discount rate results in higher cost recovery, while reducing the tolling period or increasing the discount rate reduces cost recovery
- Cost recovery is not sensitive to changes to other whole-of-life costs, like including maintenance costs or reducing toll administration costs

Sensitivity testing of changes to multiple assumptions suggests that, to achieve full cost recovery for this hypothetical case, we would need to increase traffic growth to twice as high as SNZ's P95 population projection, double users' value of travel time savings, reduce the discount rate to 3%, and extend the tolling period to 50 years.

Table 14: Sensitivity testing of toll cost recovery model

Category	Sensitivity test on input parameters	Light vehicle toll needed for full cost recovery	Maximum achievable toll revenue (after diversion)	Cost recovery rate
Baseline model	Baseline	$18.90	$2.80	15%
Model extension 1: Induced traffic	Baseline	$18.90	$2.80	16%
Model extension 2: FED/RUC rebating	Baseline	$18.90	$2.80	20%
Traffic growth	P95 population growth	$18.20	$2.80	16%
	P5 population growth	$19.60	$2.80	14%
	P50 population growth plus income effects (0.6 elasticity)	$18.00	$2.80	16%
	P95 population growth plus income effects (1.0 elasticity)	$16.90	$2.80	17%
Value of travel time savings	30% higher than baseline VOT	$18.90	$4.00	21%
	30% lower than baseline VOT	$18.90	$1.80	10%
	Higher heavy vehicle tolls (3x light vehicle tolls)	$17.60	$2.80	16%
Tolling period and discount rate	15 year tolling period, baseline discount rate	$25.90	$2.80	11%
	50 year tolling period, baseline discount rate	$14.30	$2.80	20%
	25 year tolling period, 3% discount rate	$15.40	$2.80	18%
	50 year tolling period, 3% discount rate	$10.30	$2.80	28%
	25 year tolling period, 7% discount rate	$22.80	$2.80	12%
	50 year tolling period, 7% discount rate	$19.00	$2.80	15%
Whole of life costs	Add annual maintenance costs of 1% of build cost	$21.40	$2.80	13%
	Add annual maintenance costs of 3% of build cost	$26.50	$2.80	11%
	50% reduction to toll admin costs	$18.40	$2.80	15%
	90% reduction to toll admin costs	$18.10	$2.80	16%

Source: Te Waihanga analysis. All results are for a single hypothetical case of a high-cost motorway that serves a route with 20,000 vehicles per day and offers travel time savings of 10 minutes.

Data on existing or proposed New Zealand toll roads

The following table summarises key data on existing or proposed toll roads in New Zealand. This data was used to create Figure 11 in the body of the report.

Table 15: Outcomes for existing or proposed New Zealand toll roads

Road	Approximate project cost (2023 NZD)	Average daily traffic (2023)	Travel time savings relative to untolled route	Light / heavy vehicle toll (2024)	Cost recovery from tolls
Tauranga Takitimu Drive (Route K) (2003)	$93 million	14,400	Around 5 minutes	$2.10 / $5.40	Fully funded from tolls – see below
Auckland Northern Gateway (2008)	$555 million	21,700	Around 10 minutes	$2.60 / $5.20	42%
Tauranga Eastern Link (2015)	$624 million	11,200	Around 10 minutes	$2.30 / $5.60	23%
Transmission Gully (2022; not tolled)	$1,500 million	23,500	Around 7 minutes	Various tolls modelled	7-10%
Puhoi to Warkworth (2023; not tolled)	$1,100 million	21,000	Around 10 minutes	Various tolls modelled	25%
Penlink (2026; proposed tolls)	$941 million (with toll gantries)	19,000	Around 7 minutes	Various tolls modelled	12%

Sources: Road cost from New Zealand Infrastructure Commission (2022b) and NZTA, inflated to 2023 values using SNZ Capital Goods Price Index for civil construction.[60] Traffic volumes,[61] current toll rates,[62] and toll cost recovery from NZTA.[63] Travel time savings from Google Maps (off-peak times). We do not report cost recovery

[60] https://www.nzta.govt.nz/roads-and-rail/toll-roads/toll-road-information/frequently-asked-questions/general/#takitimu
https://www.nzta.govt.nz/assets/projects/penlink/docs/penlink-toll-modelling-report.pdf

[61] Data on following roads from NZTA state highway traffic volumes: Auckland Northern Gateway: ALPURT - Telemetry Site 95, 2023, both directions; Tauranga Eastern Link: TEL Toll Gantry -Telemetry Site 122, 2023, both directions; Tauranga Takitimu Drive: Takitimu Drive Toll Gantry -Telemetry Site 123, 2023, both directions; Puhoi to Warkworth: Sth of Mckinney Rd (Sth of Warkworth), 2023, both directions. https://www.nzta.govt.nz/resources/state-highway-traffic-volumes/. Data on Transmission Gully from: https://www.nzta.govt.nz/projects/wellington-northern-corridor/transmission-gully-motorway/about-the-project/project-news/tracking-data-to-keep-drivers-safe/. Data on Penlink reflects 2018 traffic volumes on Whangaparaoa Rd (18,900 vehicles per day) from Figure 5-4 in toll modelling report: https://www.nzta.govt.nz/assets/projects/penlink/docs/penlink-toll-modelling-report.pdf.

[62] https://www.nzta.govt.nz/roads-and-rail/toll-roads/toll-road-information/tolls-and-fees/changes-to-toll-pricing/

[63] Tolls for Auckland Northern Gateway and Tauranga Eastern Link are intended to repay loans taken out to pay 42% and 23% of total project cost, respectively: https://www.nzta.govt.nz/roads-and-rail/toll-roads/toll-road-information/frequently-asked-questions/general/#construction
Transmission Gully tolling assessment suggests tolls could cover 7-10% of the cost of the road:

data for Tauranga's Takitimu Drive as the road's original owner (Tauranga City Council) ran into financial trouble due to low tolling revenue and sold the road to NZTA in 2015. Since then cost recovery has improved and the road is expected to recoup its costs.

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https://www.nzta.govt.nz/assets/projects/transmission-gully-motorway/docs/Transmission-Gully-tolling-assessment-summary-redacted-version.pdf
Puhoi to Warkworth tolling revenue assessment suggests that the net present value of toll revenues is $184 million (6% discount rate, 35 year period), compared with an NPV project cost of $744 million. https://www.nzta.govt.nz/assets/consultation/ara-tuhono-puhoi-to-warkworth-tolling-proposal/toll-modelling-assessment.pdf; https://www.nzta.govt.nz/assets/projects/puhoi-warkworth/docs/puhoi-to-warkworth-business-case-for-implementation.pdf
Penlink tolling analysis suggests that the recommended tolling scheme would cover 8% of project costs (see para 52 in https://www.transport.govt.nz/assets/Uploads/Penlink-Tolling-Docs-Redacted-with-watermark.pdf) but the tolling report suggests that cost recovery could be up to 12% with a different set of toll prices: https://www.nzta.govt.nz/assets/projects/penlink/docs/penlink-toll-modelling-report.pdf.

References

Adler, M. W., & van Ommeren, J. N. (2016). Does public transit reduce car travel externalities? Quasi-natural experiments' evidence from transit strikes. *Journal of Urban Economics*, *92*, 106–119. https://doi.org/10.1016/j.jue.2016.01.001

Alternative Transport Funding Project. (2013). *Funding Auckland's Transport Future: Final Report*. Auckland Council.

Anas, A., & Xu, R. (1999). Congestion, Land Use, and Job Dispersion: A General Equilibrium Model. *Journal of Urban Economics*, *45*(3), 451–473. https://doi.org/10.1006/juec.1998.2104

Andersson, J. J. (2019). Carbon Taxes and CO2 Emissions: Sweden as a Case Study. *American Economic Journal: Economic Policy*, *11*(4), 1–30. https://doi.org/10.1257/pol.20170144

Auckland Transport Alignment Project. (2016a). *Auckland Transport Alignment Project: Recommended Strategic Approach*. Ministry of Transport, Treasury, and Auckland Council. https://www.transport.govt.nz/assets/Uploads/Report/ATAPRecommendedStrategicApproach.pdf

Auckland Transport Alignment Project. (2016b). *Auckland Transport Alignment Project: Supporting information*. Ministry of Transport, Treasury, and Auckland Council. https://www.transport.govt.nz/assets/Uploads/Report/ATAP-Supporting-Information.pdf

Australian Productivity Commission. (2021). *Public transport pricing* [Research paper]. Australian Productivity Commission. https://www.pc.gov.au/research/completed/public-transport/public-transport.pdf

Bain, R., & Senechal, S. (2022). It's About Time. *Infrastructue Investor*. https://img1.wsimg.com/blobby/go/088f2705-9742-46a8-a889-ff8e4087b110/It's%20About%20Time.pdf

Beal, C. D., & Stewart, R. A. (2014). Identifying Residential Water End Uses Underpinning Peak Day and Peak Hour Demand. *Journal of Water Resources Planning and Management*, *140*(7), 04014008. https://doi.org/10.1061/(ASCE)WR.1943-5452.0000357

Börjesson, M., Brundell-Freij, K., & Eliasson, J. (2014). Not invented here: Transferability of congestion charges effects. *Transport Policy*, *36*, 263–271. https://doi.org/10.1016/j.tranpol.2014.09.008

Boston Consulting Group. (2022). *The Future is Electric: A Decarbonisation Roadmap for New Zealand's Electricity Sector*.

Bureau of Infrastructure, Transport and Regional Economics. (2015). *Traffic and congestion cost trends for Australian capital cities*. Department of Infrastructure and Regional Development. https://www.bitre.gov.au/sites/default/files/is_074.pdf

Byett, A., Laird, J., Falconer, J., & Roberts. (2024). *Assessing induced road traffic demand in New Zealand* (717; NZTA Research Reports). New Zealand Transport Agency.

Cook, C., & Li, P. Z. (2023). *Value Pricing or Lexus Lanes? The Distributional Effects of Dynamic Tolling*.

Covec, & MRCagney. (2016). *Signals of Under-Capacity: The practicalities of monitoring price signals under the National Policy Statement on Urban Development Capacity*. Ministry for the Environment and Ministry of Business, Innovation and Employment.

Covec, & MRCagney. (2018). *Congestion Pricing Options for Auckland: Analysis of distributional effects*. Report for The Congestion Question.

Covec, & MRCagney. (2019). *Congestion Pricing in Auckland: Analysis of effects on households and business* [Report for The Congestion Question].

Douglas, N., Brennand, T., & Wignall, D. (2021). Assessing Toll Road Demand in New Zealand. *Australasian Transport Research Forum 2021 Proceedings*. Australasian Transport Research Forum, Brisbane.

Douglas, N., Wallis, I., Lawrence, A., & Wignall, D. (2013). *International Comparison of Transport Appraisal Practice: Annex 7 New Zealand Country Report*. Institute for Transport Studies, University of Leeds.

Duranton, G., & Turner, M. A. (2011). The Fundamental Law of Road Congestion: Evidence from US Cities. *American Economic Review*, *101*(6), 2616–2652. https://doi.org/10.1257/aer.101.6.2616

Eliasson, J. (2014). *The Stockholm congestion charges: An overview* (2014:7; CTS Working Paper, p. 42). Centre for Transport Studies.

Flyvbjerg, B. (2009). Survival of the unfittest: Why the worst infrastructure gets built--and what we can do about it. *Oxford Review of Economic Policy*, *25*(3), 344–367. https://doi.org/10.1093/oxrep/grp024

Garcia-López, M.-À., Pasidis, I., & Viladecans-Marsal, E. (2022). Congestion in highways when tolls and railroads matter: Evidence from European cities. *Journal of Economic Geography*, *22*(5), 931–960. https://doi.org/10.1093/jeg/lbab025

Glaeser, E. L., & Poterba, J. M. (2021). Introduction to 'Economic Analysis and Infrastructure Investment'. In *Economic Analysis and Infrastructure Investment* (pp. 1–38). University of Chicago Press. https://www.nber.org/books-and-chapters/economic-analysis-and-infrastructure-investment/introduction-economic-analysis-and-infrastructure-investment

Heatley, D., & Sweet, A. (2024). *Simulating the impact of different ways of charging for infrastructure on households*. Infrastructure Commission.

Hsu, W.-T., & Zhang, H. (2014). The fundamental law of highway congestion revisited: Evidence from national expressways in Japan. *Journal of Urban Economics*, *81*, 65–76. https://doi.org/10.1016/j.jue.2014.02.002

Infometrics. (2008). *Economic Assessment of the Cost Allocation Model*. Ministry of Transport. https://www.transport.govt.nz/assets/Uploads/Paper/Infometrics20Economic20Analysis20of20the20Cost20Allocation20Model.pdf

Infrastructure Victoria. (2023). *Choosing Victoria's future: Five urban development scenarios*. Infrastructure Victoria. https://assets.infrastructurevictoria.com.au/assets/Resources/Infrastructure-Victoria-Choosing-Victorias-future-Five-urban-development-scenarios-_2.pdf

Koch, N., Naumann, L., Pretis, F., Ritter, N., & Schwarz, M. (2022). Attributing agnostically detected large reductions in road CO2 emissions to policy mixes. *Nature Energy*, *7*(9), 844–853. https://doi.org/10.1038/s41560-022-01095-6

Kuschel, G., Metcalfe, J., Sridhar, S., Davy, P., Hastings, K., Mason, K., Denne, T., Berentson-Shaw, J., Bell, S., Hales, S., Atkinson, J., & Woodward, A. (2022). *Health and Air Pollution in New Zealand 2016 (HAPINZ 3.0): Volume 1 – Findings and implications*. Report for the Ministry for the Environment, Ministry of Health, Te Manatū Waka Ministry of Transport and Waka Kotahi NZ Transport Agency. https://www.ehinz.ac.nz/assets/HAPINZ3/HAPINZ-3.0_Vol-1-Findings-Report.pdf

Maré, D. C., & Graham, D. J. (2009). *Agglomeration Elasticities in New Zealand* (Motu Working Paper 09–06). Motu Economic and Public Policy Research. https://doi.org/10.2139/ssrn.1433644

McFadden, D. (1974). The measurement of urban travel demand. *Journal of Public Economics*, *3*(4), 303–328. https://doi.org/10.1016/0047-2727(74)90003-6

Melo, P. C., & Graham, D. J. (2018). Transport-induced agglomeration effects: Evidence for US metropolitan areas. *Regional Science Policy & Practice*, *10*(1), 37–47. https://doi.org/10.1111/rsp3.12116

Ministry of Transport. (2006). *Auckland Road Pricing Evaluation Study 2006*. Ministry of Transport. https://www.transport.govt.nz/assets/Uploads/Report/TracklingCongestioninAuckland.pdf

Ministry of Transport. (2008). *Auckland Road Pricing Study 2008*. Ministry of Transport.

Ministry of Transport. (2014). *GPS 2015- Capital spending on roads working paper*. https://onedrive.live.com/?authkey=%21APsEXu60Z9YhJkM&cid=6C6F1925E284040B&id=6C6F1925E284040B%2110540&parId=6C6F1925E284040B%215368&o=OneUp

Ministry of Transport. (2021). *Social cost of road crashes and injuries—June 2020 update*. Ministry of Transport. https://www.transport.govt.nz//assets/Uploads/Social-Cost-of-Road-Crashes-and-Injuries-2020_final.pdf

Ministry of Transport. (2022). *He Tuapapa mo te Punaha Kaiwhakamahi Rori | Background to the road user charges (RUC) system*. Ministry of Transport.

Ministry of Transport. (2023a). *Domestic Transport Costs and Charges Study: Main report*. Ministry of Transport. https://www.transport.govt.nz/assets/Uploads/DTCC-Main-Report-June-2023.pdf

Ministry of Transport. (2023b). *Post-implementation regulatory assessment: Temporary decreases in petrol excise duty, road user charges and half-fare public transport*. Ministry of Transport. https://www.treasury.govt.nz/sites/default/files/2023-02/ria-transport-piaped-jan23.pdf

MRCagney. (2019). *Costs and benefits of urban development*. Ministry for the Environment.

National Infrastructure Commission. (2018). *Economic Growth and Demand for Infrastructure Services*. National Infrastructure Commission. https://nic.org.uk/studies-reports/national-infrastructure-assessment/national-infrastructure-assessment-1/economic-growth-and-demand-for-infrastructure-services/

New Zealand Infrastructure Commission. (2022a). *Economic performance of New Zealand's construction industry* (Te Waihanga Research Insights, p. 56). New Zealand Infrastructure Commission.

New Zealand Infrastructure Commission. (2022b). *The lay of the land: Benchmarking New Zealand's infrastructure delivery costs* (Te Waihanga Research Insights). New Zealand Infrastructure Commission.

New Zealand Infrastructure Commission. (2023a). *How much do we pay for infrastructure? Household expenditure on infrastructure services* (Te Waihanga Research Insights). New Zealand Infrastructure Commission.

New Zealand Infrastructure Commission. (2023b). *Urban land prices – a progress report* (Te Waihanga Research Insights). New Zealand Infrastructure Commission.

New Zealand Infrastructure Commission. (2023c). *Why do construction input costs change? The role of global and local factors* (Te Waihanga Research Insights). New Zealand Infrastructure Commission.

New Zealand Infrastructure Commission. (2024). *Build or maintain? New Zealand's infrastructure asset value, investment, and depreciation, 1990–2022* (Te Waihanga Research Insights). New Zealand Infrastructure Commission.

New Zealand Institute of Economic Research. (2017). *Benefits from Auckland road decongestion*. Report to the Employers and Manufacturers Association, Infrastructure New Zealand, Auckland International Airport Ltd, Ports of Auckland Ltd, National Road Carriers Association. https://www.nzier.org.nz/hubfs/Public%20Publications/Client%20reports/nzier_report_on_auckland_benefits_of_decongestion.pdf

NSW Productivity Commission. (2023). *Building more homes where infrastructure costs less*. NSW Productivity Commission. https://www.productivity.nsw.gov.au/sites/default/files/2023-08/202308_NSW-Productivity-Commission_Building-more-homes-where-infrastructure-costs-less_accessible-v2.pdf

Office of the Auditor-General. (2023). *Transport Sector: A case study of sector-level reporting*. Office of the Auditor-General. https://oag.parliament.nz/2023/transport-sector/docs/transport-sector-case-study.pdf

Palcic, D., Reeves, E., & Stafford, A. (2018). Lifting the Lid: The Private Financing of Motorway PPPs in Ireland. *The Economic and Social Review*, *49*(2).

Parry, I. W. H., & Small, K. A. (2009). Should Urban Transit Subsidies Be Reduced? *American Economic Review*, *99*(3), 700–724. https://doi.org/10.1257/aer.99.3.700

Pickford, M. (2013). State highway investment in New Zealand: The decline and fall of economic efficiency. *Policy Quarterly*, *9*(3). https://doi.org/10.26686/pq.v9i3.4454

Proost, S., & Dender, K. V. (2008). Optimal urban transport pricing in the presence of congestion, economies of density and costly public funds. *Transportation Research Part A: Policy and Practice*, *42*(9), 1220–1230. https://doi.org/10.1016/j.tra.2008.03.009

Public-Private Infrastructure Advisory Facility. (2009). *Country case study: France* (Toolkit for Public-Private Partnerships in Roads & Highways). Public-Private Infrastructure Advisory Facility. https://www.ppiaf.org/sites/ppiaf.org/files/documents/toolkits/highwaystoolkit-russian/6/pdf-version/france.pdf

PwC NZ. (2024a). *Approaches to Infrastructure Pricing Study: Part 2—Current Pricing Analysis*. New Zealand Infrastructure Commission. https://media.umbraco.io/te-waihanga-30-year-strategy/4ylpom10/approaches-to-infrastructure-pricing-study-part-2-current-pricing-analysis.pdf

PwC NZ. (2024b). *Approaches to Infrastructure Pricing Study: Part 3—Equity Exploration*. New Zealand Infrastructure Commission. https://media.umbraco.io/te-waihanga-30-year-strategy/vdlds52t/approaches-to-infrastructure-pricing-study-part-3-equity-exploration.pdf

Sapere. (2023). *Infrastructure Consenting for Climate Targets*. New Zealand Infrastructure Commission.

Sheppard, G., & Beck, M. (2023). The Impact of Covid-19 on PPP in Ireland. In T. Dolla, B. Laishram, & G. Devkar (Eds.), *Revisiting Public-Private Partnerships: Lessons from COVID-19* (pp. 49–58). Springer International Publishing. https://doi.org/10.1007/978-3-031-37015-1_4

Small, K. A., & Verhoef, E. T. (2007). *The Economics of Urban Transportation: 2nd Edition*. Routledge.

The Congestion Question. (2019). *Defining Congestion* [Working Paper]. The Congestion Question. https://www.transport.govt.nz/assets/Uploads/Paper/DefiningCongestion.pdf

The Congestion Question. (2020). *The Congestion Question Technical Report*. The Congestion Question. https://www.transport.govt.nz/assets/Uploads/Report/TheCongestionQuestionsTechnicalReport.pdf

Train, K. E. (2009). *Discrete Choice Methods with Simulation*. Cambridge University Press.

Venables, A. J. (2007). Evaluating Urban Transport Improvements: Cost–Benefit Analysis in the Presence of Agglomeration and Income Taxation. *Journal of Transport Economics and Policy*, *41*, 16.

Waka Kotahi NZ Transport Agency. (2023). *Monetised benefits and costs manual*. Waka Kotahi NZ Transport Agency. https://www.nzta.govt.nz/assets/resources/monetised-benefits-and-costs-manual/Monetised-benefits-and-costs-manual.pdf

Wallis, I., & Lupton, D. (2013). *The costs of congestion reappraised* (489; NZTA Research Reports). NZ Transport Agency. http://www.nzta.govt.nz/resources/research/reports/489/docs/489.pdf

Water Industry Commission for Scotland. (2021). *Economic analysis of water services aggregation: Final Report* (p. 68) [Report for the Department of Internal Affairs]. Water Industry Commission for Scotland. https://www.dia.govt.nz/diawebsite.nsf/Files/Three-waters-reform-programme/$file/wics-final-report-economic-analysis-of-water-services-aggregation.pdf

West, J., & Börjesson, M. (2020). The Gothenburg congestion charges: Cost–benefit analysis and distribution effects. *Transportation*, *47*(1), 145–174. https://doi.org/10.1007/s11116-017-9853-4