Paying it forward: Understanding our long-term infrastructure needs

Te Waihanga Research Insights series

September 2024

Tewaihanga.govt.nz

New Zealand Infrastructure Commission / Te Waihanga

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.

We are an autonomous Crown entity, listed under the Crown Entities Act 2004, with an independent board. We were established by the New Zealand Infrastructure Commission/Te Waihanga Act 2019 on 25 September 2019.

Information on the Commission is available at www.tewaihanga.govt.nz/

How to cite this document

New Zealand Infrastructure Commission. (2024). Paying it forward: Understanding our long-term infrastructure needs. Wellington: New Zealand Infrastructure Commission / Te Waihanga.

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Research Insights series September 2024
ISSN 2023 ISSN 2816-1190 (Online)

Acknowledgement

This research note was drafted by Peter Nunns and Graham Campbell with assistance from Philip Stevens and Shelly Biswell. We are grateful for comments and feedback from Len Cook, Stuart Donovan (Motu Institute), Ryan Greenaway-McGrevy (University of Auckland), and participants in a workshop convened by the Institution of Civil Engineers' *Enabling Better Infrastructure* programme.

Contents

Cut to the chase

Infrastructure networks are a work in progress...

Infrastructure lasts a long time. Pipes that carry water to homes are designed to last generations. Road tunnels in our cities have stood in the same place for almost 100 years.

New infrastructure assets are extensions of networks that have been built up over generations. Individual pieces of infrastructure last a long time, but it is our networks that are most enduring.

But while they are enduring, they are never static. They are constantly being added to, improved, or repurposed to meet the needs of current and future populations.

...and infrastructure requires an eye to the future

Because infrastructure lasts such a long time, infrastructure decisions need to be made with an eye on the future. We need to consider where and how we should build infrastructure to best meet the needs of current *and* future generations.

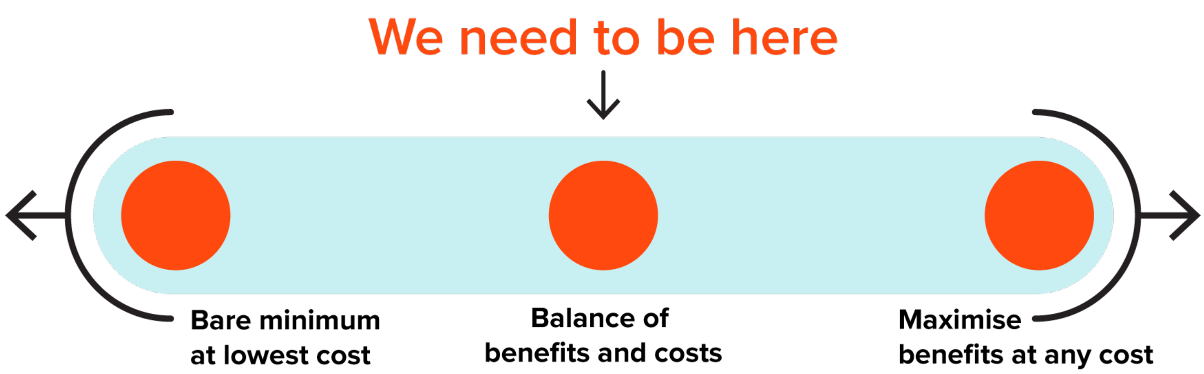
The Infrastructure Commission, Te Waihanga, was created to think about these questions. Following our legislation, our current work on a long-term National Infrastructure Plan will lay our best estimate of our long-term infrastructure needs, comparing them with current investment intentions to identify gaps and opportunities for recalibration and reforms.

How should we think about long-term infrastructure needs?

When we lay out our future infrastructure needs, we must consider how meeting one need might affect our ability to meet another need. Because infrastructure is not free and we don't have unlimited amounts of money, there are trade-offs between different spending choices.

With this view of trade-offs, our preferred definition of 'need' is one that goes beyond meeting bare minimum levels of infrastructure but stops short of building anything that provides even marginal benefit (Figure 1). Additional infrastructure investment is needed if the benefits of investment to society as a whole outweigh the cost of investment.

Figure 1: The spectrum of infrastructure needs



Our approach to assessing needs is therefore grounded in the following three questions.

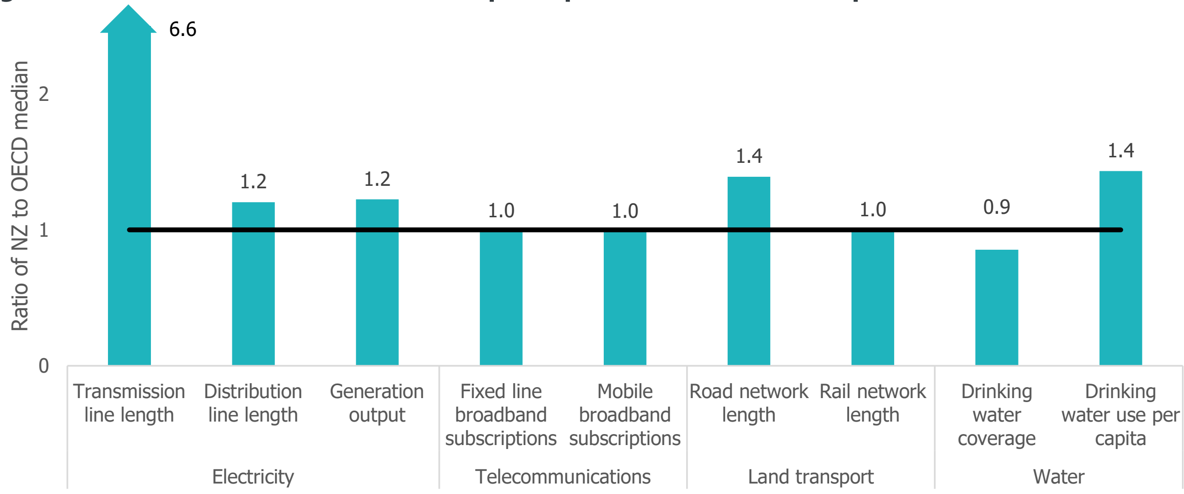
What is the current state of our networks?

To understand our needs, we first need to know what we already have and where we have gaps, relative to our peers.

As a developed country, we already have a lot of infrastructure. In 2022, New Zealand's infrastructure was worth around $287 billion in total. This is equal to $55,800 of infrastructure per New Zealander.

Compared to the median OECD country, we have a relatively typical amount of physical infrastructure for a high-income country, except for electricity infrastructure, where we have more, and piped drinking water, where we have less (Figure 2).

Figure 2: Size of infrastructure networks per capita, New Zealand compared with OECD countries



Source: New Zealand Infrastructure Commission analysis of several international data sources.

We also know, from our previous research, that we spend a similar share of our GDP on infrastructure as other high-income countries. However, on broad measures of infrastructure performance, the quality of our infrastructure is not up to scratch with our peers. This suggests that we have an 'efficiency gap' when it comes to provision and use of infrastructure.

Further research is needed to understand where our infrastructure is not meeting expectations and where there may be service gaps, relative to our peer countries.

What are we willing to pay for infrastructure?

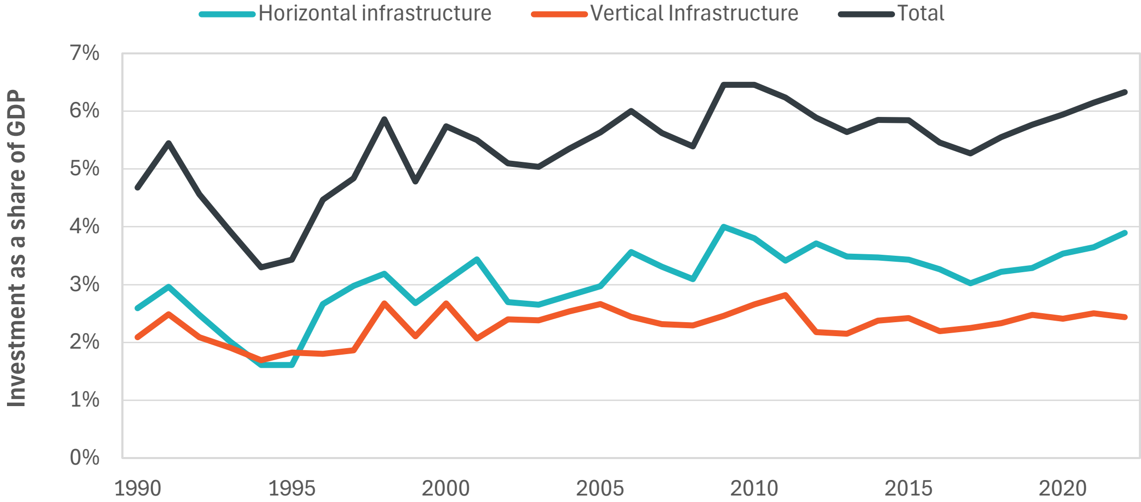
Previous analysis suggests that a significant uplift in investment may be needed to 'build our way out' of all our infrastructure challenges. For instance, the 2021 *Infrastructure Challenge* report by Sense Partners found that New Zealand's infrastructure deficit was over $200 billion. Addressing this would require us to nearly double investment on infrastructure, relative to current trends, and sustain higher investment for 30 years.

However, it is unclear whether New Zealand is willing or able to spend this much. Over the last 20 years, we've opted to spend around 5.0% to 6.5% of our GDP on infrastructure (Figure 3).

To give a sense of scale for the year 2024, 5.8% of GDP, the average we've spent since 2003, is around $24 billion. However, not all of this money is available to build new infrastructure. Based on historical trends, we estimate that almost 60% of investment is needed to renew and replace existing infrastructure that is wearing out and reaching the end of its useful life. This leaves around $10 billion for new or improved infrastructure. While this is a lot of money, given how extensive and valuable our networks are, it is not big enough to avoid thinking about trade-offs.

The actual amount we will be willing to spend on infrastructure in the future will change over time, reflecting growth in the size of our economy, as well as other factors. These are areas for future research.

Figure 3: Share of GDP invested in infrastructure in New Zealand



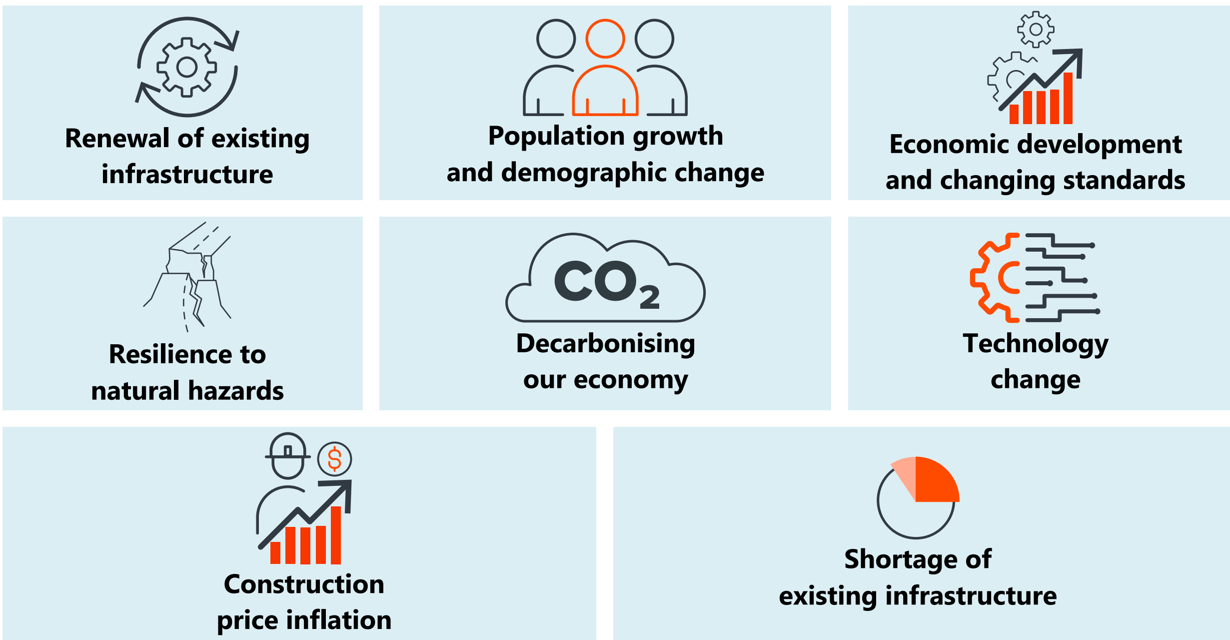
Source: New Zealand Infrastructure Commission (2024a).

Where and how should we invest in the future?

Infrastructure needs shift over time in response to many factors, such as economic growth, population growth and demographic change, climate change, and technological change. The future will be different than the past, and infrastructure investment will change as a result.

Based on our previous work, our legislation, and a review of international practices, we identify eight factors that can cause the need for infrastructure investment to change over time, both in total and at a sector or regional level (Figure 4).

Figure 4: Eight drivers of future infrastructure investment



When thinking about these drivers of change, we are aware that the future is uncertain and there is a need to consider a range of scenarios, rather than focusing on one scenario. Further work is needed to understand investment drivers and the range of future scenarios that might influence the need for infrastructure investment.

In the context of an uncertain future, some needs are easier to forecast than others. For instance, forecasting renewal investment may be more straightforward if we have good information on the size and condition of our existing assets and when they will need to be replaced.

Other needs are less certain and hence harder to forecast. For instance, population growth and demographic change play an important role in infrastructure investment demand. The future size of our population is uncertain, as population growth has been volatile in the past. However, population ageing is a more certain long-term trend that will play a stronger role in driving infrastructure investment in the future (Box 1).

Further research is needed to build our understanding of future trends that may affect infrastructure investment. We identify natural hazard risk, decarbonising our economy, and technological change as three areas where additional work would be particularly valuable.

Like our infrastructure networks, identifying long-term needs is a work in progress. The Commission is committed to adding, updating, and gathering information for needs assessments to ensure that our infrastructure spending is fit for the needs of current and future generations.

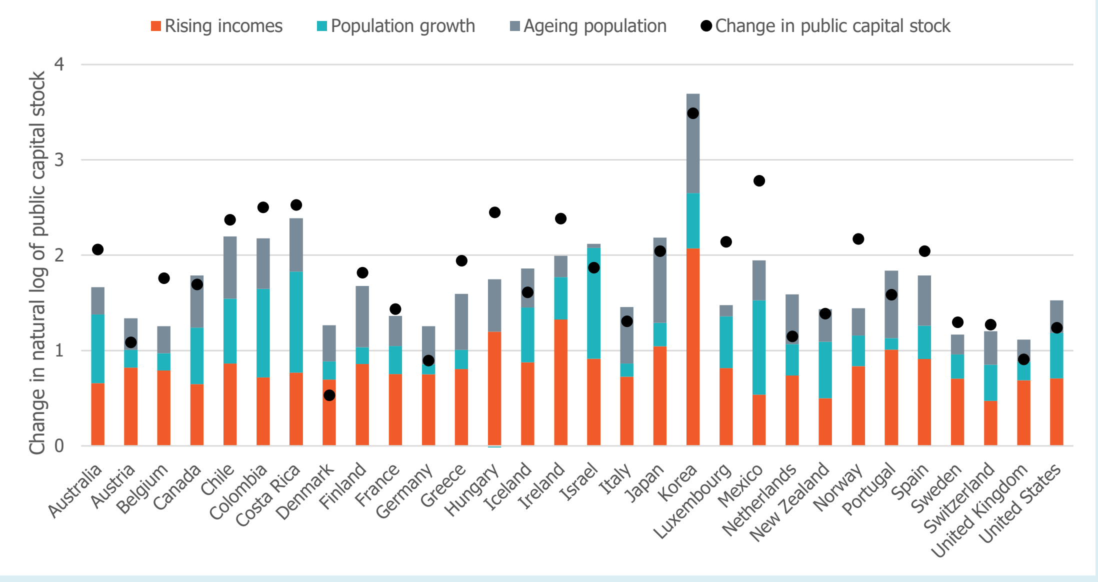
Box 1: The impact of demographics on infrastructure demand

As our population grows and changes, we often need to increase the capacity of infrastructure networks or provide different types of infrastructure to accommodate changing usage.

To understand how demographic change affects infrastructure investment at a national level, we analysed the long-term impact of economic growth and demographic change on public infrastructure stocks in 30 OECD countries over the 1960–2019 period. Different countries experienced different economic and demographic trends over this period, and this has affected how much infrastructure they have built (Figure 1A).

In New Zealand, we estimate that population growth accounted for 41% of the growth in public infrastructure stocks and population ageing accounted for 24% from 1960 to 2019. Income growth accounted for the remaining 35%.

Figure 1A: Decomposing drivers of growth in public capital stocks in OECD countries, 1960–2019

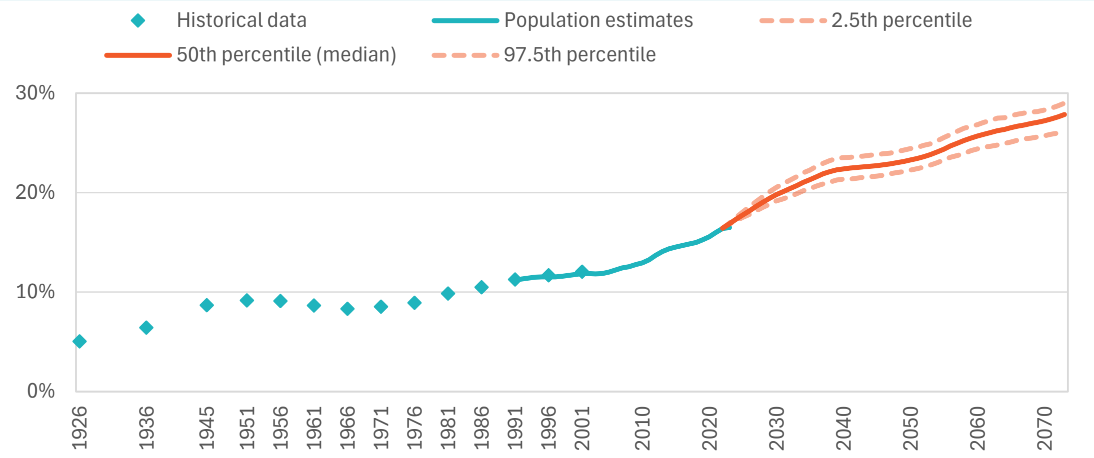


Source: New Zealand Infrastructure Commission analysis of IMF and World Bank data. Note: Log point changes can be converted to percentage changes as follows: Percent change = exp(log change)-1.

New Zealand's demographic future is likely to be different than the past in several ways. Population growth rates are projected to decline in the long term, driven by declining fertility rates and slowing growth in life expectancy. In the short to medium term, this can be offset (or exacerbated) by migration trends. This means that there is uncertainty about how large our population will grow, and how fast.

The composition of the population will also change as our population grows. Our population is getting older, more concentrated in fast-growing urban areas, and more ethnically diverse. At this point, population ageing is all but 'baked in' due to long-term trends in birth rates and life expectancies (Figure 1B).

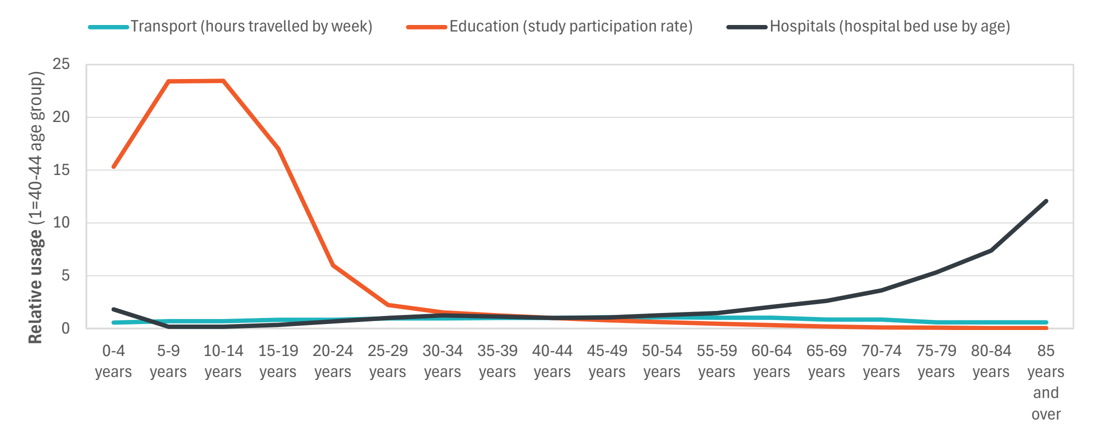
Figure 1B: New Zealand's historical and projected share of population aged 65 years and older, 1926–2073



Source: New Zealand Infrastructure Commission analysis of SNZ LTDS, population estimates, and population projections.

Future demographic changes will affect not only how much we invest in infrastructure in the future, but what types of infrastructure we need to invest in. This is because people use different types of infrastructure as they age. Figure 1C shows relative infrastructure usage by age group. Both young and old people travel slightly less than middle-aged people (and tend to travel to different places), meaning that demand for transport infrastructure will be affected by population ageing. There are more dramatic differences in usage of hospitals (which are used much more by older people) and schools and universities (which are used mainly by younger people).

Figure 1C: Relative infrastructure usage by age group in New Zealand



Source: New Zealand Infrastructure Commission analysis of Household Travel Survey data, Census study participation rate data, Education Counts data, and NZIER hospital usage estimates.

Introduction

Infrastructure for today and tomorrow

Once infrastructure networks are built, they tend to last for a long time and have persistent impacts on economic, social, and environmental outcomes. And because infrastructure is costly and long-lived, the costs to build and maintain it must be spread over many people, present and future.

One of the most striking examples is the long-run impacts of Roman roads on the European economy. Places the Romans built roads to around 2000 years ago are still better-connected and more densely populated today (Dalgaard et al., 2018).

While New Zealand is a younger country, we can also see the persistent impacts of past infrastructure decisions all around us. A positive example is how places with better education infrastructure and transport connections to Auckland have grown faster (Grimes et al., 2016). A negative example is how many Māori communities are still disadvantaged by land taken for infrastructure development in the 1800s and 1900s (Thom & Grimes, 2022).[1]

What this means is that, when we make infrastructure decisions *today*, we need to think about what might happen in the *future*. Specifically, we need to think about how demand for infrastructure services, and thus demand for infrastructure investment, will respond to future trends that play out over years or decades.

What is the future need for infrastructure?

Like any other industry, the infrastructure sector provides services to its users. For instance, roads and public transport networks provide transport services – they enable people to get around. Water infrastructure provides people with drinking water and removes wastewater from their homes. School infrastructure is an input to educating children, hospitals are an input to surgical care, and so on and so forth.

Durable physical assets are required to provide these services. Investment is needed to maintain and renew existing assets, to ensure they can continue to serve their purpose, and to build new or improved assets, to provide new or improved services.

When we talk about the 'need' for infrastructure, we are talking about how much infrastructure is needed to provide the services that people rely upon and expect.

There are several ways to define the 'need' for infrastructure services and thus physical infrastructure assets.

At one extreme, this could be defined as the bare minimum infrastructure needed for human subsistence. For example, humans can survive on as little as 15 litres of water per day, so we could in principle meet minimum needs by providing just enough water infrastructure to supply this amount (World Health Organization, 2013). However, most people would prefer to have more than the bare minimum, even if they had to pay for it.

At the other extreme, a 'need' might be any investment that provides some benefit to society, regardless of what it costs to provide. For example, this could mean providing enough water infrastructure to enable everyone to fill a spa pool and swimming pool and water a large lawn every day. However, infrastructure is not free. Investments in infrastructure need to be weighed against other uses of resources.

[1] https://teara.govt.nz/en/te-tango-whenua-maori-land-alienation/page-9

There are also several ways to assess and measure the need for infrastructure: a bottom-up or a top-down approach.

A bottom-up approach would involve surveying sectors, infrastructure providers, and the public and add these up to determine overall needs. An example of a bottom-up approach is Infrastructure Australia's (2019) *Australian Infrastructure Audit,* which included a detailed analysis of current and emerging issues on assets and networks.

A top-down approach identifies what the nation has spent on infrastructure in the past, and forecasts how factors like demographic change will increase or decrease the need for investment in the future. Examples of top-down approaches include World Bank modelling of future network infrastructure investment demands in low-income countries (Fay & Yepes, 2003) and Oxford Economics and Global Infrastructure Hub's (2017) *Global Infrastructure Outlook,* which forecasts sector-level investment demands for both high- and low-income countries.

Previous attempts at quantifying unconstrained needs

The *Infrastructure Challenge* report by Sense Partners (2021) took a funding-unconstrained, top-down approach to analysing the need for infrastructure. It estimated that New Zealand's infrastructure deficit at over $200 billion would require a spend of up to 9.6% of our GDP on public infrastructure to close the gap. This would be nearly twice what we are currently spending on public infrastructure.

However, it is unclear whether New Zealand is willing or able to spend this much on infrastructure. Paying for it would put large burdens on infrastructure users, taxpayers and ratepayers, or future generations. In our 2023 Briefing to the Incoming Minister, we highlighted that building our way out of the modelled deficit would require a 98% increase in our debt-to-GDP ratio, increasing GST from 15% to 21%, or increasing household spending on infrastructure by 38%.

The *Building a Healthy Future* report by NZIER (2023) took a funding-unconstrained, bottom-up approach to assessing the need for public hospital investment. It estimated that we would need to spend $115 billion just on hospitals over the next 30 years under a business-as-usual approach to service provision, asset management, and investment costs. This would require us to triple capital investment in public hospitals. This report highlights that taking a sector-by-sector approach to needs risks missing the larger financial picture and the trade-offs that must be considered when looking at needs at a system level.

Taking a funding-constrained view of infrastructure investment needs

Our previous work shows that is important to take a funding-constrained, top-down approach when assessing the need for infrastructure investment. This is similar to the approach taken by the UK National Infrastructure Commission (2023) in its *National Infrastructure Assessment*, which provides advice on prioritising investment needs within a fiscal affordability envelope.

It is important to take a funding-constrained view because infrastructure is not free to provide and New Zealanders must pay the cost of infrastructure investment, one way or another.[2] Money we spend on infrastructure is not available to meet our other needs. As a result, we must consider how much we are willing and able to pay for infrastructure, in light of the services we expect to receive from infrastructure. If we do not, needs analysis does not lead to practical advice that can be used to prioritise investment.

As a system lead for infrastructure, the Commission's value lies in our ability to take a top-down, system-level approach to needs analysis, rather than aggregating needs that have been identified at an asset, provider, or sector level. Individual infrastructure providers have a better understanding of the condition of their own assets and their ability to meet service needs. However, they may not have visibility across

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[2] Funding and financing are required to pay for investment. Funding refers to the revenue available for infrastructure investment, which can come from user charges, taxes, or rates. Financing refers to when investments are paid for, either on a pay-as-you-go basis or using debt finance to spread payments over time.

regions and sectors, and hence may not be able to understand how their own investment needs relate to needs elsewhere in the economy.

Three questions we need to ask

In this report, we outline three questions that we must ask to understand the long-term need for infrastructure investment, briefly review the current state of our evidence base in each area and identify areas where we think further work is needed to build the evidence base.

Question 1: What is the state of our current networks?

Before thinking about future infrastructure needs, we must understand the infrastructure that we already have and the services that it provides. This question is therefore about taking stock of our current infrastructure networks and identifying gaps in the services that they are providing.

Answering this question will provide a baseline understanding of what we already have. This can help us to understand:

- how much infrastructure we will need to maintain and renew on an ongoing basis
- where we have opportunities to make better use of existing infrastructure
- where there are shortfalls or deficits relative to service level expectations.

Question 2: What are we willing to pay for infrastructure?

The amount of money we have available to invest in infrastructure is limited by our willingness and ability to pay for it. This question is therefore about identifying what that constraint has been historically and what factors make people willing to spend more or less on infrastructure over time.

Answering this question will provide a baseline understanding of the financial resources that we have to maintain and improve our infrastructure. This can help us to understand:

- how much money we can expect to have for infrastructure investment under 'business as usual' funding settings
- where we will encounter trade-offs and opportunity costs between different investment options.

Question 3: Where or how should we invest in the future?

Our needs and priorities will shift over time in response to many factors, such as economic growth, population growth and demographic change, climate change, and technological change. This question is therefore about identifying factors that can shift demand for infrastructure expenditure and understanding how alternative future scenarios may affect the need for infrastructure investment.

Answering this question will help us to understand how the overall mix of infrastructure investment may need to change over time in response to future trends and scenarios. This can help us to understand:

- The relative size of different investment demands that are facing us – for instance, how big of a job will it be to renew hospitals, versus to respond to urban transport congestion?
- Which investment demands are likely to rise in importance over time, and which are likely to become less important – for instance, as our population ages, will demand for new school infrastructure decline?
- Whether our current investment programmes are likely to meet our future needs for infrastructure, or whether we will need to rebalance investment over time.

Because the future is uncertain, it is hard to be certain about future needs for infrastructure. However, analysing future scenarios is still valuable as it can help us to understand the nature of the uncertainties we face and how they will affect infrastructure. This can in turn improve our ability to prepare for the future, whatever it may bring.

Theme 1: What is the state of our current networks?

What types of infrastructure do we have?

We use data from Statistics New Zealand's National Accounts to understand the financial value of New Zealand's built infrastructure assets, excluding land used for infrastructure (New Zealand Infrastructure Commission, 2024a). In 2022, New Zealand's infrastructure was worth around $287 billion in total. This is equal to $55,800 of infrastructure per New Zealander.

Figure 5 summarises the value of infrastructure assets by infrastructure sector and ownership structure. 'Horizontal' infrastructure assets, like roads, water networks, and electricity, account for most of our infrastructure assets by value.

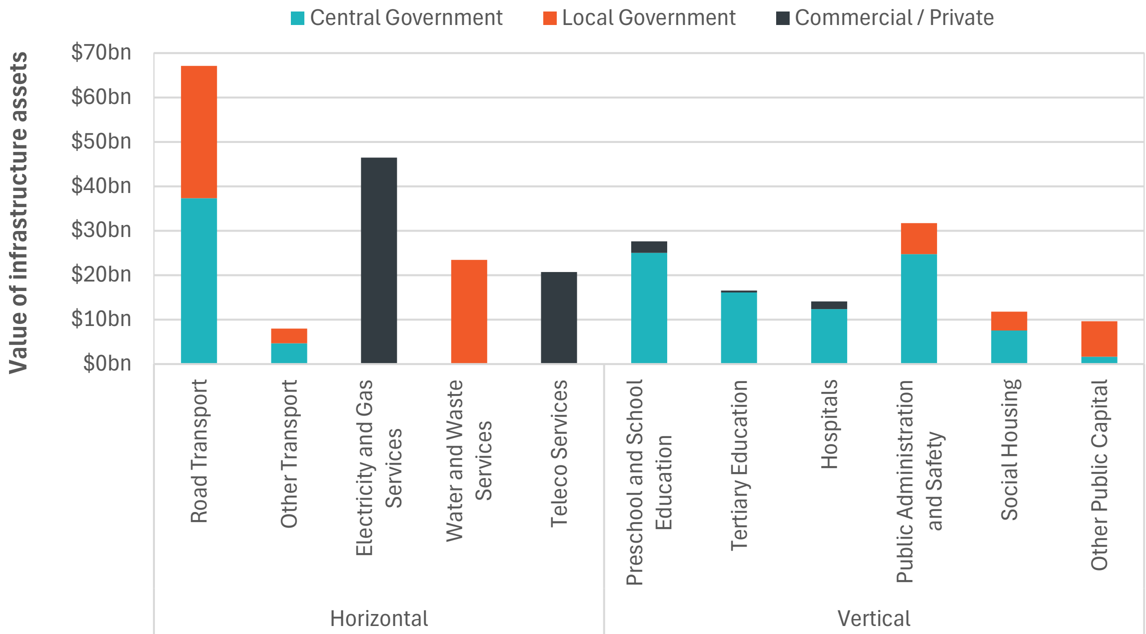
Road transport infrastructure is the single largest category, valued at $67 billion. Electricity and gas infrastructure, valued at nearly $47 billion, is the second largest category, followed by water, sewerage, drainage, and waste infrastructure, valued at $33 billion.

'Vertical' infrastructure assets, like schools, hospitals, and social housing, are also important. Preschool and school education infrastructure is the largest single category of vertical infrastructure, with a total value of almost $28 billion. Hospital infrastructure, by comparison, is valued at $14 billion.

The public administration and safety category includes various government administration assets, defence infrastructure, justice infrastructure, and public order and safety services infrastructure such as fire stations and police stations. These assets are valued at almost $32 billion in total.

We rely upon these infrastructure assets to provide services to our existing population. We will have to maintain and improve them to ensure they can continue to meet our needs in the future.

Figure 5: Dollar value of New Zealand's infrastructure assets, 2022



Source: New Zealand Infrastructure Commission (2024a).

What is the state of our physical infrastructure assets?

While information on the financial value of infrastructure is useful for comparing the relative size and value of assets in different sectors, we need information on the physical characteristics and condition of infrastructure as well. The physical condition of infrastructure assets and their capacity to meet current and future demands are important for how we meet our future need for infrastructure.

In 2021 we published a series of *Sector State of Play* reports for seven horizontal and vertical infrastructure sectors (New Zealand Infrastructure Commission, 2021g, 2021f, 2021e, 2021c, 2021h, 2021d, 2021b).[3] These reports compiled and summarised existing information on our existing infrastructure networks, including the physical assets that we have and existing and emerging challenges, such as condition or capacity pressures.

While these reports are useful, **further work is required to understand the physical characteristics and condition of our infrastructure networks and to identify gaps.** A challenge in undertaking a robust gap assessment is that we do not always have clear standards for infrastructure access and quality against which we can benchmark existing infrastructure.

How does our infrastructure compare to peer countries?

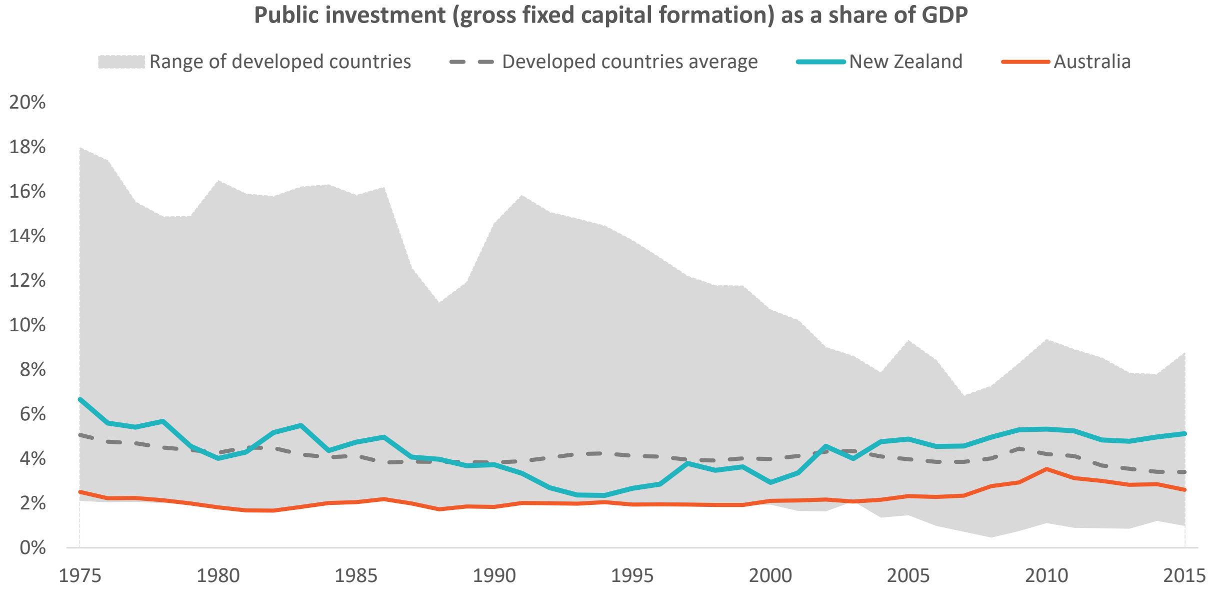
Broad international comparisons suggest that New Zealand may have some shortcomings in infrastructure relative to other high-income countries. For instance, New Zealand ranks 46th overall, and 43rd out of the 54 high-income countries, on the World Economic Forum's 2019 infrastructure quality index. While this measure is not without its flaws, it provides a broad-brush indicator of our relative performance.[4] There are likely to be areas where the availability or quality of infrastructure falls below our expectations.

In our previous research, we show that our performance on this index cannot be explained by low investment in infrastructure. In recent decades, we have spent a similar share of GDP on network infrastructure as the average high-income country, and, as shown in Figure 6, our local and central government investment is slightly higher than average (New Zealand Infrastructure Commission, 2021a).

[3] Sectors covered: transport, energy, telecommunications, water, waste and resource recovery, education, and health.

[4] The WEF's infrastructure index is based on 12 measures of the coverage and performance of transport infrastructure, electricity, and water supply. These are a mix of 'objective' measures, like the share of the population with access to electricity and clean drinking water, and 'subjective' measures, like perceived quality of road infrastructure and train services from a survey of business executives. An aggregate index is constructed by assigning 50% weight to transport metrics and 50% weight to electricity and water metrics, and, within each sub-category, assigning equal weight to each metric. These measures can suffer from bias, but the WEF index is the only infrastructure index with sufficient coverage for this analysis.

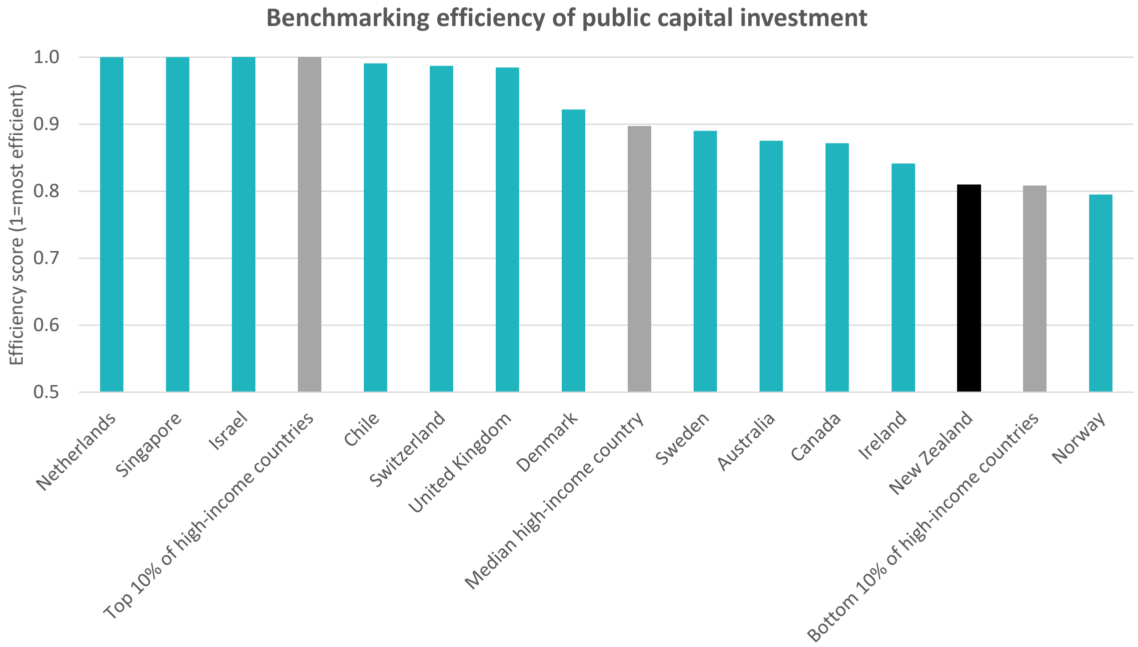
Figure 6: Public investment trends in New Zealand and other high-income countries, 1980–2019



Source: New Zealand Infrastructure Commission calculations, adapted from Infrastructure Commission (2021a).

While our spending measures up, a simple benchmarking analysis, summarised in Figure 7, suggests that New Zealand is among the least efficient high-income countries at delivering infrastructure. Our relatively low efficiency rating is determined partly by geography – larger, more densely populated countries tend to be more efficient at providing infrastructure – and partly by the quality of our infrastructure investment decision-making.

Figure 7: Comparing the efficiency of infrastructure investment in high-income countries



Source: New Zealand Infrastructure Commission (2021a).

Further work is needed to extend these comparisons, where possible, and develop a more detailed understanding of where and why our infrastructure outcomes lead or lag our peer countries.

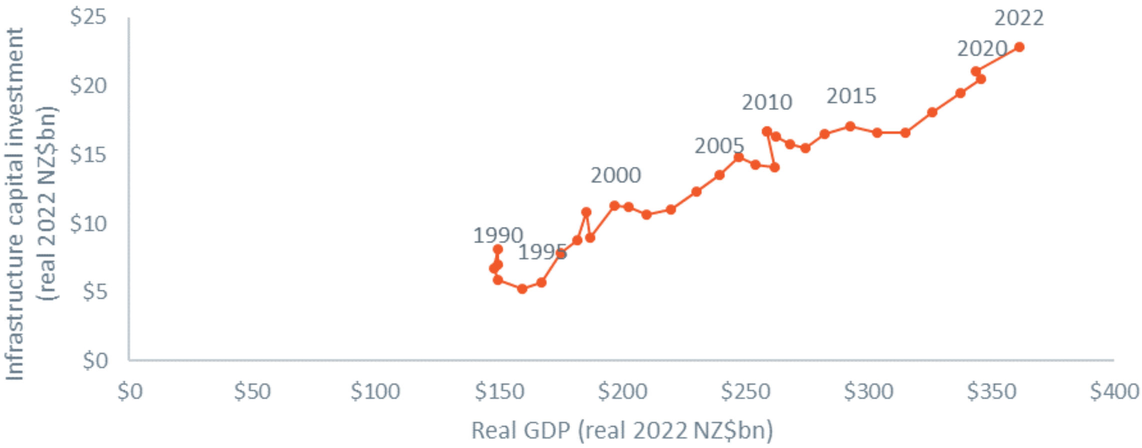
Theme 2: What are we willing to pay for infrastructure?

When we earn more, we spend more…

The dollar value of infrastructure investment has risen strongly over the last generation. Between 2002 and 2022, New Zealand's inflation-adjusted infrastructure investment doubled from $11.1 billion to $22.9 billion.

As Figure 8 shows, rising infrastructure investment is closely associated with rising GDP. When we earn more as a country, we spend more on infrastructure.

Figure 8: Economic growth and infrastructure investment in New Zealand, 1990–2022



Source: Adapted from New Zealand Infrastructure Commission (2024a).

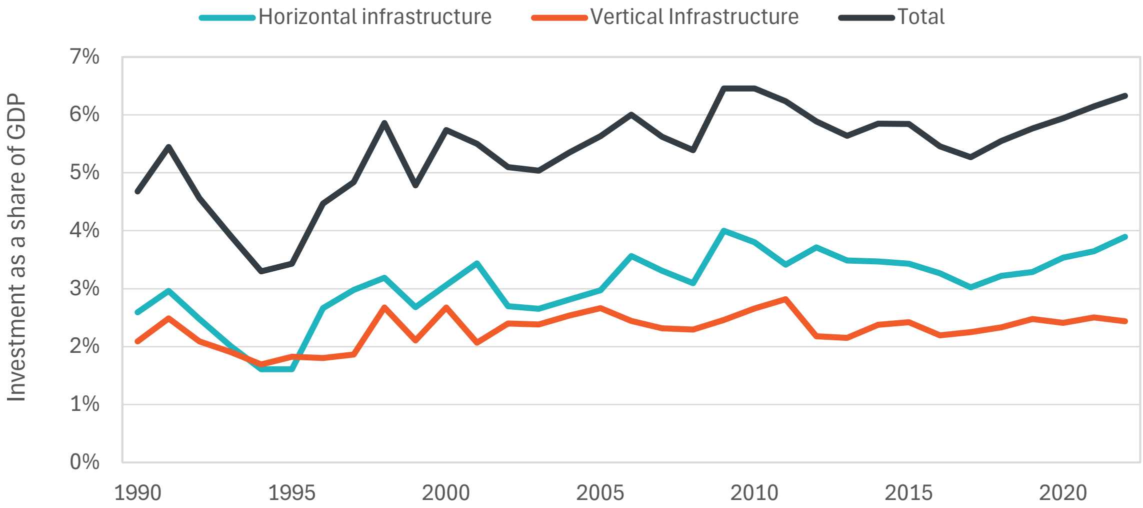
… leading to a constant share of GDP invested in infrastructure

Because infrastructure investment and economic activity have grown in parallel, the share of our GDP spent on infrastructure investment has been reasonably stable for the last generation.

Figure 9 shows that, over the last 20 years, the share of GDP invested in all types of infrastructure has ranged from 5.0% to 6.5% of GDP, with an average of 5.8%.

There have been periods where we have spent slightly more or less within this range, and shifts in what we are investing in, but infrastructure investment has not been trending upwards or downwards as a share of GDP.

Figure 9: Share of GDP invested in infrastructure in New Zealand, 1990–2022



Source: New Zealand Infrastructure Commission (2024a).

Current trends can help us understand our future choices

Our current investment rate reflects the balance between the benefit that we perceive from additional investment, and the cost of that investment, whether it is paid through user charges, taxes, rates, or debt that needs to be repaid in the future.

Right now, we seem to be willing to spend around 5.8% of our GDP – roughly one out of every seventeen dollars we earn as a country – on all types of infrastructure investment. This figure can be broken down by type of infrastructure or whether it is central government infrastructure, local government infrastructure, or commercial/private sector infrastructure.[5]

However, only a portion of the money we spend is available to build new or improved infrastructure. In the long term, most of this money will be required to renew or replace infrastructure that is reaching the end of its life. We can use depreciation on infrastructure as a rough estimate of how much we will have to spend renewing or replacing infrastructure.

Table 1 summarises current trends in capital investment and depreciation for central government infrastructure, local government infrastructure, and commercial/private sector infrastructure. We find, for instance, that central government has consistently invested around 2.5% of GDP on infrastructure over the last 30 years, while incurring depreciation costs equal to around 1.5% of GDP. These estimates cover all types of central government infrastructure – from state highways to schools to defence estate.

[5] Including commercial infrastructure providers that are publicly owned, like Transpower and many electricity distribution businesses.

Table 1: How much money we have for infrastructure investment, under business-as-usual assumptions

Sector of ownership	Average GFKF as a share of GDP, 2003–2022	Average CFK as a share of GDP, 2003–2022
Central government	2.5% *(min-max range: 2.1%-2.9%)*	1.5% *(min-max range: 1.4%-1.6%)*
Local government	1.4% *(min-max range: 1.0%-1.6%)*	0.6% *(min-max range: 0.4%-0.6%)*
Commercial / private	1.9% *(min-max range: 1.9%-2.3%)*	1.2% *(min-max range: 1.1%-1.3%)*
Total infrastructure	5.8% *(min-max range: 5.0%-6.5%)*	3.3% *(min-max range: 3.0%-3.5%)*

Source: Adapted from New Zealand Infrastructure Commission (2024a).

What will we be willing to spend on infrastructure in the future?

The figures in Table 1 provide a starting point for analysis of what we might be willing to spend on infrastructure over the next 30 years. If nothing else changes, then it would be reasonable to assume that we will continue to spend an average of around 5.8% of GDP on infrastructure.

To give a sense of scale, New Zealand's GDP is currently $410 billion (year ended March 2024). After accounting for depreciation (3.3% of GDP), which indicates roughly how much is needed to renew and replace existing infrastructure that is wearing out and reaching end of life, this leaves around $10 billion for new or improved infrastructure. While this is a lot of money, given how extensive and valuable our networks are, it is not big enough to avoid thinking about trade-offs.

Long-term economic forecasts from the Treasury's *Budget Economic and Financial Update and Long Term Fiscal Model* (Treasury, 2021) can be used to understand how rapidly the economy will grow under baseline assumptions. Based on these sources, New Zealand's GDP is projected to rise to $697 billion in 2054, in real 2024 New Zealand dollars.[6] A baseline projection is therefore that infrastructure investment will rise in line with economic growth.

However, there are other areas we need to explore and research.

We need to study other factors that may result in us spending more or less than this baseline projection. One thing to consider is how funding tools like tolling could be used to generate additional revenue to help pay for new investment (New Zealand Infrastructure Commission, 2024b). If these are widely used, we may be able to spend more than the baseline projection.

Another factor to consider is how other fiscal and economic pressures will affect our willingness and ability to invest in infrastructure. For instance, population ageing is expected to place pressure on central government budgets as fewer people are paying taxes and more people are receiving superannuation and using healthcare services (Treasury, 2021). This may place downward pressure on public infrastructure investment.

Finally, infrastructure can improve economic productivity, provided that the cost of investment is not excessive (Bom & Ligthart, 2014; Cubas, 2020; New Zealand Infrastructure Commission, 2021a; Pritchett, 2000). There is a need to consider whether choices about how to invest will affect the size of our economy and hence how much money we have for investment.

[6] This estimate is based on splicing together current medium-term forecasts from the *Budget Economic and Fiscal Update* with long-term economic growth projections from the *Long Term Fiscal Model*.

Theme 3: Where or how should we invest in the future?

Investment demands reflect both supply and demand factors

In this section, we define and describe a set of general factors that drive infrastructure expenditure. These are a mix of demand-side and supply-side factors that can change over time, leading to increased or decreased demand for investment.[7]

As discussed in the introduction, the purpose of infrastructure investment is to provide durable assets that support the provision of infrastructure services. Physical infrastructure is a means to an end, rather than an end in itself. The need for infrastructure investment reflects people's demand for the services that infrastructure provides. For instance, if we want to continue providing infrastructure services to an existing population, we need to spend money renewing or replacing the infrastructure we already have.

However, the need for infrastructure investment also reflects supply conditions. For instance, if infrastructure construction costs are rising over time, then we will need to spend more money to meet our demand for infrastructure services or look for other options to provide services.

Eight factors that can drive changes in spending

Table 2 summarises eight investment drivers that we have identified, briefly describes them, and provides a simple example of how each factor may affect infrastructure spending requirements. We identified and categorised these factors based on a review of our legislation,[8] work previously completed for the New Zealand Infrastructure Strategy (Sense Partners, 2021), and the broader international literature on long-term infrastructure needs and factors that shape demand for infrastructure (Fay & Yepes, 2003; Glaeser & Poterba, 2021; Infrastructure Australia, 2019; National Infrastructure Commission, 2023; Oxford Economics & Global Infrastructure Hub, 2017).[9]

In this section, we briefly explain each investment driver and summarise key information on emerging challenges and future trends that are relevant for analysing them. We have not attempted to quantify the relative importance of each of these drivers for different infrastructure sectors, although they are not necessarily equally important.

In this review, we identify **several areas where further work is needed to understand and analyse future infrastructure investment demands.** This includes understanding how demographic factors like location and cultural background affect infrastructure needs, how the costs of responding to natural hazards may change in the future, and how decarbonising the economy will affect infrastructure investment demand.

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[7] Our approach is conceptually related to the approach taken by Fay and Yepes (2003) and Oxford Economics and Global Infrastructure Hub (2017), who quantify future infrastructure spending demands based on a set of 'reduced form' econometric models that incorporate both supply and demand factors.

[8] Section 11 of the Infrastructure Commission/Te Waihanga Act 2019 states that 'When identifying or advising on current and future infrastructure needs, or the priorities for infrastructure, the Commission [...] (b) must have regard to long-term trends that impact on, or are impacted by, infrastructure, including (but not limited to)— (i) changes to **demographics**; and (ii) the emergence and availability of new **technology**; and (iii) matters relating to the mitigation of the effects of **climate change** (including through reducing emissions of greenhouse gases) and adapting to the effects of climate change; and (c) may have regard to **any other matters the Commission considers relevant**.'

[9] Other resources include: Canada's IFSD report: https://www.ifsd.ca/en/infrastructure; ICE EBI programme: https://www.ice.org.uk/news-insight/policy-and-advocacy/enabling-better-infrastructure; OECD Infrastructure Toolkit: https://infrastructure-toolkit.oecd.org/

Table 2: Summary of infrastructure investment drivers

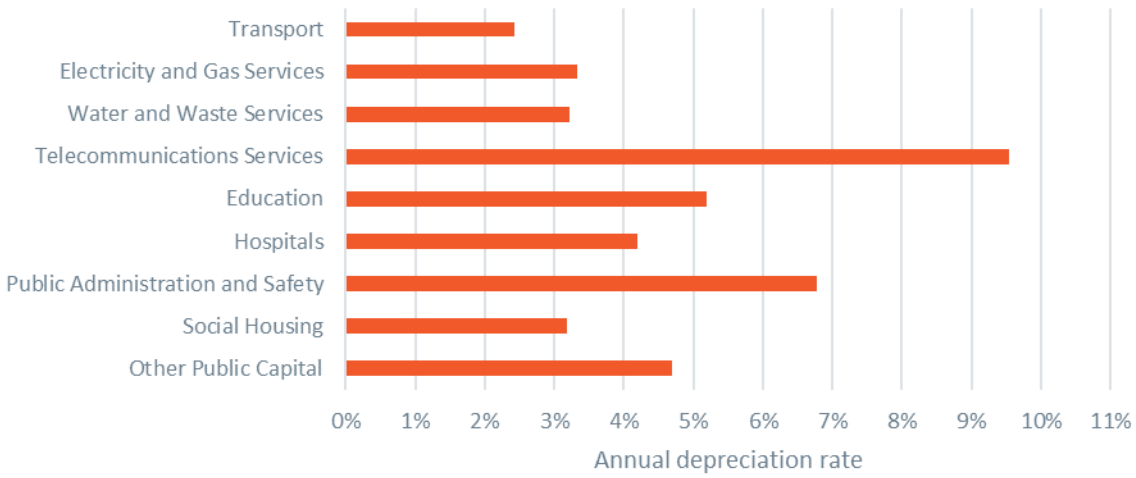
Driver	Description	Example
Renewal of existing infrastructure	As existing infrastructure wears out, there will be demand to renew or replace assets to ensure that services are still available	Replacement or reconstruction of a hospital wing that is approaching the end of its life, but which is still needed to provide healthcare services
Population growth and demographic change	Changes in the size, age structure, or other characteristics of the population lead to changes in the quantity of infrastructure that is demanded	Construction of a new school to serve an increasing number of school-aged children in an existing suburb
Economic development and changing standards	Economic development and increasing incomes cause people to use infrastructure more, demand higher-quality infrastructure, or demand better mitigation of the negative environmental and social impacts of infrastructure	Rising incomes cause an increase in demand for air travel and hence lead to demand to expand an existing airport terminal
Resilience to natural hazards	To ensure that existing infrastructure continues to provide services, there is a need to ensure that it is resilient to natural hazards	Electricity distribution lines are insured against natural disasters, and may be strengthened where this would reduce premiums
Decarbonising our economy	To meet international commitments to reduce net carbon emissions to zero by 2050, low-emission infrastructure must be available where it is demanded	Construction of a new wind farm that substitutes for existing coal-fired electricity generating capacity
Technology change	New technologies can cause people to demand new types of infrastructure, to use existing infrastructure in different ways, or reduce the need for infrastructure	Computers and the internet lead to increased demand for better telecommunications infrastructure
Construction price inflation	Rising prices for infrastructure increase the amount that must be spent to deliver infrastructure outcomes, although people will respond in part by reducing demand for infrastructure	Supply chain disruptions lead to higher construction prices – infrastructure providers respond by raising prices and also deferring some investment
Shortage of existing infrastructure	The capacity or quality of existing infrastructure falls short of expected standards, leading to demand to improve it to expected standards	An economic crisis resulted in cuts to public infrastructure maintenance budgets, and now there is a need for catch-up investment in asset renewal

Renewal of existing infrastructure

As long as we expect to continue to need infrastructure, we need to spend enough to keep it in good condition. If we do not, people will lose access to infrastructure or experience declining levels of service.

The more infrastructure we have, the more we will have to spend to maintain and renew it. The types of infrastructure that we have also matters. Figure 10 shows that depreciation rates, which measure how fast assets are wearing out or becoming obsolete, vary for different infrastructure sectors. They are lowest for long-lived infrastructure like transport, electricity and gas, water and waste, and social housing, and highest for telecommunications, reflecting the rapid rate of technological change in this area. Depreciation rates for education, hospitals, and other public capital are somewhere in the middle.

Figure 10: Annual depreciation as share of asset value, by infrastructure sector, 1990–2022



Source: New Zealand Infrastructure Commission (2024a). Depreciation is measured as 'consumption of fixed capital', or the annual decline in the value of fixed assets due to physical wear and tear, obsolescence due to technological change, or normal accidental damage, but excluding extraordinary events such as natural disasters.

Meeting this investment demand requires significant resources. Depreciation statistics suggest that renewal investment will account for most infrastructure investment demand in the long run.

Over the last decade, for every $10 we spent on new infrastructure, almost $6 of existing infrastructure wore out (New Zealand Infrastructure Commission, 2024a). If we want to maintain our existing infrastructure for future generations, that's roughly how much we need to spend on renewal investment in the long term.

This doesn't necessarily mean that we need to renew everything on a 'like for like' basis. Replacement infrastructure can be built to a higher standard, helping to meet other investment demands like population growth or rising quality expectations. And technology change sometimes makes it possible to replace obsolete infrastructure with new technologies that are cheaper to build or operate.

Population growth and demographic change

As our population grows and changes, we often need to increase the capacity of infrastructure networks or provide different types of infrastructure to accommodate greater usage.

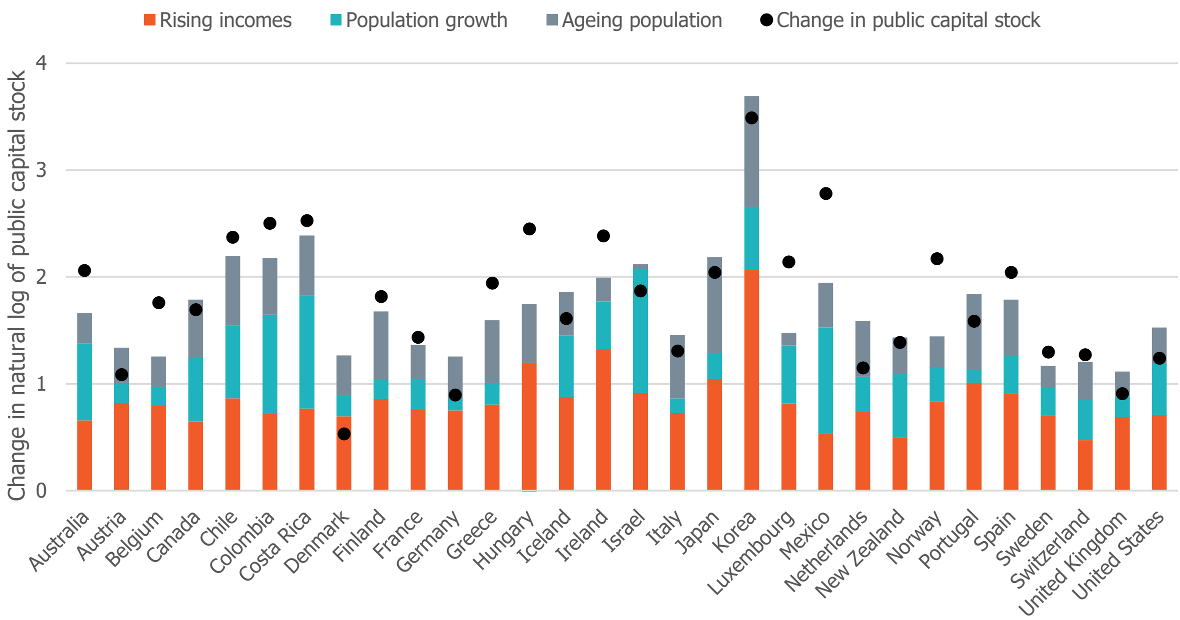
Demographics and demand for infrastructure investment

Population growth and ageing play an important role in overall demand for infrastructure investment in OECD countries. In Appendix 1, we analyse the long-term impact of economic growth and demographic change on public infrastructure stocks in 30 OECD countries over the 1960–2019 period. We show that a 1% increase in incomes is associated with a 0.6% increase in the value of public infrastructure, a 1% increase in population is associated with a 0.8% increase in public capital, and an ageing population is associated with more public capital.

Different countries experienced different economic and demographic trends over this period, and this has affected how much infrastructure they have built. Figure 11 shows that observed growth in public infrastructure over the period (the black dots) is explained by the estimated impact of rising incomes, population growth, and ageing population (the coloured bars).

In New Zealand, we estimate that population growth accounted for 41% of the growth in public infrastructure stocks and population ageing accounted for 24% from 1960 to 2019. Income growth, which we discuss next, accounted for the remaining 35%.

Figure 11: Decomposing drivers of growth in public capital stocks in OECD countries, 1960–2019



Source: New Zealand Infrastructure Commission analysis of data from IMF (2022) and World Bank (2024), using regression coefficients from Model 2, fixed effects panel model from Table 6. Note: Log point changes can be converted to percentage changes as follows: Percent change = exp(log change)-1.

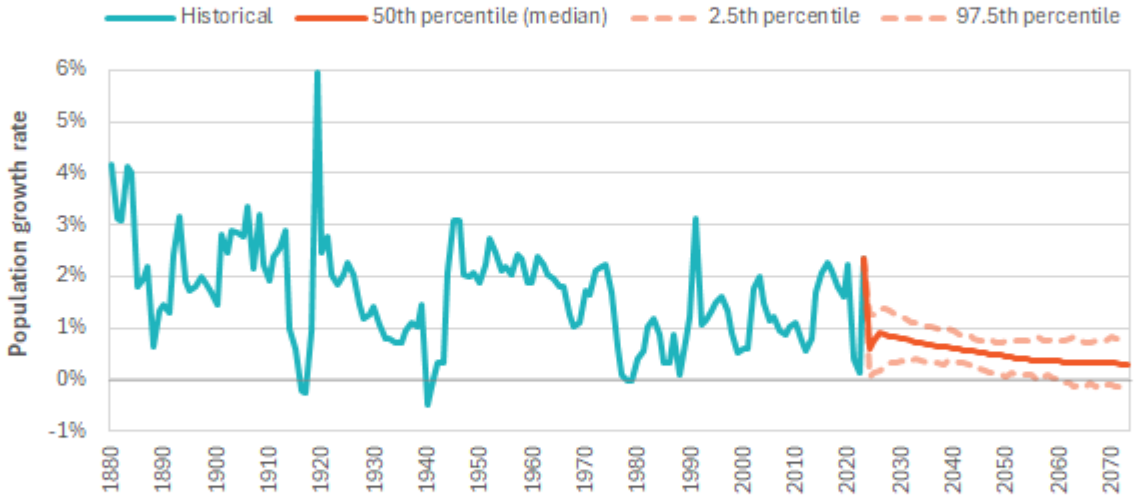
In addition to population size and age structure, other demographic factors like location (New Zealand Infrastructure Commission, 2024c) and people's cultural background and beliefs (León & Miguel, 2017) also affect patterns of infrastructure use. Where people live can also affect how costly it is to serve them with infrastructure (Carruthers & Ulfarsson, 2003; Centre for International Economics, 2015; Hortas-Rico & Solé-Ollé, 2010; Infrastructure Victoria, 2023; NSW Productivity Commission, 2023). There would be value in further work to understand these issues in the New Zealand context.

Past and future demographic trends in New Zealand

New Zealand's demographic future is likely to be different than the past in several ways. The first is that population growth rates are projected to decline in the long term, driven by declining fertility rates and slowing growth in life expectancy. In the short to medium term, this can be offset (or exacerbated) by migration trends, which are much more volatile.

Figure 12 shows that New Zealand has experienced a long-term trend towards declining population growth rates, although population growth rates can vary significantly from year to year. This is part of a larger global trend towards declining population growth rates. As this happens, it may reduce growth pressures on our infrastructure networks.

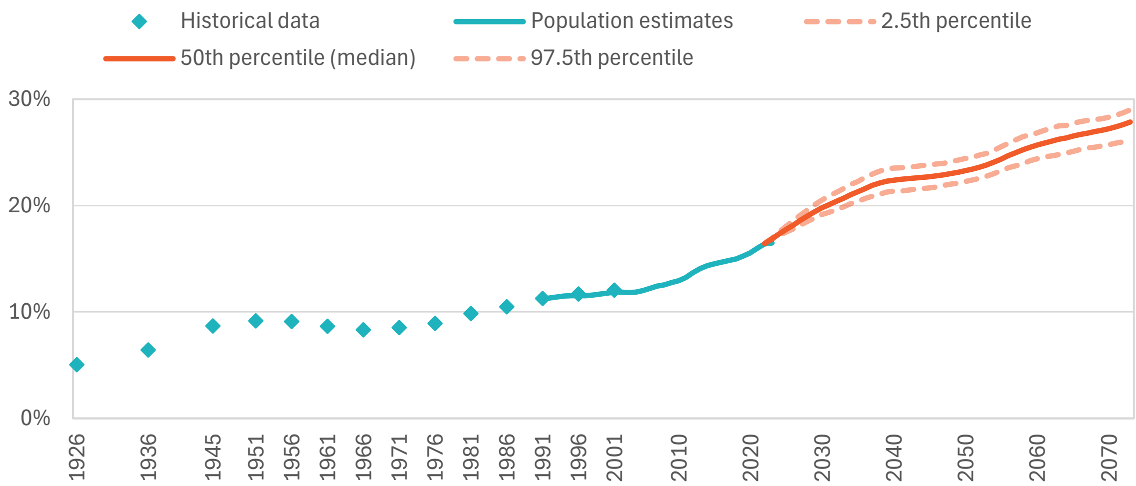
Figure 12: New Zealand's historical and projected population growth rates, 1880–2072



Source: New Zealand Infrastructure Commission analysis of NZIER Data1850, SNZ National Population Projections.

The second difference is that the composition of the population will change. New Zealand's population is projected to get older, more ethnically diverse, and more concentrated in fast-growing cities like Auckland, Christchurch, and Tauranga (Spoonley, 2021). For instance, Figure 13 shows that the share of people aged 65 or older is projected to nearly double over the next five decades. As this happens, it will change the mix of infrastructure that we need.

Figure 13: New Zealand's historical and projected share of population aged 65 years and older, 1926–2073



Source: New Zealand Infrastructure Commission analysis of SNZ LTDS, population estimates, and population projections.

Demographics and future infrastructure needs

These demographic trends have implications for our future infrastructure investment needs. As fertility rates decline, the share of our population growth from natural increases is forecast to decline over time. Future population growth will be increasingly driven by migration, which is volatile and hard to predict. Migration to New Zealand is also not evenly distributed geographically, as most migrants tend to settle in our larger cities. This means that although we know that population growth will continue to drive demand for more infrastructure, how much and where could be more difficult to plan for.

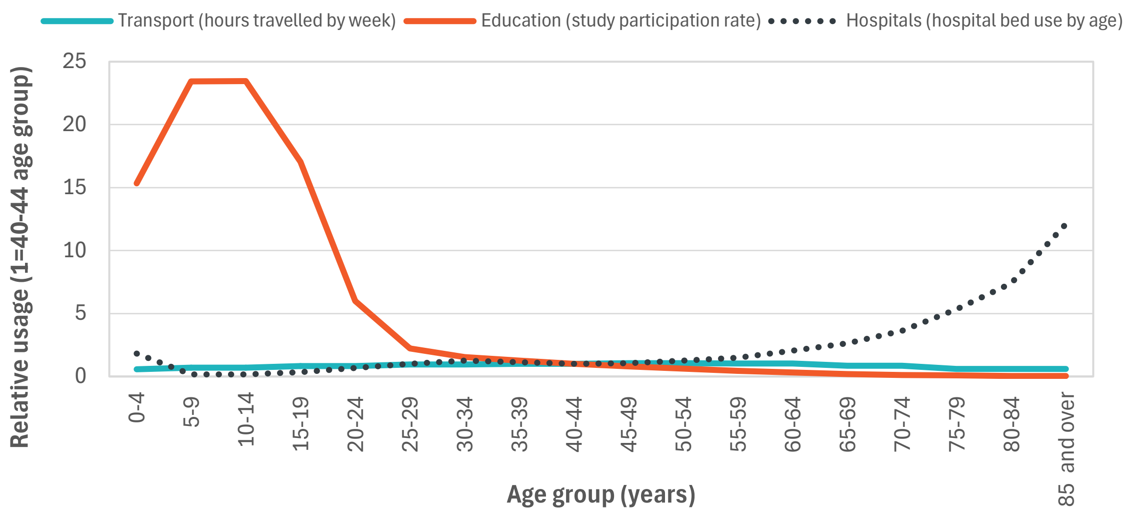
When there is uncertainty about where and whether infrastructure will be needed, it may not be prudent to invest ahead of demand. Instead, it may be better to take low-cost steps to 'future proof' our ability to invest in the future, like buying sites that could be used for infrastructure if and when it needed (New Zealand Infrastructure Commission, 2023a).

This being said, Figure 13 highlights that our population is certain to get older in coming decades, regardless of how rapidly it grows. So, while it may be difficult to predict how much infrastructure we should have to meet a growing population, we can be more certain that infrastructure investment will have to cater to an ageing population.

Future demographic changes will affect not only how much we invest in infrastructure in the future, but what types of infrastructure we need to invest in. This is because people use different types of infrastructure as they age.

Figure 14 shows relative infrastructure usage by age group. Both young and old people travel slightly less than middle-aged people and tend to travel to different places. There are more dramatic differences in usage of hospitals (which are used much more by older people) and schools and universities (which are used mainly by younger people). This means that, as our population ages, the relative demand for transport, health, and education infrastructure will change.

Figure 14: Relative infrastructure usage by age group in New Zealand



Source: New Zealand Infrastructure Commission analysis of Household Travel Survey data (Ministry of Transport, 2023), Census study participation rate data, Education Counts data, and NZIER (2023) hospital usage estimates.

Economic development and changing standards

As we grow wealthier, our expectation of infrastructure quality tends to increase. We demand infrastructure that is more comfortable and convenient to use, that is safer to build and use, and that reduces negative impacts on the environment and nearby communities. Over time, infrastructure design standards are updated to reflect rising expectations.

Economic development is a key long-term driver of rising quality expectations. At low income levels, people tend to be willing to pay for basic infrastructure services, like unpaved roads, minimum provision of safe drinking water, and basic primary school infrastructure. As people's incomes rise, they tend to be willing to pay for better infrastructure, like paved roads that are safer to drive on, better wastewater treatment, and tertiary education.

Changes to the structure of the economy also affect the type and quality of infrastructure that is demanded. For instance, an economy focused on agricultural and mining production may need more regional transport infrastructure and port infrastructure, while an economy focused on finance and professional services may need more urban public transport and telecommunications infrastructure.

Because infrastructure tends to be a 'necessity' rather than a 'luxury' good, we tend to spend a smaller share of incomes on infrastructure services as we get wealthier. In New Zealand, we estimate that a 1% increase in household income is associated with a roughly 0.4% to 0.6% increase in spending on network infrastructure (New Zealand Infrastructure Commission, 2024d).

Table 3 summarises international evidence showing that demand for network infrastructure is generally inelastic to income, although outcomes vary by sector. For example, the elasticity range of 0.2 to 0.9 for residential energy indicates that a 1% increase in income is expected to increase energy use by 0.2% to 0.9%. While income elasticities for network infrastructure are widely studied (Gallet & Doucouliagos, 2014; Havranek & Kokes, 2015; Holmgren, 2007; Sebri, 2014; Zhu et al., 2018), there is less evidence on demand for health and education infrastructure (Farag et al., 2012; Freeman, 2003; Matsuda et al., 1999; Schmidt & McCarty, 2008).

Table 3: Income elasticities of demand for network infrastructure

Sector	Subsector	Demand increase due to a 1% increase in income
Energy	Residential energy	0.2% to 0.9%
	Industrial energy	0.5% to 0.7%
	Whole economy	0.2% to 0.8%
Transport	Passenger land transport	0.2% to 1.1%
	Air transport	1.3% to 2.4%
Telco	Digital	~0.8%
Water and waste	Water	0.2% to 0.3%
	Waste	0.2% to 0.7%

Source: UK National Infrastructure Commission (2018).

As incomes rise, expectations for mitigation of the negative impacts of infrastructure also increase. People with higher incomes tend to be willing to pay more for health and safety improvements (Banzhaf, 2022; Viscusi & Masterman, 2017) and improvements to environmental quality, like better air quality and water quality (Barbier et al., 2017; Tyllianakis & Skuras, 2016). This affects how infrastructure is designed and hence what it costs (Brooks & Liscow, 2019).

Resilience to natural hazards

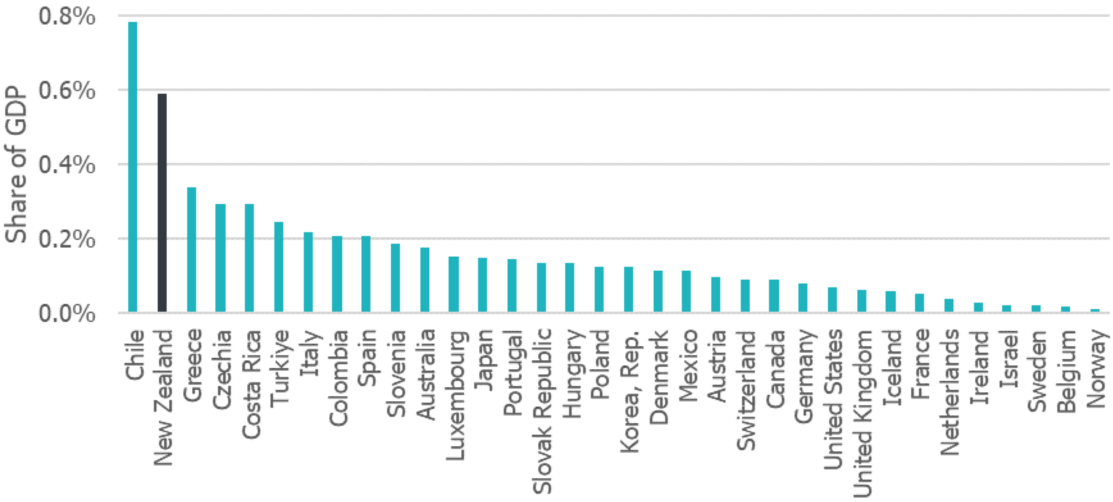
In addition to routine maintenance and renewal, we need to respond to natural hazards that damage infrastructure. This is needed to prevent people from losing access to infrastructure or experiencing declining levels of service following an event.

Unlike renewal investment demand, which is reasonably predictable over long periods of time, natural hazard damage is hard to forecast. This is because a large share of total natural disaster damage is caused by a small number of major events, like large earthquakes or severe tropical storms, and the timing of these events is not certain (Pisarenko & Rodkin, 2014). For example, earthquake modelling suggests that there is a 75% probability of a major Alpine Fault earthquake in the next 50 years, which is likely but not certain to occur (AF8, 2023).

New Zealand is highly exposed to natural disasters. Figure 15 shows that, over the 1990–2022 period, New Zealand experienced some of the highest reported damages from natural disasters out of any OECD countries. Damage to infrastructure is a subset of total damages.

Investment demands arising from natural hazards are hard to quantify because there are several ways to respond to hazards (Hallegatte et al., 2020). One option is to buy insurance policies or self-insure against risk, which means smoothing the expected cost of damages over time. Another option is to proactively invest in more resilient infrastructure to reduce risks. A third option is to do nothing and expect to retreat from damaged infrastructure after an event.

Figure 15: Annual expected natural disaster losses in OECD countries, 1990–2022



Source: New Zealand Infrastructure Commission analysis of EM-DAT database (Centre for Research on the Epidemiology of Disasters, 2024) and World Bank GDP data, using Lloyd's approach (Centre for Economics and Business Research, 2012). As reporting of natural disaster damage costs is variable even among high-income countries, these figures should be treated with some caution (Jones et al., 2022).

Our awareness of natural hazards is changing over time as scientific understanding improves. For instance, the 2022 update of the National Seismic Hazards Model resulted in large increases in estimates of the likelihood and severity of ground shaking throughout New Zealand (Gerstenberger et al., 2022). A further challenge is that climate change is intensifying hazards related to extreme weather and sea level rise (Newman & Noy, 2023). The full extent of these costs is not yet known (Clarke et al., 2022).

Decarbonising our economy

As outlined in the *Infrastructure Strategy*, there is a need to reduce net greenhouse gas emissions by 2050[10] to avoid the most severe adverse effects of climate change. This will have implications for infrastructure, as building, maintaining, operating, and using infrastructure can either generate or abate greenhouse gas emissions.

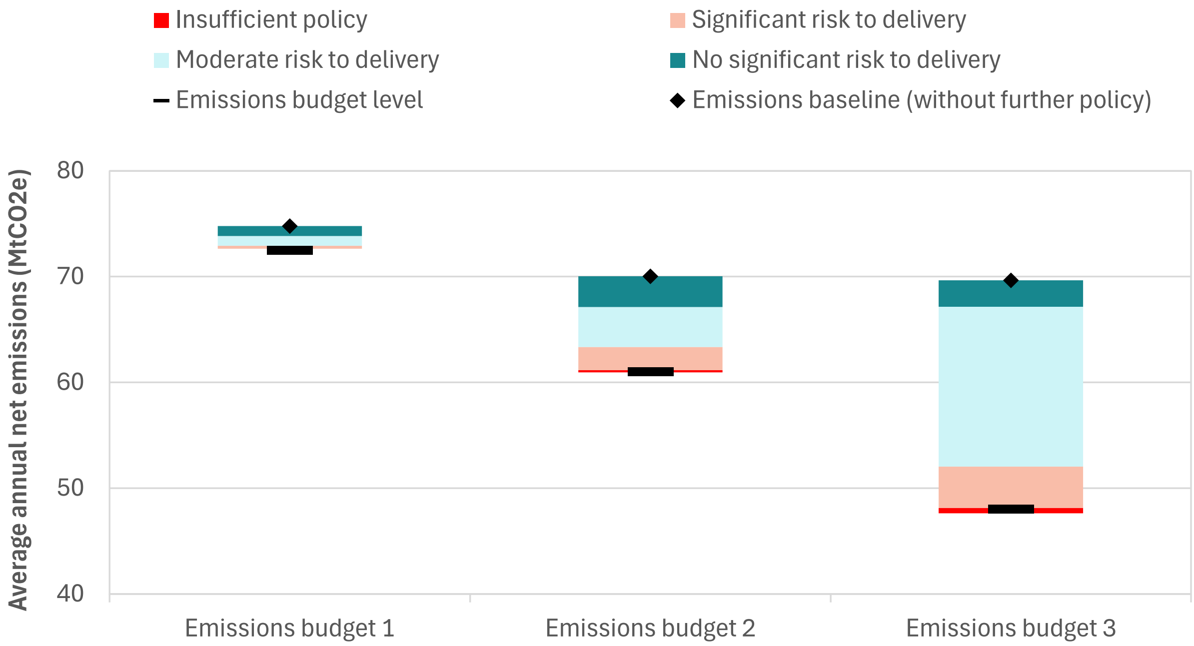
New Zealand has high per-capita emissions relative to most other OECD countries. Emissions have fallen slightly since their 2006 peak, but not as rapidly as in our peer countries. Since 2005, greenhouse gas emissions associated with electricity generation and waste infrastructure have declined but land transport emissions have risen (Ministry for the Environment, 2024b).

We have committed to emissions reduction targets under the 2015 Paris Accord and the 2019 Climate Change Response (Zero Carbon) Act. These targets require us to reduce emissions over a series of five-yearly emissions budgets, reaching net zero emissions for most gases by 2050. Our domestic emissions targets currently fall short of our Paris Accord reductions targets, meaning that we expect to buy overseas offsets to cover the gap (Treasury & Ministry for the Environment, 2023).

Our targets will not be met without policy intervention to discourage high-emission activities and incentivise low-emission activities and carbon sinks. There are several approaches to achieve this, such as pricing carbon emissions, as in New Zealand's Emissions Trading Scheme (ETS), using regulation to incentivise emission reduction, or increasing the supply of low-emission alternatives.

A recent Climate Commission monitoring report highlighted moderate to significant risks to achieving emissions budgets in the 2030s (Figure 16). This is consistent with Ministry for the Environment's (2024a) assessment of current emissions reduction plans. Moreover, if the price of overseas emissions offsets is higher than expected, then further domestic emissions reductions may be needed.

Figure 16: Assessed risks to achieving future emissions budgets



Source: Climate Change Commission (2024).

[10] The Climate Change Response Zero Carbon Amendment Bill includes New Zealand's 2050 emissions target. The 2050 target requires New Zealand to reach and maintain net zero emissions of all greenhouse gases other than biogenic methane, and to reduce biogenic methane emissions by 24-47% from 2017 levels.

Decarbonisation is likely to increase demand for investment in low-emission infrastructure, such as renewable energy generation and urban public transport, and reduce demand for investment in high-emission infrastructure, like coal power generation and urban roads. The required cost of these investments to achieve required reductions will be lower if there is an enabling planning and consenting framework for low-emission infrastructure that enables these options to be built without excessive cost and delay (Sapere, 2023).

Technology change

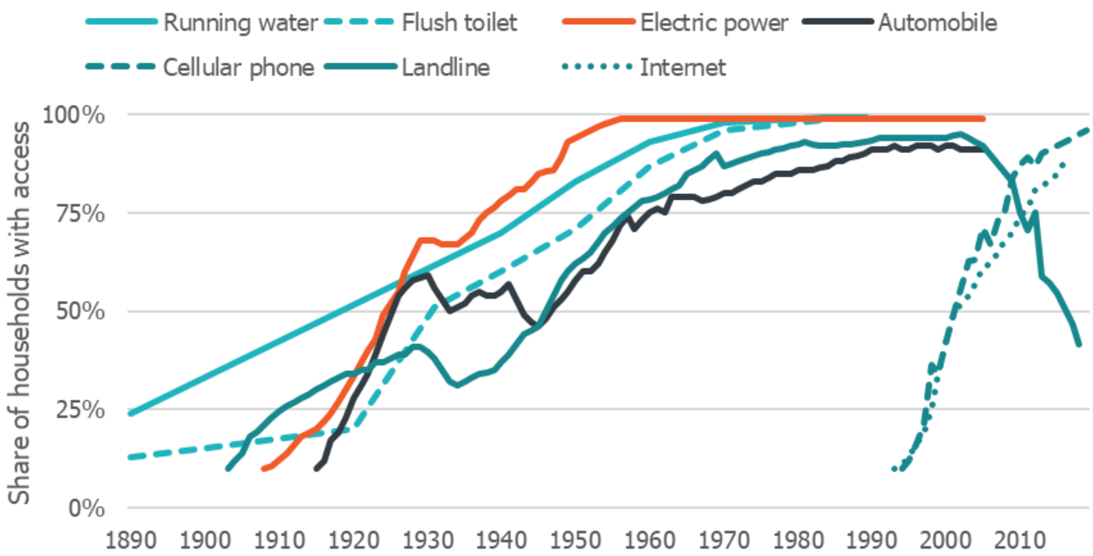
Technology change can generate demand for new types of infrastructure, change demand for existing infrastructure networks, or reduce the cost to provide infrastructure. The development of new technologies, from the steam engine to the internal combustion engine to electricity to the internet, has often created a need to invest in new types of infrastructure (Goldsmith, 2014).

Significant technological advances follow scientific advances and investment in research and development. However, technology change is hard to forecast. We can identify significant breakthroughs in retrospect, for instance by looking at patents that significantly influenced subsequent technology development (Kelly et al., 2021). An example is Elisha Graves Otis's 1861 patent for the elevator, which enabled skyscraper construction and larger, denser cities that have different infrastructure needs (Ahlfeldt et al., 2023). But it can be difficult to tell in advance which new discoveries will have a large impact.

A further challenge is that there can be significant time lags between initial innovations and widespread adoption and uptake of new technologies (David, 1990). For instance, electric power was invented in the late 1800s but not widely adopted until the 1920s.

What we know is that major new technologies that generate demand for new types of infrastructure investment come along infrequently, but have transformative impacts when they arrive (Gordon, 2016). Figure 17 shows adoption of seven major infrastructure technologies over time in the United States. These technologies reached widespread adoption over a multi-decade period, requiring significant new infrastructure investment and in some cases cost savings due to withdrawal of existing infrastructure (such as the impact of mobile phones on landline demand).

Figure 17: Diffusion of new infrastructure technologies in the United States, 1890–2019



Source: Our World In Data.[11]

[11] https://ourworldindata.org/grapher/technology-adoption-by-households-in-the-united-states

New infrastructure technologies tend to reach widespread adoption because they are significantly better or cheaper than existing options. In the past, users have been willing to pay for these benefits. While there can be challenges financing the initial development of an entirely new network, revenues from users should be sufficient to pay back the up-front costs (PwC NZ, 2024).

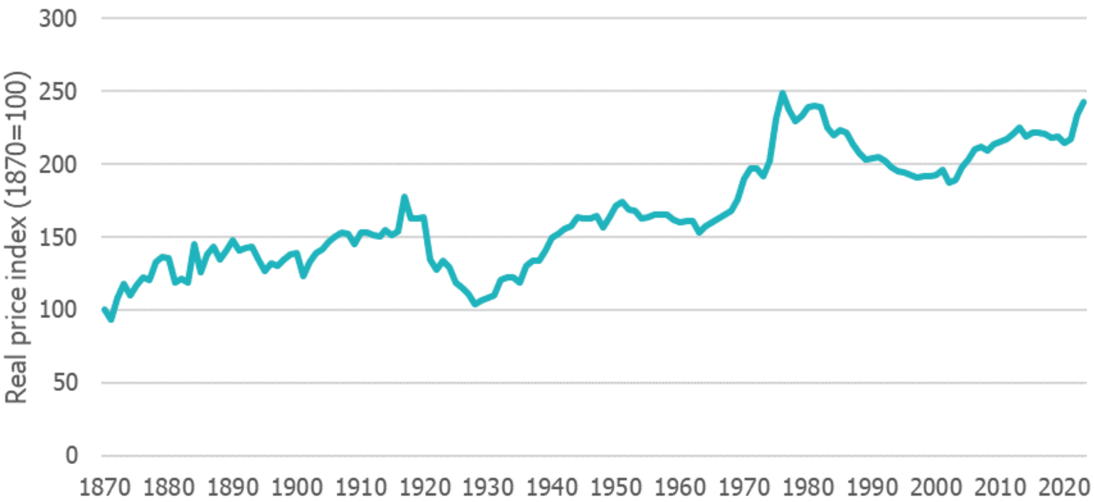
Construction price inflation

The cost to build and maintain infrastructure has tended to rise faster than prices elsewhere in the economy. Over time, this means that we need to spend more to keep up with other infrastructure investment demands. We can offset this, to a degree, by choosing non-built solutions or making better use of existing infrastructure.

Infrastructure tends to get more expensive in the long run because productivity growth tends to be slower in construction than in other parts of the economy (New Zealand Infrastructure Commission, 2022a). Industries with faster productivity growth can produce more using fewer resources, which allows them to keep costs down. This is known as the 'Baumol effect' and it has been observed empirically in high-income countries including New Zealand (Baumol, 1967; Hartwig, 2011; Nordhaus, 2008). In the short run, price fluctuations for construction labour and materials can also have a significant impact on construction costs (New Zealand Infrastructure Commission, 2023c), and workforce capacity constraints can limit how much investment can be completed (New Zealand Infrastructure Commission, 2023b).

Figure 18 shows that infrastructure construction prices have increased relative to prices elsewhere in the economy over the last 150 years, although there are some periods where infrastructure construction has gotten cheaper in relative terms. Over the whole period, we estimate that the cost to build infrastructure has risen 2.5 times faster than prices elsewhere in the economy.

Figure 18: Inflation-adjusted infrastructure price index for New Zealand, 1870–2023



Source: New Zealand Infrastructure Commission analysis of data from SNZ National Accounts and Mulcare (1993).

Different types of infrastructure may experience different productivity and price trends. In general infrastructure projects that are simpler and more standardised have stronger potential for productivity and price improvements than complex, customised projects (Flyvbjerg & Gardner, 2023; Malhotra & Schmidt, 2020).

For example, in recent decades wind farms have tended to get cheaper over time as turbine designs and manufacturing techniques improve, while rail tunnels have tended to get more expensive over time, although this can be offset by gaining more experience in tunnelling (New Zealand Infrastructure Commission, 2022b).

Shortages of existing infrastructure

If we have a shortage of existing infrastructure, due to past under-investment or mis-investment, we may need to invest more or change our mix of investment to address this shortage.

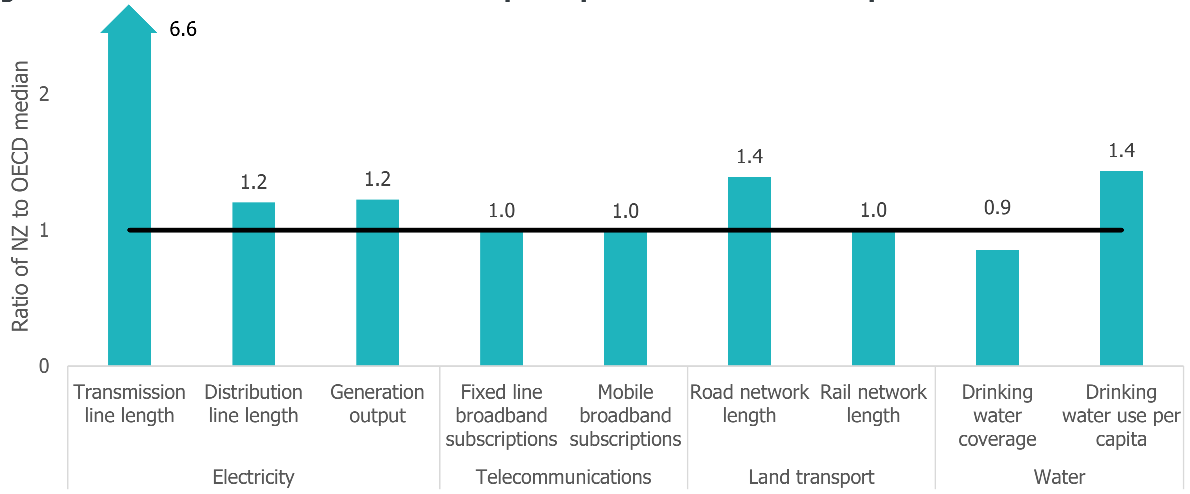
Infrastructure shortages can arise if investment is not responsive to demand. This can happen if infrastructure funding is constrained, for instance if users or beneficiaries do not have good ways to pay more for new or improved infrastructure that they would value, or if infrastructure planning is unresponsive to shifts in demand. Unresponsive planning can also result in a surplus of infrastructure relative to demand.

It can be challenging to measure existing infrastructure shortages. Shortages could reflect a lack of capacity in infrastructure networks, leading to excessive congestion, or infrastructure that is in poor condition, leading to user dissatisfaction. Users can also respond to shortages in many ways, including adopting alternative options like off-grid electricity generation.

Benchmarking against peers can help to identify shortages in the capacity, availability, and quality of infrastructure relative to demand. New Zealand appears to lag other high-income countries on a broad infrastructure quality measure, despite spending an above-average amount on infrastructure investment (New Zealand Infrastructure Commission, 2021a). This indicates that perceived shortfalls may be due to poor efficiency of spending, rather than a lack of investment.

Figure 19 compares the physical quantity of infrastructure per capita in New Zealand, relative to the median OECD country. While these are simple comparisons, they suggest that we have a typical amount of infrastructure for a high-income country. The outliers are electricity transmission lines per capita, where we have the most in the OECD, and the share of households with access to piped drinking water, where we are the lowest in the OECD.

Figure 19: Size of infrastructure networks per capita, New Zealand compared with OECD median



Source: New Zealand Infrastructure Commission analysis of data from Kalt et al. (2021), OECD (2022, 2023, 2024), and WHO and UNICEF (2023). Data is for latest available year, between 2017 and 2023.

If there are large infrastructure shortages, we would expect to see high and measurable economic and financial returns from new project. For projects funded from user charges, like tolls, we would expect to see high rates of cost recovery because users should be willing to pay to avoid existing poor-quality infrastructure options (New Zealand Infrastructure Commission, 2024b). For projects funded from general rates and user charges, we would expect to see high benefit-cost ratios, reflecting the high social value of addressing shortages.

Conclusion

Building infrastructure networks is a long game. We need to think about building infrastructure not simply as a series of isolated decisions, but as steps towards a longer-term strategy for our networks. Doing this requires avoiding a whack-a-mole approach to identifying and addressing infrastructure needs.

This paper lays out an approach to identifying long-term infrastructure needs. Investing in infrastructure involves trade-offs, so we need to think critically about what we are willing to spend and prioritise our spending. That prioritisation should be based upon how we've spent in the past but also needs to consider how the factors of the past will be different in the future.

More work is needed

Understanding our future infrastructure investment needs is no small task. Since our establishment, the Commission has been studying ways to deliver better infrastructure outcomes for New Zealanders. Much of this work relates to how we identify future infrastructure needs.

This paper has reviewed our work to date to lay out what we currently know and where future work is needed. In Appendix 1, we also add to this evidence base by summarising some key demographic trends and projections and analysing how demographic change has influenced infrastructure investment among OECD countries, including New Zealand.

In each one of our themes, we have highlighted areas where we think additional research would have high value:

- **What is the current state of our network?** Future work here will focus on identifying gaps. We need to understand more about physical characteristics and condition of our infrastructure networks. We also need extend our work on international benchmarking, digging deeper into why our infrastructure outcomes lead or lag our peer countries.
- **What is our willingness to pay for infrastructure?** We need to better understand how other fiscal and economic pressures will affect our willingness and ability to invest in infrastructure. We need to consider how new revenue tools could affect our baseline projections and whether there are investments we can make to grow our economy and increase our ability to make infrastructure improvements.
- **How and where should we invest in the future?** There is more to be done to understand how some of our identified drivers of demand will affect infrastructure needs. This includes modelling and estimating how we should respond to natural hazard risks to infrastructure and how decarbonising the economy will affect infrastructure investment demand.

There are many future scenarios

Expanding our understanding of these areas will enable us to provide a forecast of infrastructure pressures over the next 30 years. However, the future is uncertain. Any study of infrastructure demands needs to include a combination of scenarios and sensitivity testing to account for this uncertainty.

Infrastructure needs assessments also need to be periodically updated with new information to reflect the best understanding of our future paths. Otherwise, we risk planning for yesterday's vision of the future.

Appendix: A closer look at population growth

Due to the importance of population growth and demographic change for long-term infrastructure demand, we examine population growth prospects in this appendix. This is a high-level overview, drawing upon existing research and projections.

We start by briefly outlining the 'demographic transition' model that explains why population growth rates may vary over time and space. We then summarise historical population growth data and future projections for the world as a whole and for New Zealand, including implications for the age structure of the population. Finally, we present a simple panel econometric model exploring the impact of population growth and age structure on public capital stock over time in a set of high-income countries.

The demographic transition model

The world's human population has generally grown over time, but at varying rates. Prior to the 1700s, average annual population growth rates were very slow – perhaps 0.04% per annum.[12] After that point, population growth rates accelerated. In the mid-1900s, global population growth rates peaked at over 2% per annum, but they have decelerated since then.

At a global level, population growth occurs when births outstrip deaths. Varying population growth rates over time therefore reflect changes in birth and death rates, driven by technological changes like better medical care and contraception options and changing economic circumstances that affect how many children people want to have.

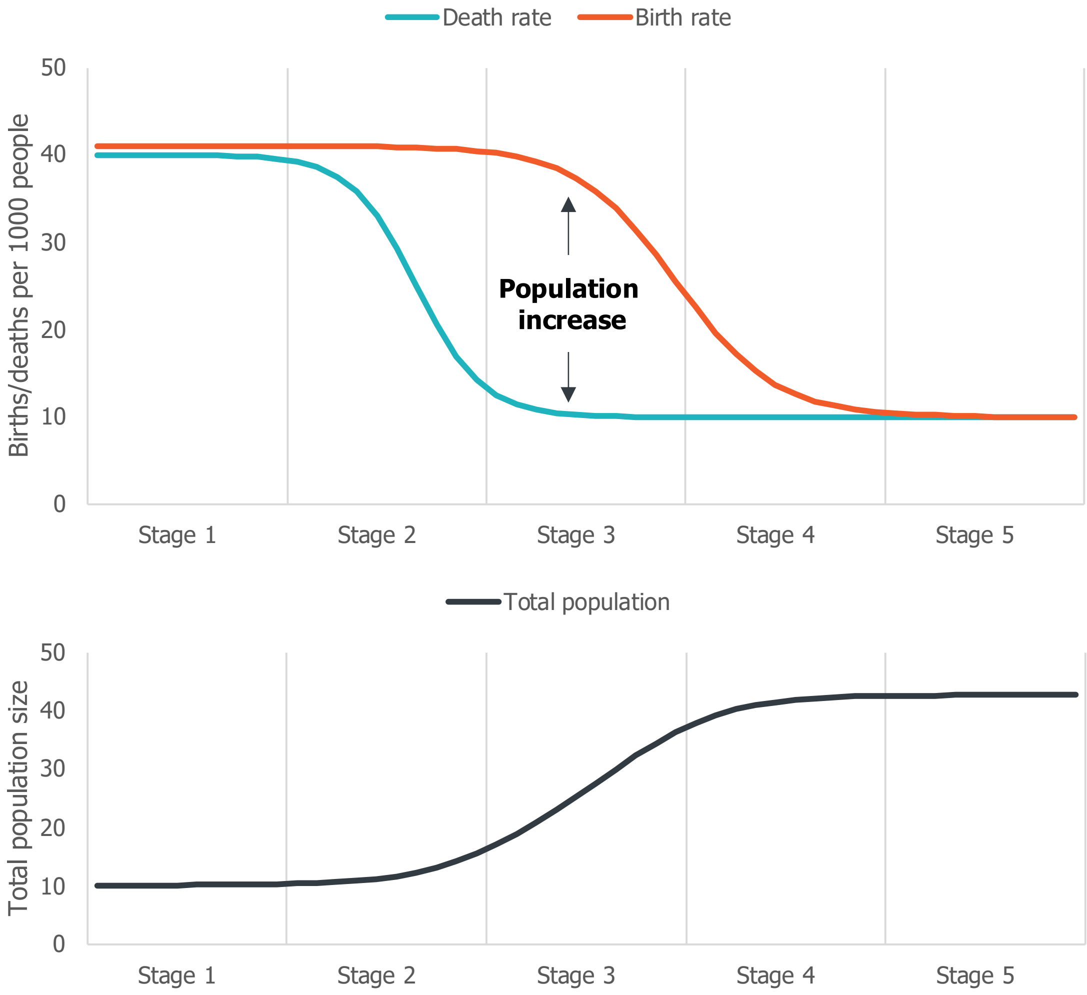
Figure 20 outlines the 'demographic transition' model, which summarises how population growth rates to accelerate, peak, and then decelerate as countries go through a process of economic development.

Initially, birth rates and death rates are high, and population growth rates are low. As economic development and health outcomes improve, death rates fall, leading to accelerating population growth. Then, birth rates fall, as people respond to improved economic opportunity and declining mortality by having fewer children and investing more in educating them.[13] This leads to decelerating population growth. Finally, birth rates and death rates stabilise at a lower level, resulting in a return to low population growth rates.

[12] https://ourworldindata.org/population-growth-over-time

[13] For a more in-depth summary of the economic causes of declining fertility rates in higher-income countries, see Bloom et al. (2023). Some researchers also highlight environmental factors, such as increased exposure to chemicals and pollutants from fossil fuels, as a contributor to declining fertility (Skakkebæk et al., 2022).

Figure 20: The demographic transition model



Source: Adapted from Our World In Data.[14]

The demographic transition model has strong empirical support. Based on a comprehensive statistical analysis of long-term trends in birth and death rates in 186 countries, Delventhal et al. (2021) conclude that 'a demographic transition has been completed or is ongoing in nearly every country [and] the speed of transition has increased over time'.

They find that 175 countries (out of a total of 186) have completed the mortality transition (arriving at stable lower death rates), and 80 have completed the fertility transition (arriving at stable lower birth rates).[15] Only one country (Chad) has not yet begun the fertility transition (beginning to experience a structural decline in birth rates).

Delventhal et al. (2021) also show that the timing and pace of demographic transitions is related to economic factors, such as the speed of technology transfer from 'frontier' countries and growth in per-capita incomes.

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[14] https://ourworldindata.org/demographic-transition

[15] Thus far, there is no evidence of significant and sustained increases in birth rates in countries that have completed the fertility transition. Some analysts pointed towards a temporary increase in fertility rates in high-income countries in the 2000s as evidence that fertility rates would rise again at a certain level of development (Myrskylä et al., 2009). However, fertility rates in these countries generally declined again in the 2010s and 2020s.

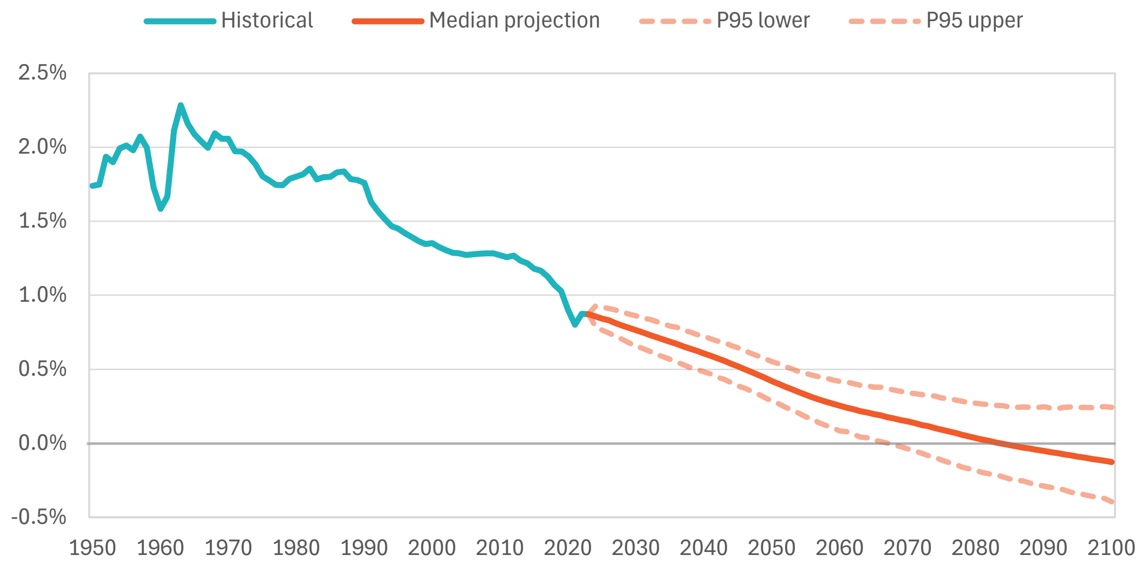
Global population growth trends

The impacts of the ongoing demographic transition can be seen in global population growth trends. We use historical estimates and future projections from the UN's 2024 *Revision of World Population Prospects* report to outline these trends.[16]

Figure 21 shows that, at the global level, population growth rates peaked in the 1960s and have been declining since then. The gap between birth rates and death rates has shrunk over time as most countries have started or completed their mortality and fertility transitions.

The UN's projections imply that the global population growth rate is likely to continue declining, and that world population is likely to peak and begin declining near the end of the 2000s. In their median projection, global population growth rates will turn negative in the mid-2080s. However, the UN also identifies a chance that this will happen several decades earlier or later.

Figure 21: Global population growth rates, historical and projected



Source: United Nations Department of Economic and Social Affairs (2024).

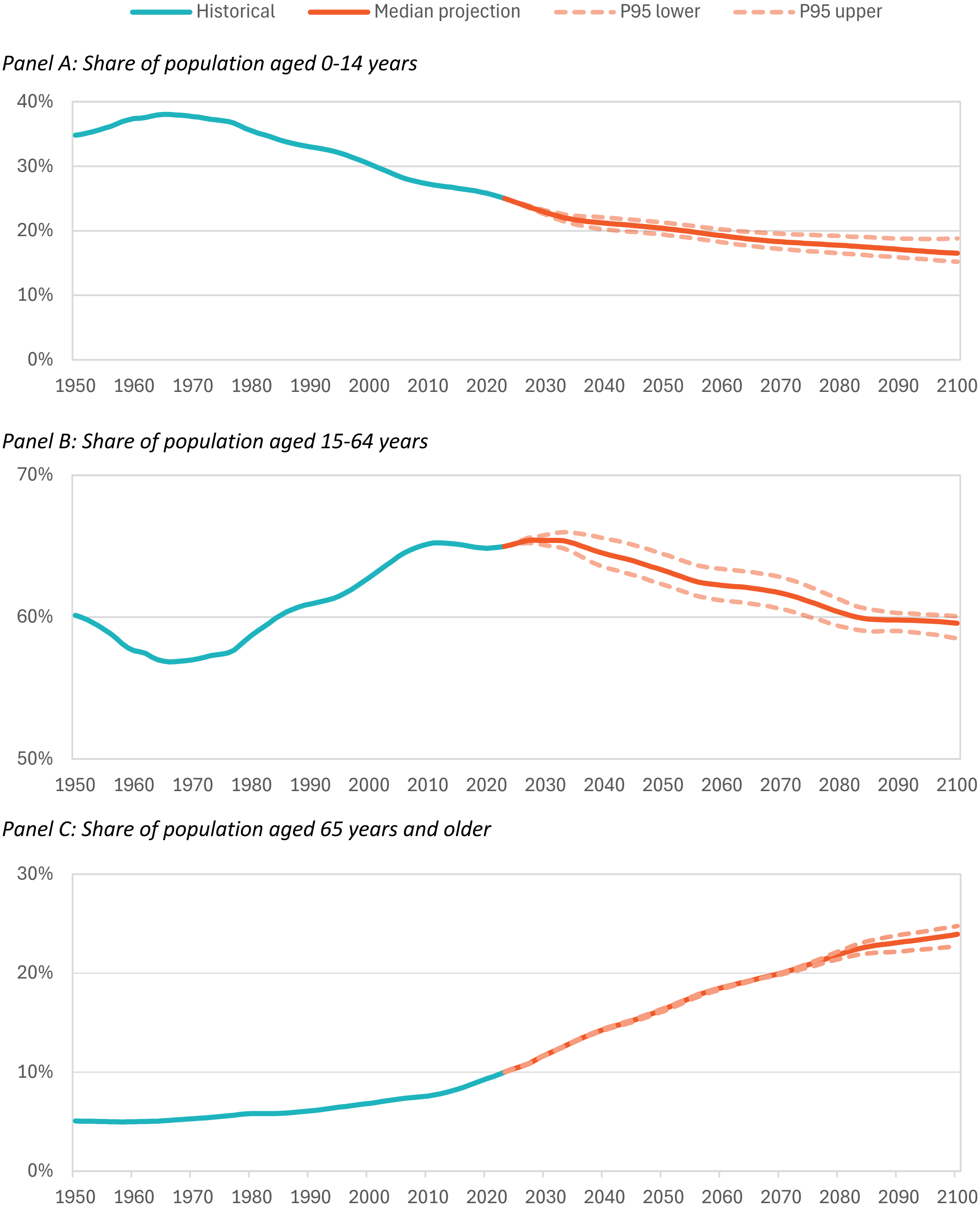
The demographic transition will also result in significant changes to the age structure of the population. The share of people who are of working age is expected to peak and decline, the share of people who are children is expected to continue declining, and the share of people who are of retirement age is expected to rise dramatically. Figure 22 summarises these trends.

As the second panel shows, the working-age share of the global population rose significantly between the late 1960s and early 2010s – from around 57% to 65%. This is now expected to reverse over the next five or six decades. Globally, the share of people who are in the workforce and paying taxes or user charges to help fund infrastructure will decline relative to the total number of adults who may demand infrastructure services.

This trend may also affect prospects for migration, a topic which we return to below.

[16] This is the 28th edition of the UN's *Population Prospects* report. At a global level, the UN's projections have been fairly accurate since the late 1960s, with errors in the range of 1% to 5% after 10 to 20 years. Country-level or regional projections are typically less accurate. https://ourworldindata.org/population-projections

Figure 22: Age structure of the global population, historical and projected



Source: United Nations Department of Economic and Social Affairs (2024).

Population growth trends in New Zealand

We now consider how these broad demographic trends may affect population growth and demographic change in New Zealand. New Zealand's population growth is influenced by the same fertility and mortality trends as the rest of the world.[17] However, because New Zealand is a single country, population growth rates are also affected by how many people immigrate to New Zealand from

[17] Delventhal et al. (2021) classify New Zealand as having completed its mortality and fertility transitions.

elsewhere in the world, and how many people emigrate from New Zealand to elsewhere (Productivity Commission, 2022).

This means that, when thinking about population growth prospects, we need to consider New Zealand's relative attractiveness as a migration destination as well as its internal demographic dynamics.

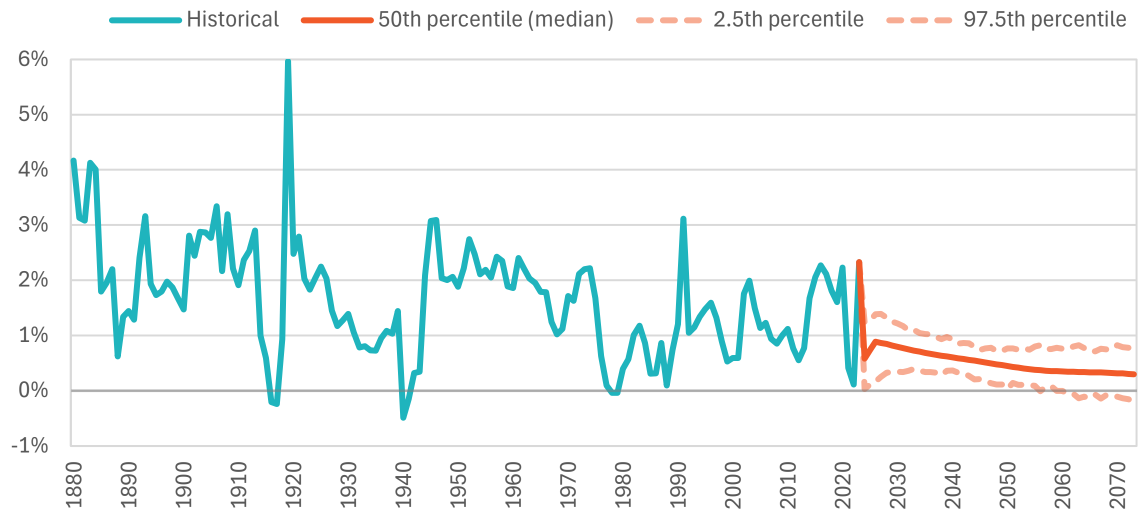
Historical and projected population growth trends

Figure 23 summarises population growth trends for New Zealand. Historical population growth estimates are drawn from NZIER's Data1850 tool, while projected population growth scenarios are drawn from SNZ's *National population projections: 2022(base)–2073*.[18]

This graph shows that population growth rates have fluctuated up and down over time. Between the early 1980s and the present day, population growth generally accelerated. However, the overall historical trend since the 1880s is for average population growth rates to gradually decline. Population growth rates were higher in the early 1900s and between the 1950s and early 1970s than they are today.

SNZ's population projections suggest that this long-term trend will continue over the next five decades. Even at the upper end of the projection range, average population growth rates are expected to fall.

Figure 23: New Zealand population growth rates, historical and projected



Source: New Zealand Infrastructure Commission analysis of data from NZIER Data1850 and SNZ projections.

Drivers of population growth are expected to shift over time

Population growth rates are expected to decline mainly due to trends in births and deaths.

Fertility rates – the number of children that the average woman is expected to have – are now significantly below the 'replacement' level of 2.1 children per woman. SNZ's most recent median population projections assumed a long-run fertility rate of 1.65 in the mid-2000s.[19] Actual fertility rates recently fell below this level, with an average fertility rate of 1.56 in 2023.[20] Because declining fertility is not being fully offset by rising life expectancy, the number of people dying will eventually outstrip the number of people being born.

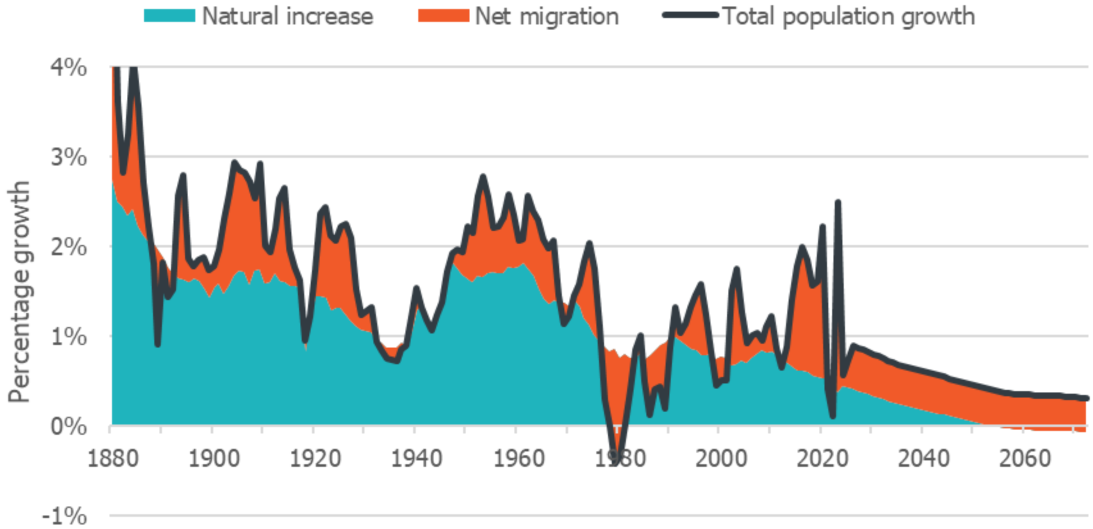
[18] https://nzier.shinyapps.io/data1850/
https://www.stats.govt.nz/information-releases/national-population-projections-2022base2073
[19] Prior to its 2016 update to population projections, SNZ assumed a median long-run fertility rate of 1.9 children per woman. It revised fertility rate assumptions downwards in 2016 and 2020. Long-run life expectancy assumptions were also revised downwards between 2016 and 2022.
[20] https://www.stats.govt.nz/news/lowest-natural-increase-in-80-years/

To maintain current population growth rates, net migration to New Zealand would have to increase to offset trends in births and deaths. SNZ's projections assume that net migration to New Zealand will continue at the average rates observed over the last several decades.[21]

Figure 24 shows that the overall impact of these two trends is that migration is expected to contribute a larger share of overall population growth in the future than it did in the past.

Between the 1880s and 1980s, natural increase – the excess of births over deaths – contributed more than 80% of New Zealand's total population growth. Since 1990, natural increase has contributed slightly less than 60% of total population growth. In future decades, natural increase is expected to decline and turn negative. In SNZ's median projection, net migration is expected to account for all of New Zealand's population growth from the 2050s onwards.

Figure 24: Composition of historical and projected population growth in New Zealand



Source: New Zealand Infrastructure Commission analysis of data from Figure 2.17 in Productivity Commission (2022), plus SNZ population projections.

Migration is considerably more volatile than births and deaths – it varies more from year to year. An implication of New Zealand's demographic trends is therefore that overall population growth is likely to become more variable from year to year, unless something else changes.

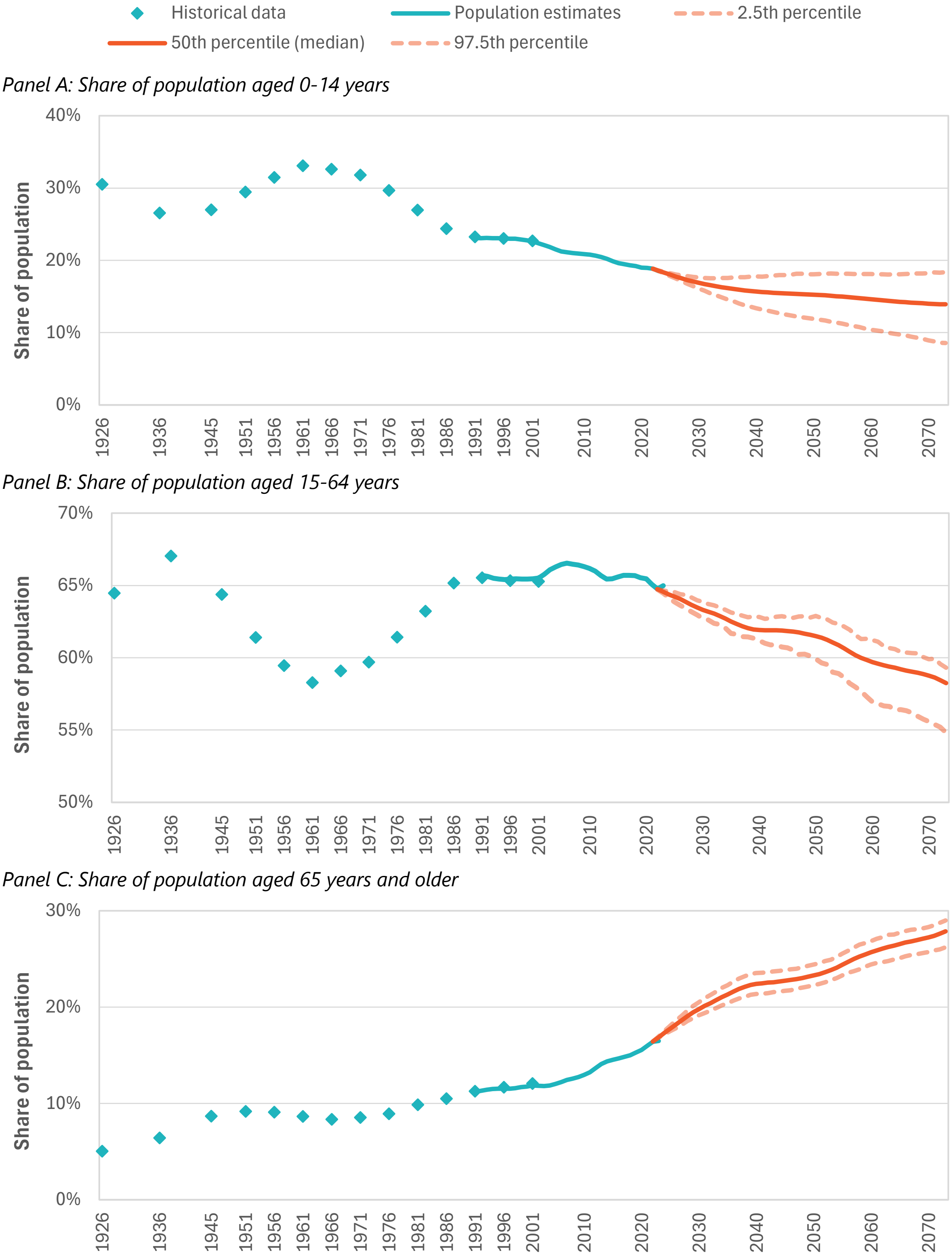
Age structure of the New Zealand population

Figure 25 shows that the age structure of the New Zealand population is expected to undergo similar changes as the rest of the world, over a similar timeframe. The share of people who are of working age is expected to peak and decline, the share of people who are children is expected to continue declining, and the share of people who are of retirement age is expected to rise.

The second panel shows that the working-age share of New Zealand's population declined between the 1940s and late 1950s, due to the post-war baby boom. Between the early 1960s and early 1990s it rose from around 57% to 65%. It has declined slightly relative to its late-2000s peak and is expected to decline further over the coming decades.

[21] SNZ has progressively increased its median long-run net migration assumptions over the last two decades. In its 2001 population projections update, it assumed long-run annual net migration of 5000 people. It raised this figure to 10,000 in the 2004 update, 12,000 in the 2011 update, 15,000 in the 2016 update, and 25,000 in the 2020 update. Net migration has been substantially higher in some recent years, but it has also been substantially lower than 25,000 in other years.

Figure 25: Historical and projected age structure of New Zealand's population



Source: New Zealand Infrastructure Commission analysis of SNZ LTDS, population estimates, and population projections.

Changing uncertainty about population growth

While global and national population growth rates are expected to decline and turn negative, some places will continue to grow. However, they may only be able to grow by attracting people away from other places that then experience more rapid population decline as a result.

Population-related uncertainty in infrastructure investment demand will therefore increase as the world proceeds through a demographic transition.
This is starting to manifest as increased uncertainty about whether some places will grow or decline in coming decades. SNZ's *Subnational population projections: 2018(base)–2048 update* suggest that more places are facing the potential, but not the certainty, of population decline over the next three decades.[22]

While our major cities and other fast-growing areas like the upper North Island are seen as highly likely to continue growing, many smaller towns and rural areas face more uncertainty about whether they will continue to grow. And even within growing cities and regions, some suburbs and towns may grow strongly while others peak or decline in population.

This will create challenges for infrastructure investment.

When total population is growing at a high and sustained rate, there may be uncertainty about the optimal *timing* of infrastructure capacity upgrades, but less uncertainty about *whether* new infrastructure will be used. For instance, a new school in a growing suburb may reach its capacity in five years, ten years, or twenty years, depending upon how rapid growth is at the local level, but it is highly likely that the school will be used.

But when total population growth is slower, or even negative, then there is greater uncertainty about whether capacity upgrades will ever be needed. For instance, a new school in a city that may or may not experience population growth in the future may end up being closed due to low enrolments.

When there is uncertainty about whether infrastructure will be needed, it may not be prudent to invest ahead of demand. Instead, it may be better to take low-cost steps to 'future proof' the ability to invest in the future, like buying sites that could be used for future schools. Analytical methods like real options analysis can be used to value these future-proofing investments (New Zealand Infrastructure Commission, 2023a).

[22] https://www.stats.govt.nz/information-releases/subnational-population-projections-2018base2048-update/

Population growth and infrastructure investment

To help understand how population growth affects infrastructure investment demand, we undertake an econometric analysis of public capital stock trends over time at the country level. 'Public capital' refers to fixed assets owned by local and central governments, including many infrastructure assets. For a discussion of how public capital relates to infrastructure assets, see Infrastructure Commission (2021a).

The aim of this exercise is to understand how the value of public capital stock changes in response to population growth and growth in GDP per capita at a country level. We are interested in estimating the elasticity of public capital stock in response to population size. An elasticity of one means that a 1% increase in population leads to a 1% increase in the value of public capital assets, holding other factors constant. An elasticity of less than one indicates that there are economies of scale in provision of public capital – a 1% increase in population leads to less than a 1% increase in capital stock. An elasticity greater than one indicates that there are diseconomies of scale, such as congestion – a 1% increase in population leads to a more than 1% increase in capital stock.

We also explore whether population age structure has an impact on public capital stock.

Data sources

Our analysis draws upon two primary data sources:

- The IMF's (2022) *Investment and Capital Stock Database*, which provides annual estimates of public and private capital investment and capital stock for 170 countries over the 1960–2019 period.
- The World Bank's (2024) *World Development Indicators*, which provide annual estimates of population and GDP per capita (constant-price PPP exchange rates) for 265 countries over the 1960–2023 period.

After joining and cleaning these datasets to exclude countries that have missing data for key model variables at any point during the 1960–2019 period, we have a balanced panel of 87 countries, including 30 out of 38 OECD countries.[23]

Descriptive analysis

Figure 26 shows the country-level correlation between population and capital stock for a single year (2019). Because there are such large differences in size between countries, with populations ranging from 280,000 to over one billion, we present the value of population and public capital stocks in log form, for ease of exposition. Panel A shows the relationship for the 30 OECD countries included in our analysis, and Panel B shows the relationship for all 87 countries included in the analysis, including low-income countries.

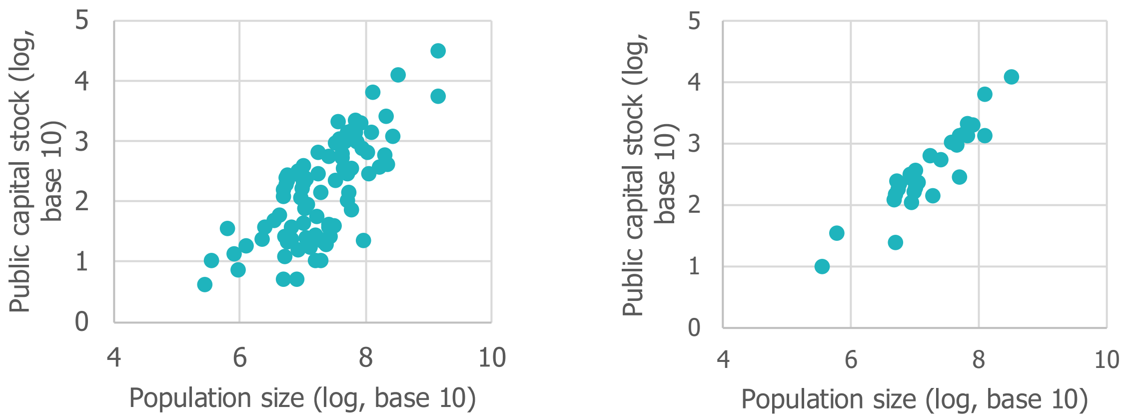
Among OECD countries, there is a strong positive correlation between population size and the total value of public capital stock. We estimate a cross-sectional elasticity of 0.95 (standard error 0.07), indicating a roughly one-to-one correlation between population size and capital stock.

For all countries, we estimate a slightly lower elasticity of 0.87 (standard error 0.09). This is partly because some large countries have low GDP per capita, and hence little money to build public infrastructure with.

While these are merely correlations, they highlight that countries that have larger populations tend to have proportionately more infrastructure.

[23] These OECD countries are: Australia, Austria, Belgium, Canada, Chile, Colombia, Costa Rica, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea (Rep), Luxembourg, Mexico, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States.

Figure 26: Cross-country correlation between population and public capital stock in 2019

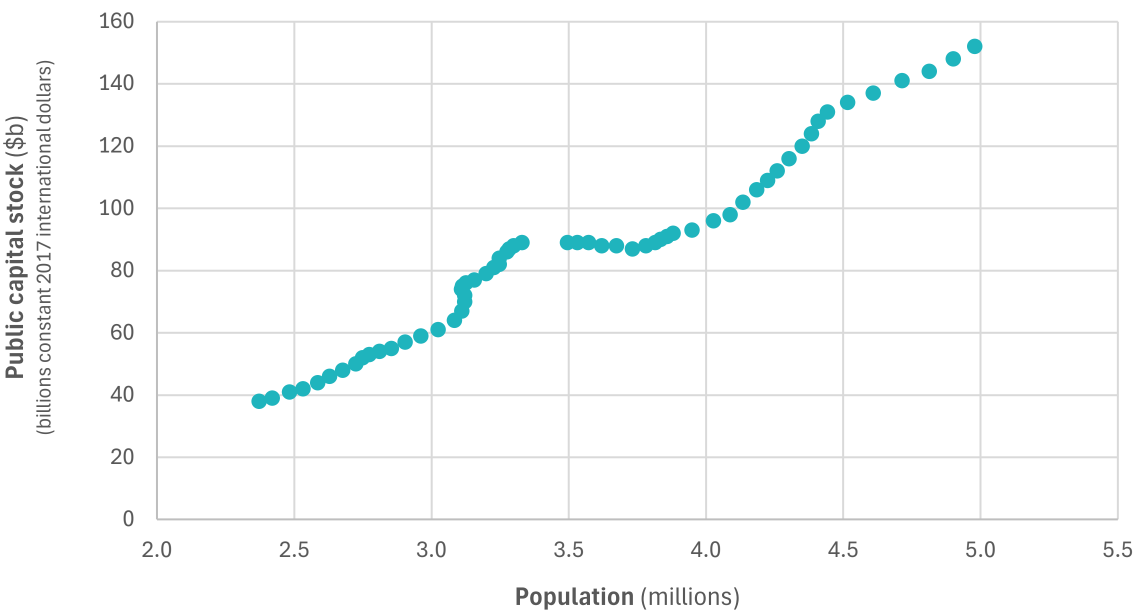


Source: New Zealand Infrastructure Commission analysis of IMF and World Bank data.
Notes: Public capital stock = General government capital stock, in billions of constant 2017 international dollars.

However, to understand the impact of population growth, we also need to consider how public capital stock changes over time in response to population growth at a country level. To motivate this analysis, Figure 27 shows how population size and public capital stock evolved in New Zealand from 1960 to 2019. Each point in the figure represents data for a single year.

While there is an overall positive correlation between population size and public capital stock, the relationship seems to be stronger in some time periods and weaker in others. Data for other OECD countries reinforces this picture – while population growth tends to be associated with growth in public capital stocks, this relationship varies over time and between countries.

Figure 27: Correlation between population and capital stock over time in New Zealand (1960-2019)



Source: New Zealand Infrastructure Commission analysis of IMF and World Bank data.
Notes: Public capital stock = General government capital stock, in billions of constant 2017 international dollars.

Approach to econometric analysis

Following Fay and Yepes (2003), we assume that infrastructure is demanded by firms and individuals as an input into their production and consumption activities, and that it is supplied in response to demand. Rather than modelling a full supply and demand system, we estimate a reduced form 'law of motion' for public capital stocks.

Like Fay and Yepes, we treat capital stock per capita as the outcome variable and include GDP per capita as an explanatory variable. We also include country effects that proxy for factors like physical geography, regulation, or institutional and market design that may affect the level of public capital that is provided in the long term. Unlike them, we include variables for population in different age groups to enable us to test whether there are economies or diseconomies of scale in infrastructure provision.

Following unit root and cointegration testing, which we summarise below, we estimate the model in Equation 1. The outcome variable in this model is the natural log of public capital stock per capita in real, PPP-adjusted terms ($K_{i,t}^{gov}$). The explanatory variables are: the natural log of GDP per capita in real, PPP-adjusted terms ($I_{i,t}$) and the natural log of the number of people aged between 0 and 14 years ($P_{i,t}^{0-14}$), between 15 and 64 years ($P_{i,t}^{15-64}$) and aged 65 years and up ($P_{i,t}^{65up}$).

The coefficients on the population variables can be used to understand whether there are economies or diseconomies of scale in public infrastructure provision and whether different age groups are associated with more or less public infrastructure.

Equation 1: Econometric models of public capital stocks

$$K_{i,t}^{gov} = \gamma I_{i,t} + \beta_1 P_{i,t}^{0-14} + \beta_2 P_{i,t}^{15-64} + \beta_3 P_{i,t}^{65up}$$

We estimate both models using country-level panel data at an annual frequency. We focus on results for models run on OECD countries only, but we also report results for all countries as a robustness test.

Prior to estimating these models, we first test whether all model variables are stationary, i.e., whether they have constant mean and variance over time, and whether they are cointegrated, i.e., whether there is a long-run relationship between non-stationary variables. If model variables are non-stationary but not cointegrated, a naïve approach to estimation may result in spurious correlations.

We then estimate Models 1 and 2 using three alternative panel estimators: a pooled OLS model, a fixed effects model and a random effects model.[24] We run standard panel model tests to determine which panel modelling approach is preferred and whether to include country effects, time effects, or both in the fixed effects and random effects model, but report results for all model variants.[25]

We also estimate both models in 'long differenced' form, looking at changes in public capital stock as a function of changes in incomes and population size and demographics over the full 1960–2019 period. We estimate long differenced models using OLS regression.

Stationarity and cointegration tests

We run unit root tests and cointegration tests over the annual panel dataset. We report detailed results for OECD countries, as this is the focus of our analysis. We also conduct, but do not report, unit root and cointegration tests for all countries, which are very similar.

[24] We estimate these models using the R package 'plm'.

[25] We first run a Lagrange Multiplier test ('plmtest' function in the R package 'plm') to test whether a fixed effects model is preferred over a pooled OLS model. This tests the null hypothesis that time and country fixed effects are equal to zero. We then run a Hausman test ('phtest' function in the R package 'plm') to test whether fixed effects are preferred over random effects. This tests the null hypothesis that random effects are preferred. We identify a 'preferred' model based on the following rules:

- Pooled OLS: Preferred if the LM test is not statistically significant at the 5% level
- Fixed effects: Preferred if both the LM test and the Hausman test are statistically significant at the 5% level
- Random effects: Preferred if the LM test is statistically significant at the 5% level and the Hausman test is not.

We start by running a set of panel unit root tests on all model variables to understand whether they are stationary or non-stationary. These tests are:

- The Levin-Lin-Chu (LLC) test, with and without a time trend. LLC tests whether there is a common unit root for all TLAs in the panel; and
- The Im-Pesaran-Shin (IPS) test, again with and without a time trend. IPS tests whether any individual TLAs in the panel exhibit a unit root.[26]

The null hypothesis for these tests is that the variable contains a unit root, i.e., that it is non-stationary. A p-value below a given critical value (say 5%) indicates that we can reject the null hypothesis of a unit root.

Table 4 summarises the results, with tests that did not reject a unit root at least the 5% level highlighted. For all variables, we fail to reject the null hypothesis of a unit root on at least one test. As a result, we consider that it is safest to assume that all model variables are non-stationary.

Table 4: Panel unit root tests for annual panel of OECD countries

Model variable	LLC, intercept only		LLC, trend		IPS, intercept only		IPS, trend	
	Test stat	p-value	Test stat	p-value	Test stat	p-value	Test stat	p-value
$K_{i,t}^{gov}$	-9.665	0.000	-7.060	0.000	-3.429	0.000	-1.508	0.066
$I_{i,t}$	-17.809	0.000	-5.370	0.000	-9.254	0.000	0.054	0.522
$P_{i,t}^{0-14}$	-1.238	0.108	-1.381	0.084	-0.295	0.384	-6.255	0.000
$P_{i,t}^{15-64}$	-2.356	0.009	3.610	1.000	-3.873	0.000	-1.025	0.153
$P_{i,t}^{65up}$	10.376	1.000	6.896	1.000	12.866	1.000	4.923	1.000

After testing for unit roots, we test whether the model variables are cointegrated for both models that we estimate. We use the suite of Pedroni panel cointegration tests to do so, conducting tests for each model with and without a time trend.[27] The null hypothesis for this test is that model variables are not cointegrated. A p-value below a certain critical value (say 5%) indicates that we can reject the null hypothesis of no cointegration.

Table 5 summarises the results, highlighting tests that did not reject the null of no cointegration at the 5% level. All tests suggest that we can reject the null of no cointegration. This suggests that it is possible to estimate the model without first transforming the variables to remove unit root behaviour.[28]

Table 5: Cointegration tests for annual panel of OECD countries

Test type	Intercept only		Trend	
	Normalised test stat	**p-value**	**Normalised test stat**	**p-value**
Panel v-statistic	-8.858	0.000	-11.034	0.000
Panel ρ-statistic	5.011	0.000	5.518	0.000
Panel t-statistic (non-parametric)	2.133	0.008	2.038	0.010
Panel t-statistic (parametric)	-42179	0.000	-51255	0.000
Group ρ-statistic	6.751	0.000	7.147	0.000
Group t-statistic (non-parametric)	4.056	0.000	4.581	0.000
Group t-statistic (parametric)	5.022	0.000	5.680	0.000

Note: The raw test statistics are normalised so that they follow a normal distribution with mean 0 and standard deviation 1. This enables p-values to be computed from the normal distribution.

[26] We implement these tests using the 'purtest' function in the R package 'plm' (https://search.r-project.org/CRAN/refmans/plm/html/purtest.html). For each test, the number of lags was selected with the Schwarz information criterion (SIC).
[27] These tests are explained in Pedroni (1999): https://web.williams.edu/Economics/wp/pedronicriticalvalues.pdf. We implement these tests using the 'pedroni99m' function in the R package 'pco' (https://search.r-project.org/CRAN/refmans/pco/html/pedroni99m.html).
[28] When model variables are not cointegrated, it is common to first-difference model variables to remove unit roots.

Key model results and interpretation

Table 6 summarises model estimates for OECD countries, highlighting coefficients from our 'preferred' panel models and the long-differenced model. There are three key findings from this analysis.

First, the preferred panel model suggests that the income elasticity of public capital stock is around 0.6. This suggests that a 1% increase in GDP per capita is associated with a 0.6% increase in public capital stocks. This is consistent with our previous estimates of the income elasticity of infrastructure spending based on household microdata, which are in the range of 0.4 to 0.6 (New Zealand Infrastructure Commission, 2024d). It is also consistent with the broader evidence on income elasticities of demand for infrastructure services (National Infrastructure Commission, 2018).

Second, the preferred panel model suggests that there are economies of scale in public infrastructure provision. We sum up the coefficients on the three population variables to understand the impact of increasing the total population while holding age structure constant. We estimate an overall population elasticity of per-capita public capital stocks of around -0.2. This suggests that a 1% increase in total population is associated with a 0.2% reduction in the amount of public capital per capita. The joint hypothesis test reported in the first row of Table 7 indicates that this effect is statistically significant.

Third, the preferred panel model suggests that the age structure of the population affects public capital stocks. We find that children (aged 0 to 14) are associated with lower per-capita public capital stocks, while both working-age people (aged 15 to 64) and retirement-age people (aged 65 and up) are associated with higher per-capita public capital stocks. The joint hypothesis tests reported in the last three rows of Table 7 indicate that the impacts of children are statistically significantly lower than either working-age or retirement-age peoples, but that differences in impacts between working-age and retirement-age people are not statistically significant.

These results are qualitatively similar in the other model specifications, although the estimated magnitude of effects varies slightly.

Table 6: Public capital stock models for OECD countries, 1960–2019

Model type	Annual panel			Long differences
Estimation approach	Pooled OLS	Fixed effects	Random effects	OLS
Dependent variable	$K_{i,t}^{gov}$	$K_{i,t}^{gov}$	$K_{i,t}^{gov}$	$\Delta K_{i,t}^{gov}$
Explanatory variables				
$I_{i,t}$ ($\Delta I_{i,t}$ in last column)	0.842*** (0.016)	0.602*** (0.019)	0.598*** (0.019)	0.669*** (0.181)
$P_{i,t}^{0-14}$ ($\Delta P_{i,t}^{0-14}$ in last column)	-0.098** (0.046)	-0.620*** (0.042)	-0.557*** (0.041)	-0.540 (0.414)
$P_{i,t}^{15-64}$ ($\Delta P_{i,t}^{15-64}$ in last column)	-0.182** (0.077)	0.173*** (0.057)	0.182*** (0.057)	0.283 (0.527)
$P_{i,t}^{65up}$ ($\Delta P_{i,t}^{65up}$ in last column)	0.339*** (0.039)	0.247*** (0.031)	0.257*** (0.031)	0.059 (0.292)
Country effects?	No	Yes	Yes	No
Year effects?	No	No	No	N/A
Total observations	1800	1800	1800	30
'Preferred' model: Fixed effects model with country effects Lagrange Multiplier test: reject hypothesis that country fixed effects are equal to zero (p<0.001) but fail to reject hypothesis that time fixed effects are equal to zero (p=0.282). Hausman test: reject hypothesis that random effects are preferred (p<0.001).				

*Note: Statistical significance indicators: *p<0.1; **p<0.05; ***p<0.01.*

Table 7: Joint hypothesis tests (F-tests) on population coefficients

Null hypothesis	Interpretation	Chi-squared	p-value
$\beta_1 + \beta_2 + \beta_3 = 0$	Rejection of null hypothesis indicates economies of scale in public capital provision	47.3	0.000
$\beta_1 = \beta_2$	Rejection of null hypothesis indicates that children have smaller impacts on public capital than working-aged people	74.1	0.000
$\beta_1 = \beta_3$	Rejection of null hypothesis indicates that children have smaller impacts on public capital than retirement-aged people	451.9	0.000
$\beta_2 = \beta_3$	Rejection of null hypothesis indicates that retirement-aged people have larger impacts on public capital than working-aged people	0.8	0.379

Results for all countries

We also estimate this model using data for all countries. As noted above, we find evidence of the same cointegrating relationship among all countries as we do for only OECD countries. Table 8 reports key results, again highlighting the 'preferred' panel model and long-differenced model.

In the preferred panel model, we obtain qualitatively similar results for the income elasticity of public capital (around 0.51) and the relative impact of different age groups on public capital stocks.

However, among all countries we find evidence of diseconomies of scale in public infrastructure provision. Summing up the coefficients on the three population variables, we estimate an overall population elasticity of per-capita public capital stocks of around +0.2. This suggests that a 1% increase in total population is associated with a 0.2% *increase* in the amount of public capital per capita among all countries. This might suggest that lower-income countries with less infrastructure to begin with face higher congestion costs due to population growth.

Table 8: Public capital stock models for all countries, 1960–2019

Model type	Annual panel			Long differences
Estimation approach	Pooled OLS	Fixed effects	Random effects	OLS
Dependent variable	$K_{i,t}^{gov}$	$K_{i,t}^{gov}$	$K_{i,t}^{gov}$	$\Delta K_{i,t}^{gov}$
Explanatory variables				
$I_{i,t}$ ($\Delta I_{i,t}$ in last column)	0.844*** (0.012)	0.514*** (0.013)	0.528*** (0.013)	0.496*** (0.111)
$P_{i,t}^{0-14}$ ($\Delta P_{i,t}^{0-14}$ in last column)	-0.163*** (0.05)	-0.195*** (0.031)	-0.206*** (0.031)	-0.106 (0.283)
$P_{i,t}^{15-64}$ ($\Delta P_{i,t}^{15-64}$ in last column)	0.354*** (0.076)	-0.030 (0.045)	-0.024 (0.045)	-0.175 (0.403)
$P_{i,t}^{65up}$ ($\Delta P_{i,t}^{65up}$ in last column)	-0.179*** (0.037)	0.437*** (0.026)	0.422*** (0.026)	0.213 (0.225)
Country effects?	No	Yes	Yes	No
Year effects?	No	No	No	N/A
Total observations	5220	5220	5220	87
'Preferred' model: Fixed effects model with country effects Lagrange Multiplier test: reject hypothesis that country fixed effects are equal to zero (p<0.001) but fail to reject hypothesis that time fixed effects are equal to zero (p=0.521). Hausman test: reject hypothesis that random effects are preferred (p<0.001).				

*Note: Statistical significance indicators: *p<0.1; **p<0.05; ***p<0.01.*

Discussion

These results suggest that incomes, population size, and demographic characteristics are likely to have an impact on public infrastructure stocks. Among high-income countries, rising incomes are associated with more public capital, increasing population tends to be accommodated without a one-to-one increase in public capital stocks, and an ageing population is associated with more public capital.

Different countries have experienced different economic and demographic trends over time. We would expect this to flow back through into public infrastructure investment outcomes.

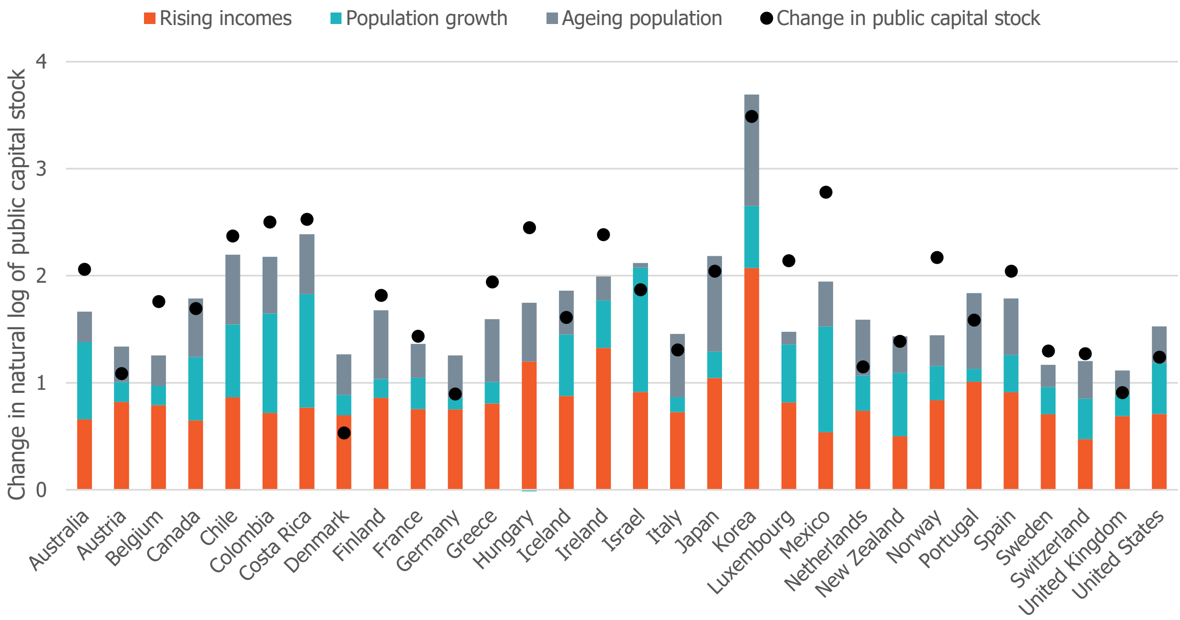
We therefore use results from our preferred public capital stock model (fixed effects panel model from Table 6) to understand why public capital stocks may have changed at different rates in different OECD countries over the 1960–2019 period.

In inflation-adjusted terms, public capital stocks grew at the fastest rate in in South Korea (which saw an almost 3200% increase in the value of public capital) and at the slowest rate in Denmark (which saw a 70% increase over this period). New Zealand was slightly below the OECD average, with a roughly 300% increase in public capital stock. However, income growth rates, population growth rates, and population ageing vary between countries, affecting demand for investment.

Figure 28 decomposes the drivers of growth in public capital stocks in OECD countries. We estimated these by applying the regression coefficients from Table 6 to the observed changes in GDP per capita, population size, and age structure over the full period.[29] We then compared these estimates with observed changes in public capital stocks.

While there are 'overs and unders', we find that these three factors account for almost all observed variation in public capital stock.[30] Countries with faster income and population growth, and more rapid population ageing tend to experience faster growth in public capital stocks.

Figure 28: Decomposing drivers of growth in public capital stocks in OECD countries, 1960–2019



Source: New Zealand Infrastructure Commission analysis of data from IMF (2022) and World Bank (2024), using regression coefficients from Model 2, fixed effects panel model from Table 6. Note: Log point changes can be converted to percentage changes as follows: Percent change = exp(log change)-1.

[29] To estimate the overall impact of population growth, we multiplied observed change in total population by 1 plus the sum of the coefficients on population size in the model. This is a simple rearranging of the model.

[30] We note that this is an 'in sample' prediction. An alternative approach would be to estimate thirty 'leave one out' regressions and make a prediction for each country based on a regression that excludes that country.

Over the full period, New Zealand's public capital stock has grown at almost exactly the rate that we would expect given its GDP growth and demographic changes. While other countries, such as Australia or Canada, have experienced faster growth in public capital stocks, this is mostly due to faster GDP growth or population-based investment demand.

This analysis suggests that approximately 35% of New Zealand's growth in public capital is related to rising per-capita incomes, 41% is related to growth in its total population, and the remaining 24% is due to population ageing. As noted earlier in this Appendix, New Zealand's demographic trends will continue to change in the future, meaning that the balance of different investment drivers will also change.

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