Nation Building: A Century and a Half of Infrastructure Investment in New Zealand

Te Waihanga Research Insights series

September 2025

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.

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

How to cite this document

New Zealand Infrastructure Commission. (2025). *Nation Building: A Century and a Half of Infrastructure Investment in New Zealand*. Wellington: New Zealand Infrastructure Commission/Te Waihanga.

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Acknowledgement

This report was drafted by Peter Nunns, with assistance from Graham Campbell, Philip Stevens, and Ezra Barson-McLean. We are grateful for feedback on drafts of the report from Dr Stuart Donovan (Motu Research) and Dr Brian Easton.

Contents

Cut to the chase

Infrastructure lasts a long time

Infrastructure is a long game. It takes years, even generations, to build and improve infrastructure networks. For instance, over the last 200 years our land transport networks have evolved from walking tracks and waka portages to railways to paved roads, cycleways, and footpaths.

The infrastructure networks we have today are the result of decisions made by previous generations. The average wastewater pipe in Invercargill was built almost 60 years ago. Almost 40,000 vehicles a day pass through the Mount Victoria Tunnel in Wellington, built in 1931.

Decisions we make today will have an impact on multiple future generations of New Zealanders. The New Zealand Infrastructure Commission's role is to look ahead, helping ensure that we make decisions that meet both current and future infrastructure needs.

We need to understand our past to prepare for the future

We can make better investment decisions, today and tomorrow, if we know more about our past investment decisions.

Infrastructure assets are often long-lived, but they don't last forever. Once we build them, we need to start preparing to maintain and eventually replace them. Knowing when our infrastructure assets were built can help to identify when investment might be needed to repair or replace them.

More broadly, history also helps to put our current needs into perspective and highlights how we could respond to those needs.

Today, we are facing many infrastructure challenges. These include deferred maintenance and renewal needs, growing populations, climate hazards, and rising construction costs. But past generations faced their own challenges and found ways to overcome them.

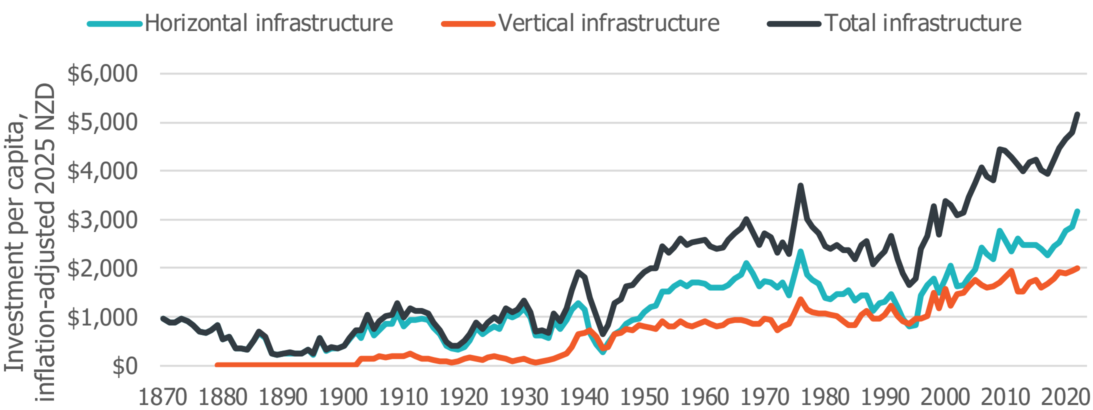
By looking back, we can understand the factors that drive infrastructure investment, as well as how much of our national income we have been willing to commit to building or improving infrastructure.

In previous research, we presented data on infrastructure investment and asset values for most infrastructure sectors as far back as 1990. This report extends our historical estimates of infrastructure investment and asset values, for the same sectors, back as far as 1870 (or to the earliest date of significant capital investment, for sectors like electricity that did not exist in 1870). It also provides new information on the physical size or usage of infrastructure networks over time.

We are spending more than ever on infrastructure

Today, we are spending more than ever on building, renewing, and maintaining infrastructure networks, even after adjusting for inflation and population growth. We estimate that 50 years ago, we invested an average of around $3,000 per person, per year, on infrastructure. As of 2022, that figure is closer to $5,000 per person (Figure 1).

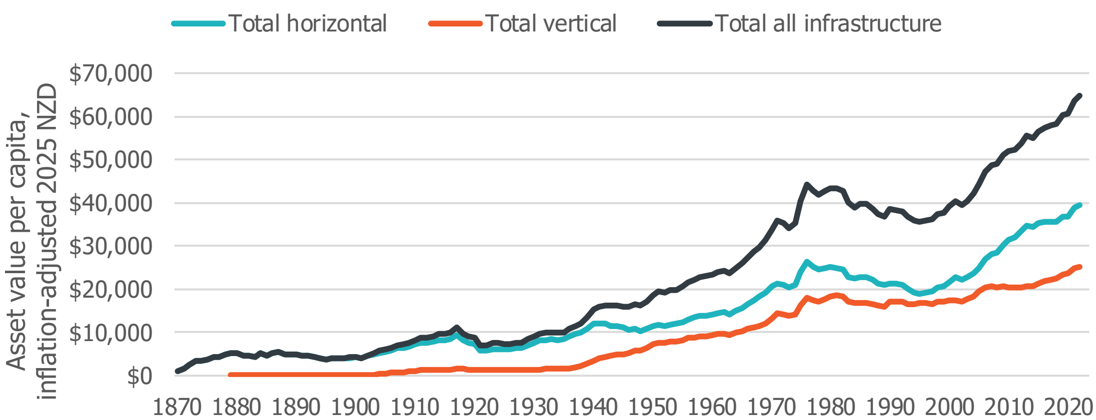
Figure 1: Annual estimates of real infrastructure investment per capita, 1870–2022



Source: New Zealand Infrastructure Commission estimates. Note: Post-1990 estimates should be treated as <u>most reliable</u>, while estimates for the 1870s to the 1920s should be treated as <u>less reliable</u> than estimates for later years.

Because we are spending more, the value of our infrastructure assets is also growing faster than inflation or population growth. We estimate that 50 years ago, we had around $40,000 of infrastructure assets per person. As of 2022, the per-person value of infrastructure assets had risen to almost $70,000 (Figure 2).

Figure 2: Estimated value of real infrastructure capital stock per capita, 1870–2022



Source: New Zealand Infrastructure Commission estimates. Note: Post-1990 estimates should be treated as most reliable, while estimates for the 1870s to the 1920s should be treated as less reliable than estimates for later years.

Growth in spending has tracked growth in incomes

The main reason we are spending more in per-capita terms is that our incomes have grown over time. For instance, GDP per person has doubled over the last 50 years, after adjusting for inflation.

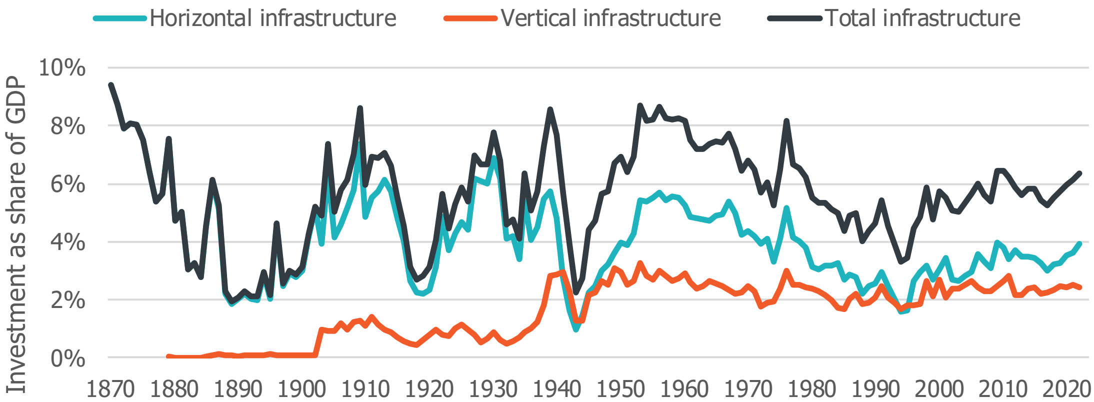
We are spending about the same 'share of our wallet' on infrastructure as we did back then, but because we're earning more, we have more to spend. Overall infrastructure investment and asset values are reasonably stable relative to the size of our economy.

The share of our income or economy dedicated to building infrastructure has hovered around 5.6% of GDP over the last 150 years. There are periods of time where this is above or below, but these booms or busts rarely last more than 20 years before returning to trend (Figure 3).

Over multi-decade periods, we have historically been willing to spend between 5% to 7% of GDP on infrastructure investment. We may spend a bit more for a few years, in response to high demand, or a bit less, in response to competing budget pressures, but periods of higher or lower investment don't tend to last.

If the past is any indication of the future, we can expect total infrastructure investment to rise in line with population and income growth. We are likely to spend more in the future, but growth in investment must be balanced against the size of our economy.

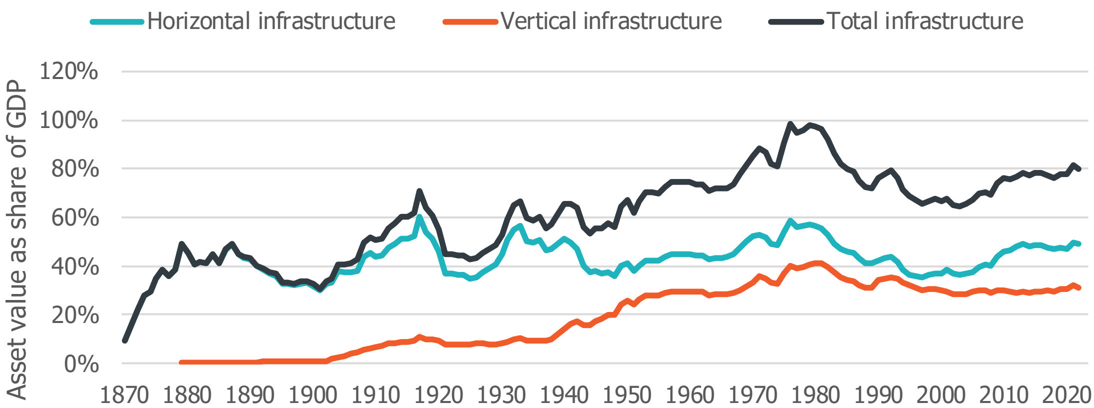
Figure 3: Annual estimates of total infrastructure investment as a share of GDP 1870–2022



Source: New Zealand Infrastructure Commission estimates. Note: Post-1990 estimates should be treated as most reliable, while estimates for the 1870s to the 1920s should be treated as less reliable than estimates for later years.

Today, the ratio of infrastructure asset values relative to GDP, a simple measure of the importance or intensity of infrastructure in our economy, is similar to where it was in the 1950s and 1960s, after a temporary increase in the 1970s. Prior to the 1950s, the value of infrastructure assets relative to GDP was rising as we built out the foundations of our infrastructure networks (Figure 4).

Figure 4: Estimated value of infrastructure assets relative to GDP, 1870–2022



Source: New Zealand Infrastructure Commission estimates. Note: Post-1990 estimates should be treated as most reliable, while estimates for the 1870s to the 1920s should be treated as less reliable than estimates for later years.

Transformative technology change can drive investment booms

We identify four periods where overall investment investment, across all networks, was meaningfully above long-term trends for a decade or more (see box right).

During these investment boom periods, spending was higher in a single large sector (land transport in the Vogel boom) or across multiple infrastructure sectors (schools, social housing, hospitals and electricity in the post-war boom).

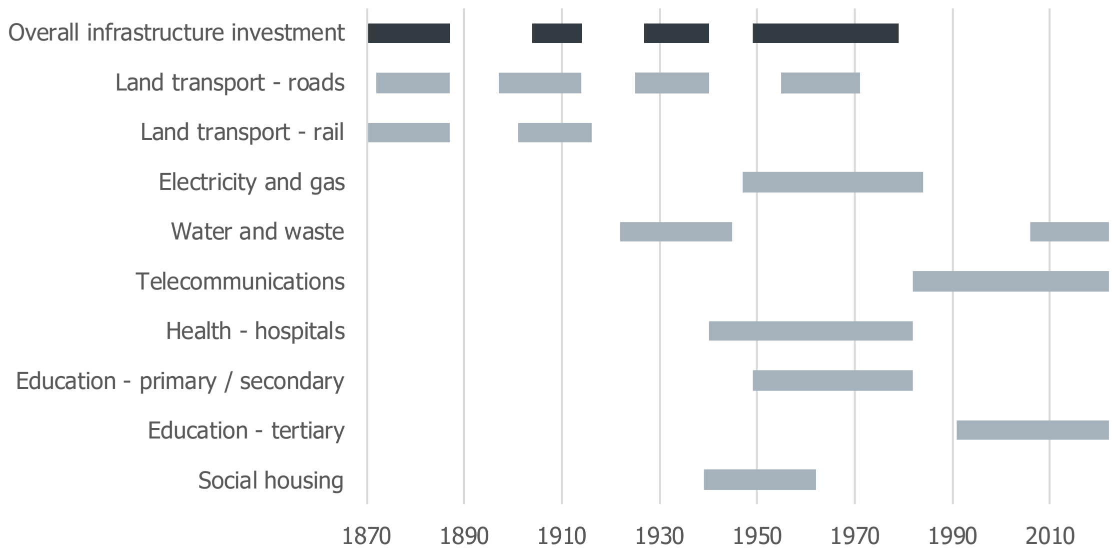
Going down to the sector level, we identify 14 investment booms across nine separate infrastructure sectors. Some sectors experienced multiple booms (such as land transport) while others had a single, sustained boom (hospitals, education, telecommunications) (Figure 5).

The Four Investment Booms

We identify four periods of time where total infrastructure investment was well above its historical average:

- **The Vogel boom**, from around 1870 to 1887, includes Premier Julius Vogel's public works schemes for network infrastructure (road, rail, telegraphs).
- **The pre-war boom**, from around 1904 to 1914, was a period of higher investment following recovery from the Long Depression. This was a time when the economy was being reshaped by refrigeration.
- **The inter-war boom**, from around 1927 to 1940, was a period of higher investment following the recovery from the First World War and continuing through the Great Depression public works programmes.
- **The post-war boom**, from around 1949 to 1979, coinciding with the period of population and economic growth after the Second World War.

Figure 5: Estimated timing of sector-level infrastructure booms, 1870–2022



Source: New Zealand Infrastructure Commission estimates. Note: Post-1990 estimates should be treated as most reliable, while estimates for the 1870s to the 1920s should be treated as less reliable than estimates for later years.

Sector-level infrastructure investment booms tend to follow transformative technological innovations that created demand for building an entirely new infrastructure investment or significantly improving the quality of an existing network. For example, land transport investment booms coincide with or closely follow the invention of new transport technologies, like railways and internal combustion engines, and the recent telecommunications investment boom coincides with rapid innovation in information and computing technology.

By the end of an investment boom, we have more infrastructure than before. In some booms, infrastructure networks get a lot bigger, as more people are connected to growing networks. In other booms, infrastructure quality improves rapidly, such as when we paved most our road network.

Sector-level investment booms change the mix of infrastructure we have. For example, prior the long post-war electricity investment boom, electricity infrastructure accounted for around one-tenth of the total value of our infrastructure assets. By the end of the boom, electricity had doubled to almost one-fifth of the total value of infrastructure assets. The amount of electricity available per person rose dramatically as a result.

However, investment booms do not last forever. There are limits to how much infrastructure people can productively use, meaning that the per-person size and value of infrastructure networks cannot keep rising indefinitely. And once network expansion slows down, so too does investment. It costs more to build a network from scratch than it does to maintain the network and incrementally upgrade it to serve new growth.

If the past is any indication of the future, future infrastructure investment booms are most likely to follow a transformative technological change, on par with the invention of the electric dynamo, the internal combustion engine, or the computer. These technological innovations led to meaningful improvements in people’s lives, generating the demand for rapid expansions of infrastructure that people were willing to pay for.

Looking ahead

Over the last 150 years New Zealand has experienced many economic, demographic, natural, and geopolitical shocks. These shocks have included (but are not limited to) oil and wool price shocks, two world wars, two global depressions and a major global financial crisis, multiple pandemics, and three large earthquakes. Despite all of this, we’ve found that overall infrastructure investment has generally stayed within a band of 5% to 7% of GDP.

Spending is likely to be remain somewhere in this range over the next 30 years. We are currently developing a National Infrastructure Plan that includes forward guidance on the level of infrastructure investment that will be demanded to maintain our existing assets and grow them to meet future demographic, economic, and climate scenarios. These forecasts sit at the midpoint of this range, and slightly above the 150-year average.

The future is always uncertain. We will face novel challenges that require our attention, like mitigating and adapting to climate change. But past generations have already navigated many of the issues we face today, such as demographic change, economic growth, technology change, and political and policy change. Understanding how they responded to those challenges can help guide our thinking about the future.

Did you **know?**

Roads

1925
Over 2/3 of our road network length existed

74,350km then compared to 97,230km today

But, in **1925** less than **2%** of **roads were paved**.
Today, **67%** of our **roads are paved**.

Water

1900s
40% of all homes had piped drinking water.

1947
80% of all homes had piped drinking water.

2023
100% of all homes had piped drinking water.

Electricity

1947
generation capacity for our electricity network was 460MW

1984
capacity had increased by over **16x** to 7,580MW

Today
our generation capacity stands at 9,850MW

Telecommunications

1917
Telegraph line length peaked

1999
Fixed-line telephone subscriptions peaked

2017
Mobile telephone subscriptions peaked

Broadband internet subscriptions are still rising

Note: Numbers have been rounded.

Introduction

We need to understand the past to forecast the future

Taking a long-term view on infrastructure investment is important because infrastructure networks, as well as individual infrastructure assets, are generally long-lived. Networks take decades to build, and once they have been built it is necessary to maintain and incrementally improve them on a perpetual basis, unless they are replaced by new technologies.

A short-term view on investment, covering only a few years, may not allow us to understand how much is being spent on networks, and whether this is appropriate to meet long-term needs. For instance, a few years of low investment may not be a concern, but if investment is systematically too low to maintain asset condition for decades, then this could cause more serious problems.

However, New Zealand, like many other countries, has a significant deficit of long-run infrastructure investment data. We know what we are currently spending on infrastructure, but we know less about what we spent in the decades when we originally built our networks.

This report sets out to address this knowledge gap. We expect the long-run infrastructure data presented in this report to improve the New Zealand Infrastructure Commission's ability to advise on long-term infrastructure needs and the ability of our current infrastructure to meet community expectations.

Long-run data sheds light on the drivers of investment

Infrastructure responds to economic, technological, and policy factors. When demand for infrastructure services grows, investment in new or improved infrastructure assets is needed to meet that demand.

In the future, infrastructure will have to deal with some novel challenges, such as the impacts of mitigating and adapting to climate change. These challenges will no doubt drive changes to infrastructure investment. But most future challenges facing infrastructure networks, such as demographic change, economic growth, technology change, and political and policy change, have precedents in the historical data. What happened in the past can therefore help us form expectations about the future.

In the long term, investment rates reflect economic fundamentals

Infrastructure investment has both benefits and costs. The benefits of infrastructure networks for economic productivity and well-being must be weighed up against the costs of building and maintaining those networks (Glaeser & Poterba, 2021; New Zealand Infrastructure Commission, 2021). In previous research, we outlined a 'golden rule' for infrastructure investment, which is to target a ratio of infrastructure capital to output that balances this trade-off.[1]

Ongoing investment is needed to maintain the optimal ratio of infrastructure stock to GDP. This includes investment to renew and replace existing assets that are wearing out, and investment to expand or improve networks to keep pace with population and productivity growth (including rising quality expectations). Required investment levels are higher when population and productivity growth is higher, and lower when growth is slower.[2]

For instance, if our population starts to grow more rapidly, then we will need to build more roads, water pipes, schools, and hospitals to serve added demand. While we may need to take out loans to finance the investment, increased tax revenues, rates, and user charges should ultimately allow us to repay those loans. On average, growth should create demand *and* the means to supply it.

Empirical evidence is consistent with this theoretical model. Since 1960, OECD countries (a grouping of high-income countries) have chosen to invest more in public infrastructure when their population and incomes are growing more rapidly (New Zealand Infrastructure Commission, 2024d; Oxford Economics & Global Infrastructure Hub, 2017). Relative to how fast its population and productivity has grown, New Zealand has invested at the expected rate over the entire 1960–2019 period, although there have been periods of higher and lower investment during this time.

Large technology changes can create networks

Over very long periods of time, transformative changes in technology can create demand for entirely new types of infrastructure, or large-scale changes to existing infrastructure (Fouquet, 2014; Goldsmith, 2014; Gordon, 2016; Grimes, 2008). When this happens, higher investment is needed to build out new networks. Often, these networks provide entirely new services or replace inferior alternatives that did not rely on networked infrastructure.

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[1] We use an infrastructure-augmented version of the Solow long-run growth model, following Barro (1990) and Mankiw et al (1992), to show that the optimal ratio of infrastructure capital stock to GDP (K*) depends upon the marginal productivity of infrastructure capital (ε), the efficiency of investment delivery (γ), real interest rates (r), and depreciation rates for infrastructure assets (δ). Formally, $K^* = \frac{\varepsilon * \gamma}{r+\delta}$. See New Zealand Infrastructure Commission (2021) for derivation.

[2] Based on the infrastructure-augmented Solow long-run growth model described in the previous footnote, we observe that optimal infrastructure investment as a share of GDP (I*) can be expressed as a function of the optimal ratio of capital stock to GDP (K*), population growth rate (n), productivity growth rate (a), and depreciation rate for infrastructure assets (δ). Formally, $I^* = K^* * (n + a + \delta)$. This is the rate of investment that results in a stable ratio of capital stock to GDP in the context of a growing economy.

For instance, electric lighting replaced gas lighting and candles, and sewer networks replaced cesspits and night-soil collection.

Development and uptake of new infrastructure networks tends to follow an 'S-curve' pattern, with rapid deployment once they reach a critical threshold of connectivity or usefulness followed by slowing growth once demand is saturated (Goldsmith, 2014).[3] Significant investment is needed to build a new network from scratch – well ahead of what would be needed to keep up with underlying population and productivity growth. However, once the network is built, less investment is needed to maintain it and improve it to keep pace with population and productivity growth.

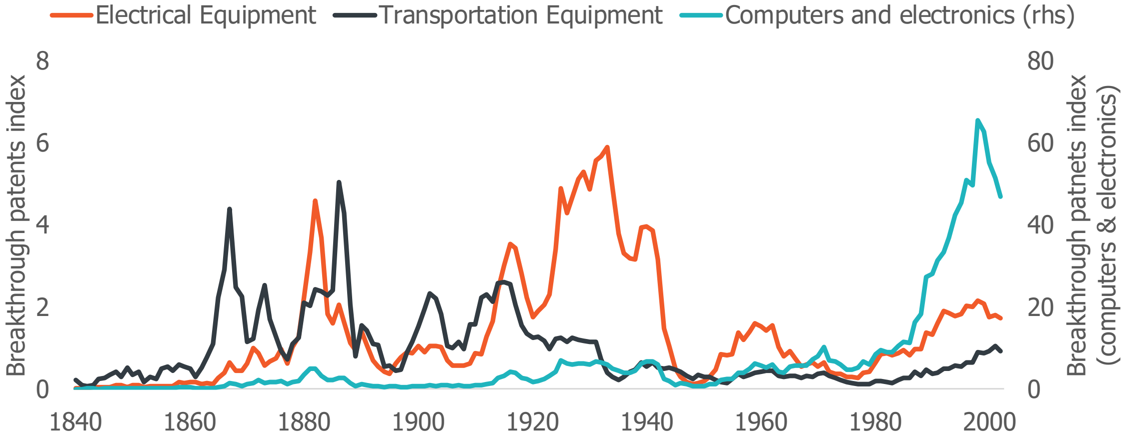
Technology change can also lead to decommissioning of old, obsolete networks. For instance, copper telecommunication lines have mostly been replaced by fibre-optic networks. When this happens, investment in the network declines, ultimately to zero, as new assets are no longer built and existing assets are removed rather than being renewed.

Infrastructure technologies are constantly improving in small steps. However, transformative technology changes that create the need for new networks are rare.

Figure 6 illustrates this point using data from a 'breakthrough patents index' that identifies transformative technology changes in several sectors that affect network infrastructure (Kelly et al., 2021). There was a period of rapid, fundamental innovation in transportation equipment and electrical equipment in the late 1800s and early 1900s, followed by a slowdown in the pace of change. Computers and electronics, which shape demand for modern telecommunication networks, experienced rapid technology change starting in the 1980s.

[3] We can analyse uptake of a new infrastructure service using the 'discrete choice' model pioneered by Daniel McFadden for assessing demand for new transport options. This model predicts users' choices between two or more separate alternatives, based on their preferences and the relative price and quality of alternatives. For instance, a household may choose between different energy sources for home heating and power – such as wood stoves/fireplaces, piped gas, grid-connected electricity, or off-grid electricity from solar panels and battery storage. The probability that the household chooses one option over others is a function of the relative cost and quality of that option. If one option is getting cheaper or better over time, more households will choose it. Under standard modelling assumptions, this leads to an S-curve pattern of uptake for a new technology that improves significantly over time. See Train (2009) for more details.

Figure 6: Breakthrough patents index for three sectors related to network infrastructure, 1840–2002



Source: Adapted from Kelly et al (2021). Note: Important transportation equipment patents include the bicycle (1866), internal combustion engine (1877), pneumatic tyres (1891), diesel engine (1898), airplane (1906), and automotive transmission (1911). Important electrical equipment patents include incandescent lighting (1880), AC induction motor (1888), radio (1897), and television (1929). Important computers and electronics patents include the microcomputer (1979), packet-switching technology (1989), spreadsheets (1993), 1-click online buying (1999), and Google Pagerank (2001).

Public policy can shape demand, but there are limits to how much

Public policy can shift demand for infrastructure services, changing perceptions of investment needs. One example is how peak-time congestion charges on urban roads may reduce demand for new road capacity and increase demand for public transport services (New Zealand Infrastructure Commission, 2024b). Another example is how land-use policies, such as zoning regulations, can influence where new housing is built and how expensive it is to service with infrastructure (New Zealand Infrastructure Commission, 2022b).

Public policy may also encourage infrastructure to be built ahead of expected future demand. For instance, governments may build infrastructure with significant excess capacity for growth or provide subsidies for commercial providers to build extra capacity.

Public policies can therefore boost infrastructure investment in the short run, but in the long run it is hard to sustain investment levels significantly higher than what's needed to respond to fundamentals. This is because we rely upon growth in demand to generate new tax and user charge revenues to repay the costs of building and maintaining infrastructure.

For instance, if we choose to increase expenditure on roads, water pipes, schools, and hospitals *without* a matching increase in population growth, then the loans that financed the added investment would be difficult to repay without increasing tax rates, or user charges on the existing population (New Zealand Infrastructure Commission, 2025). We would therefore need to cut back on other investment to service the loans. In the long run, investment levels may ultimately be lower, not higher, as a result (New Zealand Infrastructure Commission, 2024c).

We show how New Zealand's infrastructure has grown over time

We analyse a period that includes many fundamental changes

This technical report addresses a roughly 150-year period that includes many fundamental economic, technological, and policy changes that have affected infrastructure investment, as well as society in general (Easton, 2020). Our estimates illustrate how infrastructure investment has responded, at a national level, to large changes as well as little ones.

Over the last 150 years New Zealand has seen periods of very high inward migration as well as periods of very low migration, or even net migration outflows (Productivity Commission, 2022). It has experienced significant price shocks for export commodities, such as the 1966 wool price collapse and the dairy price boom in the 2000s and 2010s, and import commodities, such as the 1973 and 1979 oil price shocks (Productivity Commission, 2024). More generally, economic and population growth rates have varied from year to year and decade to decade (New Zealand Institute of Economic Research, 2024).

New Zealand has responded to rare but high-impact events, including two world wars (1914–1918, 1939–1945), two global depressions (the Long Depression in the 1870s thru 1890s and the Great Depression in the 1930s), the 2008 Global Financial Crisis, and multiple global pandemics (the 1918–1920 flu pandemic, the 1957–1958 influenza pandemic, the ongoing HIV/AIDS pandemic, and the recent COVID-19 pandemic). There have also been several major natural hazard events, including the 1886 Tarawera eruption, the 1931 Hawke's Bay earthquake, Cyclone Bola in 1987, the 2010–2011 Canterbury earthquakes, and the 2016 Kaikōura earthquake.

On the positive side, New Zealand, like many other countries, has benefitted from technological innovation. This includes uptake of transformative technologies like the electric motor, internal combustion engine, and computer (Gordon, 2016).

Politics and public policy have changed dramatically over the last 150 years. New Zealand saw several major changes to voting rights (universal male suffrage in 1879 and female suffrage in 1893) and electoral systems (notably the 1996 introduction of mixed-member proportional representation). New political parties were established, and some existing parties declined. There were 15 changes in party government during this time. Sometimes, elections led to large shifts in public policy. The 1891–1912 Liberal Government, 1935–1949 First Labour Government, and 1984–1990 Fourth Labour Government were notable for major social and economic reforms.

We collected a wide variety of infrastructure-related variables over a long period of time

In this report, we compile and present new long-run estimates that show how New Zealand's infrastructure networks have grown over time. These estimates cover both 'horizontal' or 'network' infrastructure, like roads and electricity, and 'vertical' or 'social' infrastructure, like hospitals and schools.[4] They cover the years from 1870 to 2022, although data is not available for the full period for all types of infrastructure. In some cases, this is due to insufficient data quality or availability in the pre-1900 period. In other cases, it is because investment in these networks only began after 1870.

Prior to 1870, New Zealand had a small population (less than 280,000 people) served by a small amount of infrastructure (for example, only 74 km of rail track were open at this point). Most of the technologies underpinning modern infrastructure, from the internal combustion engine to the fibre optic cable, had not yet been invented. Starting our analysis at this point allows us to capture almost all infrastructure investment in New Zealand that is likely to be relevant for modern-day outcomes.

This report presents *estimates*, corresponding as closely as possible to modern sectoral definitions, but that the underlying data sources are not compiled in a consistent way over time. In general, post-1990 estimates, which are based on Stats NZ National Accounts data coded to a consistent sectoral classification, should be treated as *most reliable*. Pre-1990 estimates should be treated as *less reliable* than post-1990 estimates, and the reliability of estimates for the 1870s to the 1920s should be treated as *less reliable* than estimates for later years.

For each infrastructure sector, we provide estimates for four key variables:

- **Capital investment**: We estimate annual capital expenditure in new, improved, or renewed infrastructure assets (excluding land purchase). This definition excludes operational maintenance expenditure and other costs involved in operating infrastructure networks.
- **Capital stocks**: We estimate the annual dollar value of infrastructure assets (excluding land values), based on what's been spent on those assets in the past, and how fast existing assets are wearing out.
- **Physical size and characteristics**: We provide information on the quantity, quality, and/or usage of infrastructure networks over time.
- **Infrastructure construction prices**: We provide long-term estimates of how infrastructure construction prices have changed over time, relative to prices elsewhere in the economy.

The second section of this report outlines key trends in investment and capital stock across all infrastructure networks, while the third section examines trends at a sectoral

[4] The Appendix explains how we defined infrastructure sectors.

level. We conclude by discussing the implications of our findings. The Appendix explains sources and methods for our estimates, which build upon previous work by Mulcare (1994) and information published by Stats NZ and other government agencies.

Overall infrastructure investment trends

We begin by outlining overall trends in infrastructure investment and capital stocks over the 1870–2022 period and considering the relationship between infrastructure investment and underlying demographic and economic trends.

Comparisons across time are challenging because New Zealand's population and economy grew significantly over this period, and prices for infrastructure construction and other goods and services have risen significantly. A dollar of spending today is not equivalent to a dollar of spending 50 or 100 years ago. We must adjust for changes to prices, population, and incomes.[5]

In 1870, national population was less than 280,000 and economic output (gross domestic product, or GDP) was around $2.8 billion, in 2025 inflation-adjusted terms. At this point, we invested around $260 million in infrastructure (again in inflation-adjusted terms). In 2022, New Zealand's population had risen almost twenty-fold to 5.1 million people and economic output had risen to almost 150 times its 1870 level, to nearly $430 billion. Infrastructure investment in 2022 was 100 times higher, at over $26 billion (in inflation-adjusted 2025 dollars).

To adjust for population and economic growth over this period, we present overall infrastructure investment and capital stock estimates in two ways:

- **In real, per-capita terms**: This indicates how much we are spending on infrastructure investment per person, adjusted for economy-wide inflation, and how much infrastructure we have per person.[6]
- **As a share of annual GDP**: This indicates the 'share of our wallet' that we are spending on infrastructure investment and how valuable our infrastructure assets are relative to annual economic output.

[5] It is also challenging to construct long-term estimates of economy-wide prices, population size, and economic activity, as the data sources used for modern economic statistics are not available consistently through time. There are several sources for historical estimates. In recent decades we use Stats NZ data for population estimates (1991–2024), nominal GDP (1972–2025), and real GDP (1978–2025). Prior to this point we use population and GDP estimates from NZIER's Data1850 tool. We construct GDP deflators using nominal and real GDP series. We use 2025 as a base year for real GDP estimates.

[6] We adjust prices using an economy-wide GDP deflator, which controls for how rapidly prices are rising for all the goods and services produced in the New Zealand economy. An alternative would be to deflate prices using a consumer price index (were one available over the required timeframe) or an infrastructure construction price index.

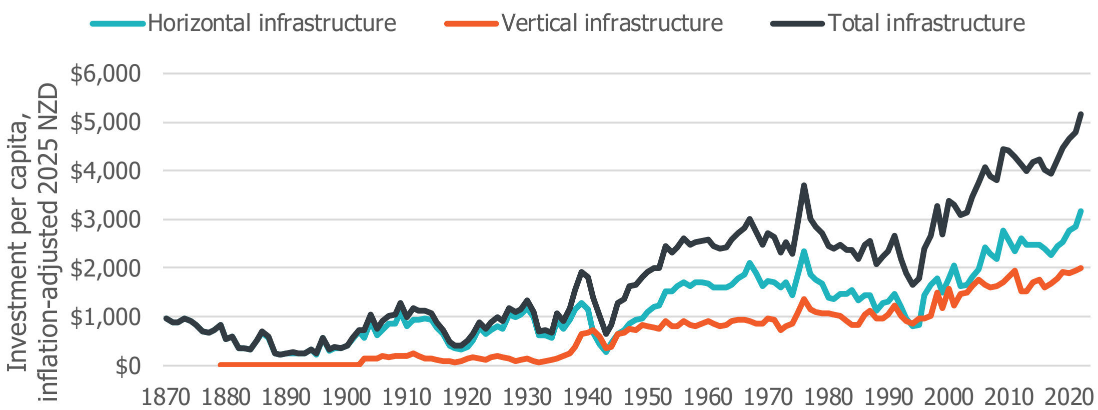
Infrastructure investment has risen as the economy grows

Investment per person has risen over time

Figure 7 shows how infrastructure investment per person has risen over time, adjusting for economy-wide inflation. Prior to the 1930s, annual spending on infrastructure was typically less than $1000 per person. Annual spending rose to over $2000 per person in the decades after the Second World War.

Per-person infrastructure investment rose significantly starting in the mid-1990s, averaging almost $4500 per person from 2013 to 2022. Per-person spending on both horizontal infrastructure like land transport, water, and electricity and vertical infrastructure like schools, hospitals, and courthouses is at a historic high.

Figure 7: Annual estimates of real infrastructure investment per capita, 1870–2022



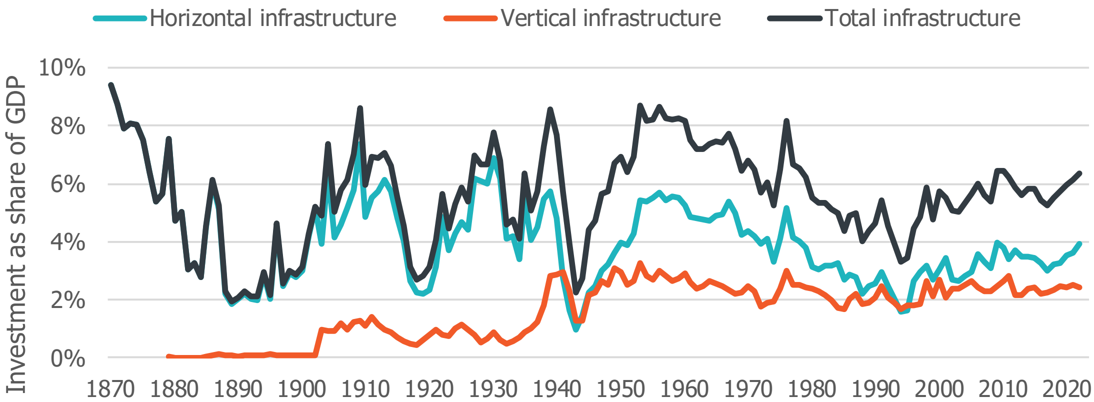
Source: New Zealand Infrastructure Commission estimates. Note: Post-1990 estimates should be treated as most reliable, while estimates for the 1870s to the 1920s should be treated as less reliable than estimates for later years.

The ‘share of our wallet’ spent on infrastructure has been reasonably consistent over time

Per-person investment has risen over time because average incomes have risen, meaning we now have more money to spend on investment. Figure 8 shows how infrastructure investment as a share of GDP has changed over the last 150 years. Overall infrastructure investment has averaged 5.6% of GDP over this time. There is no clear upwards or downwards trend in investment as a share of GDP.

However, investment levels vary from year to year and from decade to decade. Annual investment has been as low as 1.9% of GDP and as high as 9.4%, although extremely high or low investment levels tend to last for only a few years. When averaged over 30-year periods, investment levels have never been higher than 7.3% (1949–1978 average) nor lower than 5.0% (1978-2007 average).

Figure 8: Annual estimates of infrastructure investment as a share of GDP, 1870–2022



Source: New Zealand Infrastructure Commission estimates. Note: Post-1990 estimates should be treated as most reliable, while estimates for the 1870s to the 1920s should be treated as less reliable than estimates for later years.

Investment levels fell to a post-Second World War low in the early 1990s but subsequently rebounded. By the early 2000s, infrastructure investment had returned to near its long-run average. From 2003 to 2022, overall infrastructure investment averaged 5.8% of GDP, slightly higher than the long-run average, but with much less year-to-year volatility than we observe in previous decades.

We observe some sustained investment 'booms'

There are several periods where infrastructure investment as a share of GDP is sustained at a considerably higher level than the long-run average. We define these periods as infrastructure investment 'booms' – a concept that we will return to in the next section on sectoral investment trends.[7]

We identify four investment boom periods, plus a more recent period where infrastructure investment is consistently close to the long-run average (Figure 9).

The **Vogel boom**, from around 1870 to 1887, includes Premier Julius Vogel's public works schemes for network infrastructure (road, rail, telegraphs). It was ended by the impacts of the global Long Depression on New Zealand's economic growth. Investment subsequently declined as growth prospects slowed and high public debt levels constrained investment.

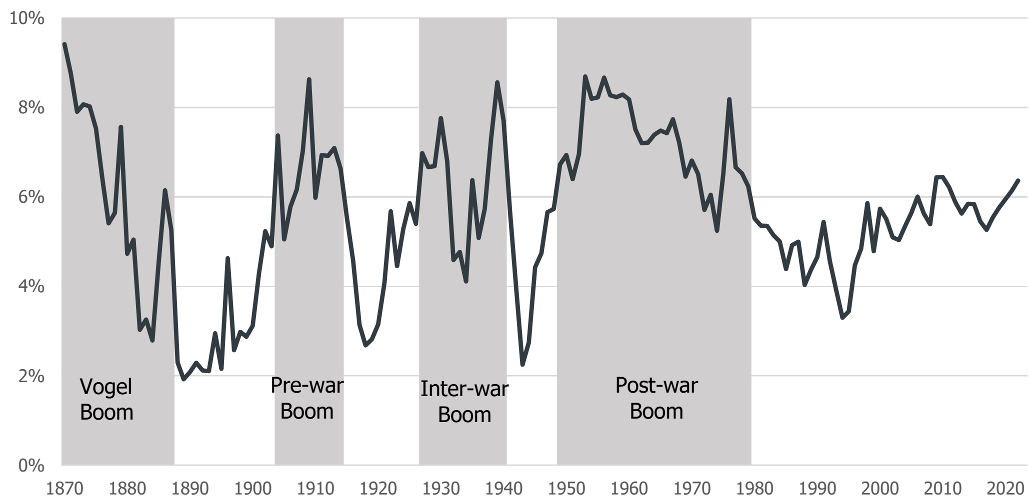
[7] We define a 'boom' as a continuous or near-continuous period of at least 10 years where investment as a share of GDP is 10% or more above the long-run average (i.e., more than 6.5% of GDP). At most one-quarter of years can be more than 10% below the long-run average. Because data coverage and quality for vertical infrastructure investment is lower prior to 1900, we define the late 1800s infrastructure investment boom period using data on horizontal infrastructure investment only rather than total infrastructure investment. Boom periods identified using this definition are similar to the central and local government investment cycles that we identified in previous research (New Zealand Infrastructure Commission, 2024c).

The **pre-war boom**, from around 1904 to 1914, was a period of higher investment following recovery from the Long Depression. This was a time when the economy was being reshaped by refrigeration. It ended due to the First World War, which diverted public spending to the war effort.

The **inter-war boom**, from around 1927 to 1940, was a period of higher investment following the recovery from the First World War and continuing through the Great Depression public works programmes. It ended due to the Second World War, which again diverted public spending to military ends.

The **post-war boom**, from around 1949 to 1979, is the longest period of consistently above-trend investment that we observe. It coincides with the period of population and economic growth after the Second World War. It ended during the late 1970s, following adverse price shocks for exports (the 1966 wool price shock) and imports (1973 and 1979 oil shocks).

Figure 9: Infrastructure investment booms, as a share of GDP, 1870–2022



Source: New Zealand Infrastructure Commission estimates. Note: Post-1990 estimates should be treated as most reliable, while estimates for the 1870s to the 1920s should be treated as less reliable than estimates for later years.

Lastly, infrastructure investment over the last two decades has consistently been close to the long-run average. This period is notable for several external shocks, such as the 2008 Global Financial Crisis and COVID-19 pandemic, against a backdrop of reasonably stable economic performance and rising population growth.

Table 1 shows how overall infrastructure investment levels compare between boom periods and periods of lower investment. In general, booms tend to be followed sustained periods of lower-than-average investment.

Table 1: Average infrastructure investment as a share of GDP in periods of high and low investment

Investment period	Horizontal infrastructure	Vertical infrastructure	Total infrastructure
Vogel boom, 1870–1887	6.1%	(limited data)	6.1%
1888–1903	2.9%	0.1%	3.0%
Pre-war boom, 1904–1914	5.6%	1.1%	6.7%
1915–1926	3.6%	0.8%	4.4%
Inter-war boom, 1927–1940	5.2%	1.1%	6.4%
1941–1948	2.2%	2.2%	4.4%
Post-war boom, 1949–1979	4.7%	2.6%	7.2%
1980–2002	2.7%	2.1%	4.8%
Recent decades, 2003–2022	3.4%	2.4%	5.8%
1870–2022 average	**4.1%**	**1.6%**	**5.6%**

Source: New Zealand Infrastructure Commission estimates. Note: Post-1990 estimates should be treated as most reliable, while estimates for the 1870s to the 1920s should be treated as less reliable than estimates for later years. Table shows the simple average of investment rates in each period. Numbers may not sum correctly due to rounding.

Periods of higher population and income growth don't necessarily align with investment booms

While population size and economic activity influence demand for infrastructure, investment booms do not necessarily coincide with faster growth in population and GDP.

Table 2 compares average annual growth rates in population and per-capita GDP (a proxy for incomes) in investment booms periods and periods of lower investment. Periods with above-average population growth rates or per-capita GDP growth rates are highlighted in bold.

Growth rates are often similar between boom periods and adjacent periods of lower investment, and in some cases are higher in periods of lower investment. For instance, per-capita GDP growth was slightly higher in the 1980–2002 period than in the post-war boom, while population growth was significantly lower in the inter-war boom relative to adjacent periods of lower investment.

This highlights the need to consider other factors, like technological innovation that enables or requires new types of infrastructure networks to be built, as a driver of investment over time. We return to this point in the following section when considering sectoral trends.

Table 2: Average population and GDP per capita growth rates in periods of high and low investment

Investment period	Population growth	Per-capita real GDP growth
Vogel boom, 1870–1887	**5.1%**	0.8%
1888–1903	1.9%	**1.8%**
Pre-war boom, 1904–1914	**2.5%**	1.1%
1915–1926	1.9%	0.5%
Inter-war boom, 1927–1940	1.0%	**2.6%**
1941–1948	1.6%	**2.7%**
Post-war boom, 1949–1979	1.7%	1.4%
1980–2002	1.0%	1.5%
Recent decades, 2003–2022	1.3%	1.5%
1870–2022 average	**2.0%**	**1.5%**

Source: New Zealand Infrastructure Commission analysis of data from Stats NZ and NZIER Data1850. Note: Table shows the simple average of growth rates in each period.

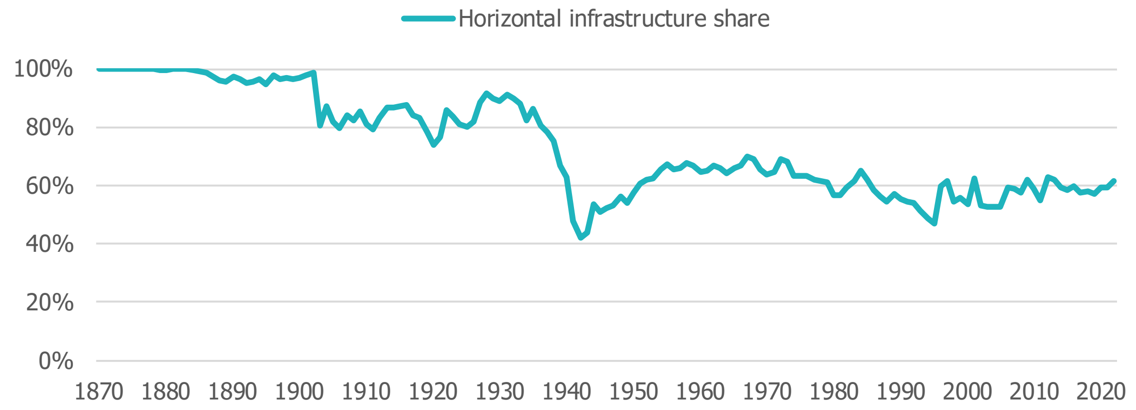
The mix of investment has changed over time

While overall investment levels have been reasonably consistent over time, the mix of investment has changed significantly over time. We now invest in a wider range of infrastructure than we did in the past, in response to social, economic, and technology changes that create demand for new types of infrastructure.

Figure 10 shows how the broad balance between horizontal and vertical infrastructure investment has shifted over time. In the late 1800s, horizontal infrastructure, like roads, railways, telegraphs, and water networks, accounted for almost all investment. From the early 1900s to mid-1930s, horizontal infrastructure accounted for around 80% of total investment, as we increased investment in schools, hospitals, and public safety and administration to serve rising expectations for these services.

During the 1930s and 1940s, the share of total investment going towards vertical infrastructure increased significantly, as central government provision of hospitals, education, and social housing increased further. Since the early 1950s, horizontal infrastructure has consistently accounted for around 60% of total infrastructure investment. We discuss these trends in more detail in the following section.

Figure 10: Horizontal infrastructure investment as a share of total infrastructure investment, 1870–2022



Source: New Zealand Infrastructure Commission estimates. Note: Post-1990 estimates should be treated as most reliable, while estimates for the 1870s to the 1920s should be treated as less reliable than estimates for later years. Pre-1900 estimates likely over-state the horizontal infrastructure investment share as data quality for vertical infrastructure sectors is lower prior to 1900.

The value of infrastructure capital has risen over time

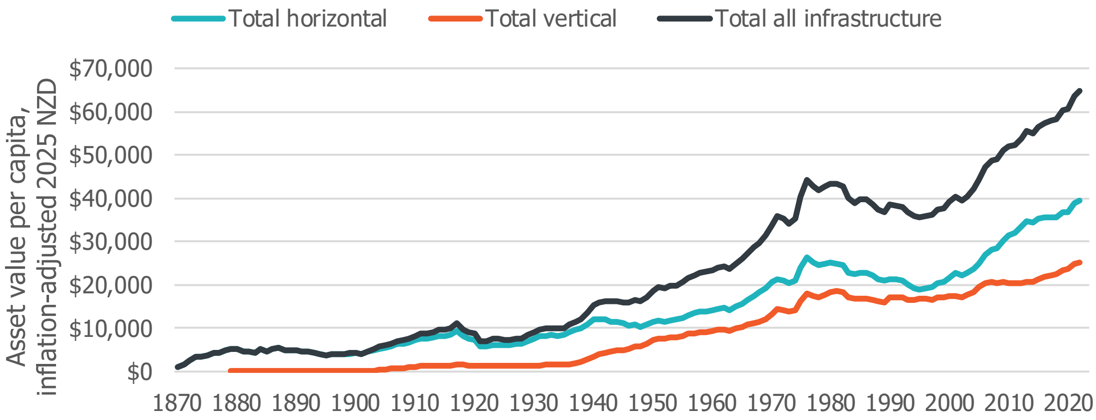
The per-person value of infrastructure capital has risen over time

Figure 11 shows how the per-person value of infrastructure assets has risen over time, adjusting for economy-wide inflation. Per-capita infrastructure asset value has increased by a factor of ten over the last century. This means that investment has outpaced population growth and depreciation of infrastructure assets.

However, there are some periods where the per-person value of infrastructure assets has stagnated or even declined. This includes short periods during and after the world wars, as well as a longer period between the late 1970s and late 1990s.

The per-person value of infrastructure assets started rising in the late 1990s. Since then, the per-person value of infrastructure assets has nearly doubled, from around $36,000 to over $60,000 per capita, with faster growth in horizontal infrastructure assets. Again, this indicates that investment has outpaced population growth and depreciation.

Figure 11: Estimated value of real infrastructure capital stock per capita, 1870–2022



Source: New Zealand Infrastructure Commission estimates. Note: Post-1990 estimates should be treated as most reliable, while estimates for the 1870s to the 1920s should be treated as less reliable than estimates for later years.

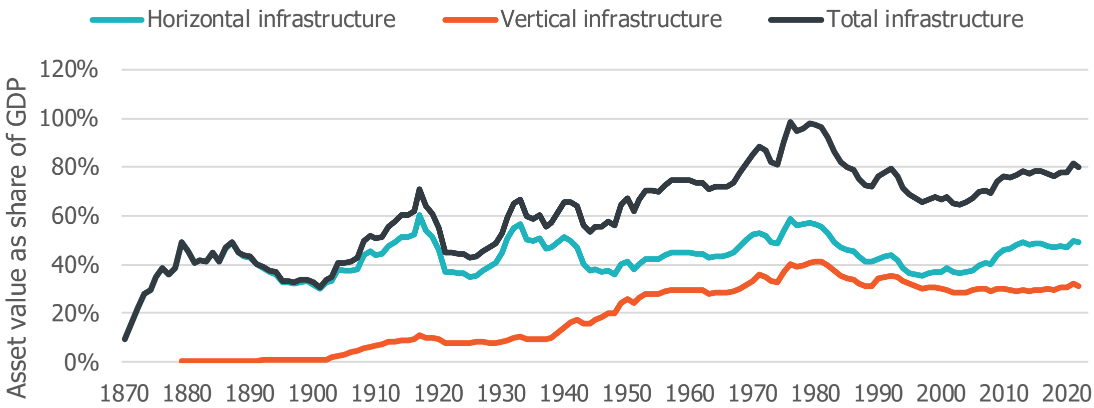
The value of infrastructure assets relative to GDP varies over time

The per-person value of infrastructure assets has risen over time because average incomes have risen. Figure 12 shows how estimated infrastructure asset value relative to GDP has changed over the last 150 years. This provides a summary measure of how 'infrastructure-intensive' the New Zealand economy has been over time.

Over the whole period, the value of infrastructure assets has generally risen relative to GDP. We estimate that infrastructure assets were valued at around 40% of GDP in the late 1800s, rising to around 60% prior to the First World War and increasing further following the Second World War.

Since 1950, the ratio of infrastructure asset values to GDP has varied within a range, but not trended upwards or downwards. Over this period, the asset value to GDP ratio has ranged from a low of around 65% (in the early 1950s and late 1990s) to a high of around 98% (in the late 1970s). Over the last decade, it has stabilised at the midpoint of this range, with a value of around 80% in 2022.

Figure 12: Estimated value of infrastructure assets relative to GDP, 1870–2022



Source: New Zealand Infrastructure Commission estimates. Note: Post-1990 estimates should be treated as most reliable, while estimates for the 1870s to the 1920s should be treated as less reliable than estimates for later years.

Capital to output ratios rise during investment booms

Table 3 shows that the investment boom periods identified above correspond with increases in the value of infrastructure assets relative to GDP, while periods of lower investment tend to see declines.

There are two reasons why infrastructure asset values increase more rapidly during investment booms. The first reason, which we discuss above, is that we invest a greater share of GDP in infrastructure during investment booms. The second reason is that infrastructure construction prices tend to rise more rapidly during booms than during periods of lower investment. Rising construction prices lead to upwards revaluation of existing infrastructure assets, as the cost to replace them is rising (Statistics New Zealand, 2014).

For example, we estimate that infrastructure construction prices rose 1.2% annually, relative to prices elsewhere in the economy, during the 1949–1979 post-war boom. Conversely, real infrastructure prices fell by 1.1% annually during the subsequent period of lower investment from 1980 to 2002. The rise and decline of the asset value to GDP ratio that we observe over this period is due partly to changing prices, rather than changing investment levels.

Table 3: Changes in the value of infrastructure assets as a share of GDP and changes in real infrastructure construction prices in periods of high and low investment

Investment period	Infrastructure asset value as a share of GDP at:		Compound annual average change in real infrastructure construction prices
	Start of period	End of period	
Vogel boom, 1870–1887	9%	49%	2.1%
1888–1903	49%	35%	0.2%
Pre-war boom, 1904–1914	35%	60%	0.9%
1915–1926	60%	43%	-2.5%
Inter-war boom, 1927–1940	43%	65%	2.4%
1941–1948	65%	56%	0.4%
Post-war boom, 1949–1979	56%	98%	1.2%
1980–2002	98%	65%	-1.1%
Recent decades, 2003–2022	65%	80%	1.1%

Source: New Zealand Infrastructure Commission estimates. Note: Post-1990 estimates should be treated as most reliable, while estimates for the 1870s to the 1920s should be treated as less reliable than estimates for later years.

The mix of infrastructure assets has changed over time

New Zealand's mix of infrastructure assets has changed significantly over the last 150 years, including during periods where the overall ratio of infrastructure asset values to GDP is stable.

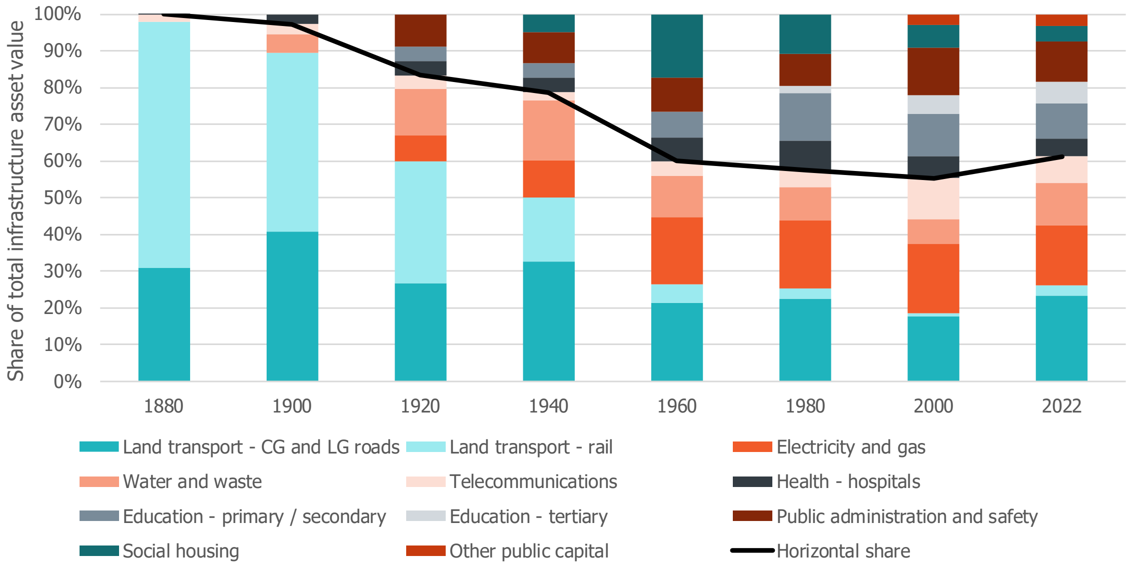
Figure 13 summarises the composition of New Zealand's infrastructure assets, by value, at 20-year intervals from 1880 onwards. Coloured bars show the share of total asset values that fall into each asset category, and the solid black line shows horizontal infrastructure assets as a share of the total.

In the late 1800s and early 1900s, land transport – road and rail assets – accounted for almost all infrastructure assets by value. Our infrastructure asset base diversified substantially from 1900 to 1960, with the development and growth of electricity infrastructure, substantial growth in water infrastructure, the expansion of school and hospital networks, and significant investment in social housing.

Our infrastructure asset base has diversified further in recent decades. From 1980 to 2022, telecommunication networks and tertiary education assets grew as a proportion of total asset value, while social housing declined in relative terms. Water and land transport assets declined as a share of total asset values between 1980 and 2000, but subsequently increased.

In short, asset values do not grow at the same rate across all infrastructure sectors. Rather, the mix of investment changes over time, in response to changing demands for different types of infrastructure services. In the next section, we explore how investment and asset values have evolved at a sectoral level.

Figure 13: Estimated mix of infrastructure assets, by share of total asset value, 1880–2022



Source: New Zealand Infrastructure Commission estimates. Note: Post-1990 estimates should be treated as <u>most reliable</u>, while estimates for the 1870s to the 1920s should be treated as <u>less reliable</u> than estimates for later years. Pre-1900 estimates likely over-state the horizontal infrastructure investment share as data quality for vertical infrastructure sectors is lower prior to 1900.

Sectoral investment trends

We now examine trends in infrastructure investment and capital stocks at a sectoral level over the period for which we have long-term data for each sector. We also provide information on how the physical size of infrastructure networks has expanded over time.

To adjust for population and economic growth over this period, we present estimates of infrastructure investment and asset values as a share of annual GDP. This indicates the 'share of our wallet' that we are spending on infrastructure investment and how valuable our infrastructure assets are relative to annual economic output. We present information on the physical size of infrastructure networks in per-capita terms, indicating how much infrastructure we have per person.[8]

We identify 14 sector-level investment booms

We previously observed that overall infrastructure investment has experienced several boom periods that are not always correlated with higher population and economic growth. A possible explanation for this is that large increases in investment are driven by technological changes that create demand for new or significantly improved infrastructure networks.

In this section, we analyse and summarise sector-level investment booms, which are periods where infrastructure investment as a share of GDP is sustained at a considerably higher level than the long-run average.[9] Based on this definition, we identify a total of 14 investment boom periods across nine infrastructure sectors. There are no well-defined infrastructure sectors where investment levels are stable over time, without periods of above- or below-trend investment.

Different sectors boom at different times

Figure 14 shows the estimated timing of 'sector-level investment booms', relative to overall infrastructure investment booms. Sectoral boom periods generally coincide with or overlap the overall boom periods we identified in the previous section. However, different sectors tend to boom at different times, and individual sectors can experience investment

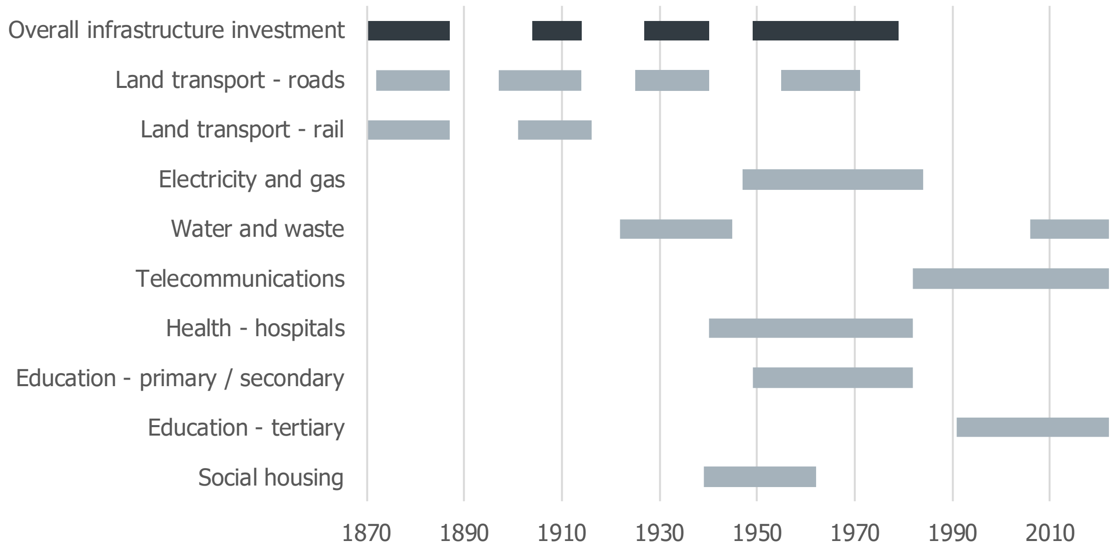
[8] We adjust prices using an economy-wide GDP deflator, which controls for how rapidly prices are rising for all the goods and services produced in the New Zealand economy. An alternative would be to deflate prices using a consumer price index (were one available over the required timeframe) or an infrastructure construction price index.

[9] At the sector level, we define a 'boom' as a continuous or near-continuous period of at least 10 years where investment as a share of GDP is 25% or more above the long-run average for that sector. At most, one-quarter of years can be more than 25% below the long-run average. We choose a higher threshold for defining sectoral booms than we used for defining overall investment booms because sector-level investment is smaller than the total and hence can vary more from year to year. We vary this approach for tertiary education because we only have investment estimates for the 1972–2022 period. As pre-1972 investment in tertiary education is likely to be small, we define the boom period based on years where investment is above the 1972–2022 average.

booms during times when overall infrastructure investment is at or below the long-run average.

For instance, the long post-war infrastructure investment boom, which lasted from around 1949 to 1979, was driven by higher investment in roads (booming from around 1955 to 1971), electricity and gas infrastructure (around 1947 to 1984), hospitals (around 1940 to 1982), primary and secondary education (around 1949 to 1982), and social housing (around 1939 to 1962). However, other sectors, such as rail, water, telecommunications, and tertiary education, were not booming during this time.

Figure 14: Estimated timing of sector-level investment booms, 1870–2022



Source: New Zealand Infrastructure Commission estimates. Note: Post-1990 estimates should be treated as most reliable, while estimates for the 1870s to the 1920s should be treated as less reliable than estimates for later years.

On average, capital investment is two-thirds higher during investment booms

Investment levels tend to be higher during investment booms. But periods of high investment do not last forever.

Table 4 summarises the estimated length of each sectoral investment boom and average investment levels, as a share of GDP, during each boom. We find that the median sectoral investment boom lasts around 21 years, although some booms have gone on for twice as long as this.

In the median investment boom, capital investment is around 67% higher than the long-run average for that sector. For example, capital investment in hospitals averaged 0.42% of GDP during the 1940-1982 boom, which is 67% higher than the sectoral long-run average of 0.25% of GDP. However, some booms are larger or smaller in relative terms.

Table 4: Summary of sectoral investment booms by length and investment levels

Sector	Start	End	Boom length (years)	Long-term average investment (% GDP)	Average investment during boom (% GDP)	Percentage deviation from long-run average
Land transport – roads	1872	1887	16	1.20%	1.88%	57%
	1897	1914	18	1.20%	1.63%	36%
	1925	1940	16	1.20%	1.99%	67%
	1955	1971	17	1.20%	1.55%	30%
Land transport – rail	1870	1887	18	1.12%	4.05%	261%
	1901	1916	16	1.12%	2.39%	113%
Electricity and gas	1947	1984	38	1.19%	2.04%	71%
Water and waste	1922	1945	24	0.48%	0.76%	60%
	2006	2022	17	0.48%	0.65%	37%
Telecommunications	1982	2022	41	0.43%	0.88%	103%
Health – hospitals	1940	1982	43	0.25%	0.42%	68%
Education – primary/secondary	1949	1982	34	0.41%	0.72%	75%
Education – tertiary	1991	2022	32	0.44%	0.54%	23%
Social housing	1939	1962	24	0.44%	1.10%	150%
Median sectoral boom			21			67%

Source: New Zealand Infrastructure Commission estimates. Note: Post-1990 estimates should be treated as most reliable, while estimates for the 1870s to the 1920s should be treated as less reliable than estimates for later years. In each sector, long-run average investment is calculated over the full period for which data is available, which is longer in some sectors than others.

We build our networks during booms

Sectoral investment booms coincide with rapid, one-off increases in the coverage or quality of infrastructure networks. Investment booms tend to start with unfinished networks that are only serving part of the population or providing lower levels of service, and end with relatively mature networks that are serving almost all potential users, typically at a higher level of service.

We have data on growth in the physical size of networks (or a proxy measure) for 12 of the 14 sectoral investment booms and estimates of growth in the inflation-adjusted value of infrastructure assets in each sector. We use this information to summarise how the physical size and quality of infrastructure networks evolved through infrastructure investment booms.

Investment booms result in more infrastructure per person

Table 5 summarises growth in per-capita network size and asset values over the course of 14 sectoral investment booms. This table provides summary information on how rapidly infrastructure networks expanded in size or quality, relative to population growth, during booms.

Sector-level booms result in large increases in per-person infrastructure stocks. In the median investment boom, the inflation-adjusted financial value of infrastructure assets per person tripled, while the physical size of infrastructure networks increased by around 42%. In short, investment booms result in larger and higher-quality infrastructure networks.

Table 5: Growth in per-capita network size and asset values during sector-level investment booms

Sector	Start	End	Percentage change in per-capita network size				Percentage change in real capital stock per capita
				Measure 1		Measure 2	
Land transport – roads	1872	1887		No data			+351%
	1897	1914		No data			+79%
	1925	1940	+27%	Total road length	+557%	Paved road length	+170%
	1955	1971	-18%	Total road length	+86%	Paved road length	+119%
Land transport – rail	1870	1887	+1520%	Total railway length			+354%
	1901	1916	-3%	Total railway length			+86%
Electricity and gas	1947	1984	+673%	Electricity generation capacity	+76%	Transmission and distribution line length	+295%
Water and waste	1922	1945	+322%	Dwellings with indoor/flush toilets	+48%	Dwellings with piped water	+217%
	2006	2022	0%	Dwellings with indoor/flush toilets	+1%	Dwellings with piped water	+81%
Telecommunications	1982	2022	+253%	Total telephone subscriptions	+∞%	Broadband internet subscriptions	+124%
Health – hospitals	1940	1982	-11%	Public hospital beds			+430%
Education – primary/secondary	1949	1982	+22%	Primary and secondary students	-37%	Primary and secondary schools	+535%
Education – tertiary	1991	2022	+37%	Tertiary students			+239%
Social housing	1939	1962	+822%	State rental units available			+985%
Median sectoral boom			**+42%**				**+227%**

Source: New Zealand Infrastructure Commission estimates. Note: Post-1990 estimates should be treated as most reliable, while estimates for the 1870s to the 1920s should be treated as less reliable than estimates for later years. Network size measures are generally more reliable than capital stock estimates. However, in some cases, estimating changes in network size involved interpolating between data points (as in the case of water network coverage) or adjusting for changes in how data was reported at the start and end of the boom period (as in the case of transmission and distribution line length). The 'Total road length' measure sums together the length of *paved roads and metalled roads, but excludes the length of dirt roads. The 'Total telephone subscriptions' measure sums together fixed-line and mobile telephone subscriptions.*

Table 6 provides an alternative view on this data, showing how network size and asset values grew relative to underlying economic growth. In the median investment boom, the ratio of infrastructure assets to GDP doubled. This suggests that the economy becomes more 'infrastructure-intensive' during sectoral investment booms.

Table 6: Growth in network size and asset values per unit GDP during sector-level investment booms

Sector	Start	End	Percentage change in per-capita network size				Percentage change in real capital stock per capita
			Measure 1		Measure 2		
Land transport – roads	1872	1887		No data			+353%
	1897	1914		No data			+36%
	1925	1940	-8%	Total road length	+375%	Paved road length	+95%
	1955	1971	-40%	Total road length	+36%	Paved road length	+59%
Land transport – rail	1870	1887	+1372 %	Total railway length			+312%
	1901	1916	-21%	Total railway length			+51%
Electricity and gas	1947	1984	+363%	Electricity generation capacity	+5%	Transmission and distribution line length	+137%
Water and waste	1922	1945	+14%	Dwellings with indoor/flush toilets	-21%	Dwellings with piped water	+72%
	2006	2022	-16%	Dwellings with indoor/flush toilets	-16%	Dwellings with piped water	+51%
Telecommunications	1982	2022	+102%	Total telephone subscriptions	+∞%	Broadband internet subscriptions	+28%
Health – hospitals	1940	1982	-55%	Public hospital beds			+170%
Education – primary/secondary	1949	1982	-30%	Primary and secondary students	-64%	Primary and secondary schools	+267%
Education – tertiary	1991	2022	-17%	Tertiary students			+105%
Social housing	1939	1962	+521%	State rental units available			+631%
Median sectoral boom			**-11%**				**+100%**

Source: New Zealand Infrastructure Commission estimates. Note: Post-1990 estimates should be treated as <u>most reliable</u>, while estimates for the 1870s to the 1920s should be treated as <u>less reliable</u> than estimates for later years. Network size measures are generally more reliable than capital stock estimates. However, in some cases, estimating changes in network size involved interpolating between data points (as in the case of water network coverage) or adjusting for changes in how data was reported at the start and end of the boom period (as in the case of transmission and distribution line length). The 'Total road length' measure sums together the length of paved roads and metalled roads, but excludes the length of dirt roads. The 'Total telephone subscriptions' measure sums together fixed-line and mobile telephone subscriptions.

Different booms lead to different outcomes

However, different investment booms lead to different outcomes for infrastructure networks. By comparing the pace of changes in per-capita network size and per-capita asset values, we can understand the types of outcomes that were being purchased in each boom period.

We can draw a rough distinction between two different types of booms.

First, **network expansion booms** involve rapid expansion of both per-capita network size and per-capita asset values. During these booms, the physical size of networks grows, indicating that coverage or usage of these networks is growing rapidly.

An example is the 1947–1984 electricity networks boom. During this boom, per-capita asset values quadrupled, electricity generation capacity per capita increased by 673%, and the per-capita length of transmission and distribution lines increased by 76%. Other examples of network expansion booms include the 1870–1887 railway boom, the 1922–1945 water network boom, the 1982–2022 telecommunications boom, and the 1939–1962 social housing boom. The 1872–1887 and 1897–1914 road investment booms are likely to fall into this category, but we lack information on the physical size of the road network during this period.

Second, **quality improvement booms** involve rapid increases in per-capita asset values in the context of stable per-capita network size. During these booms, the physical size of networks grows roughly in line with population while asset values rapidly increase, indicating that the average quality or condition of these networks is growing rapidly.

An example is the 1955–1971 road network boom. During this boom, per-capita asset values doubled, but per-capita road length declined slightly. While the physical extent of the network lagged behind population growth, the quality of the network improved dramatically. The per-capita length of paved roads increased by 86% and the country's motorway network expanded rapidly. Other examples of quality improvement booms include the 1901–1916 railway boom, the 2006–2022 water networks boom, the 1940–1982 hospitals boom, and the 1949–1982 primary/secondary education boom. The 1991–2022 tertiary education boom has aspects of a network expansion boom and aspects of a quality improvement boom.

Infrastructure booms come to a natural end

The high investment levels observed in booms cannot be sustained indefinitely. There is a limit to how much infrastructure people can productively use, meaning that the per-capita size and value of infrastructure networks cannot keep rising. Once networks are mature, demand to continue expanding or improving them slows down.

Network size tends to stabilise, either in total or per-capita terms, at the end of investment booms. For instance, per-capita electricity generation capacity has been stable since the early 1980s, as investment slowed down to keep pace with population growth and asset renewal and replacement needs.

Sector-level investment booms tend to follow transformative technology changes

In the previous section, we observed that overall infrastructure investment booms were not well correlated with surges in population and economic growth. In this section, we have shown that sectoral investment booms happen at different times, and generally lead to rapid, one-off increases in the physical size or quality of infrastructure networks.

In turn, sectoral investment booms tend to be associated with transformative technology changes that create demand for new or fundamentally improved infrastructure networks.

We use the Kelly et al. (2021) breakthrough patents dataset to identify periods of unusually rapid and transformative technology change in four industries related to network infrastructure: transportation equipment, electrical equipment, utilities, and computers and electronics.[10] These industries sometimes relate to infrastructure sectors, but do not always correspond perfectly to specific networks. In particular, the 'Utilities' industry includes both electricity and gas and water and waste sub-industries.

This approach suggests that there have been two periods of rapid innovation in transportation equipment (1865–1891 and 1900–1929), two for utilities (1881–1896 and 1909–1936), one for electrical equipment (1914–1942), and one for computers and electronics (1981–2002). We note that:

- The two periods of rapid innovation in transportation equipment coincide with three out of four road network booms and with both railway booms.
- The period of rapid innovation in electrical equipment coincides with the early stages of New Zealand's investment in electricity networks and is closely followed by the electricity network boom.
- The second period of rapid innovation in utilities coincides with the first water network boom, which saw rapid network expansion.
- The period of rapid innovation in computers and electronics coincides with the telecommunications network boom.

While we cannot make causal statements about the link between technology change and investment booms, we note that contemporary commentators often highlighted technology change as a key driver for increased investment. For example, Stats NZ's 1950 *Official Yearbook* notes that the invention and adoption of the automobile created a need

[10] Patents are coded to NAICS industries using a classification system explained in the paper. We identify periods of high breakthrough patent activity using the same method we use to date sectoral investment booms. Periods of high breakthrough patenting activity are considered to start with a year where the breakthrough patents index is 25% or more above the long-run average, followed by 10 or more years where the index is generally 25% or more above the long-run average. At most one-quarter of years can be more than 25% below the long-run average.

to seal a much larger share of the network and strengthen road surfaces to accommodate greater volumes of heavy traffic:[11]

> *Prior to the advent of the motor-vehicle only a small proportion of the total road-mileage outside of boroughs was permanently surfaced. The development of motor-traffic, however, entirely changed the complexion of the roading problem in New Zealand, as elsewhere, and better roads were demanded as motor transport became popular. Later on, with the rapid increase in the use of motor-vehicles, particularly heavy ones, it became very evident that the type of road that was suitable for slow-moving horse-drawn traffic was inadequate. It was found that under the strain of motor traffic the roads, particularly those between the main centres running parallel with railways, were deteriorating, while the necessity for changes in both construction and administration became more and more obvious.*

Long-term data shows how infrastructure sectors evolved

Following the above summary of key features of sectoral investment booms, we examine investment and capital stock trends over time in four horizontal infrastructure sectors (roads; electricity and gas; water and waste; and telecommunications) and two vertical infrastructure sectors (hospitals and primary and secondary education). Full data on all infrastructure sectors is available in the databook accompanying this report. Our descriptive analysis illustrates how different infrastructure sectors have evolved over time.

Road investment: Expanding and then improving networks

Road capital investment is undertaken by both local and central government. We provide estimates for total road capital investment and for the share of the total that is undertaken by local government (for local roads) and central government (for state highways).

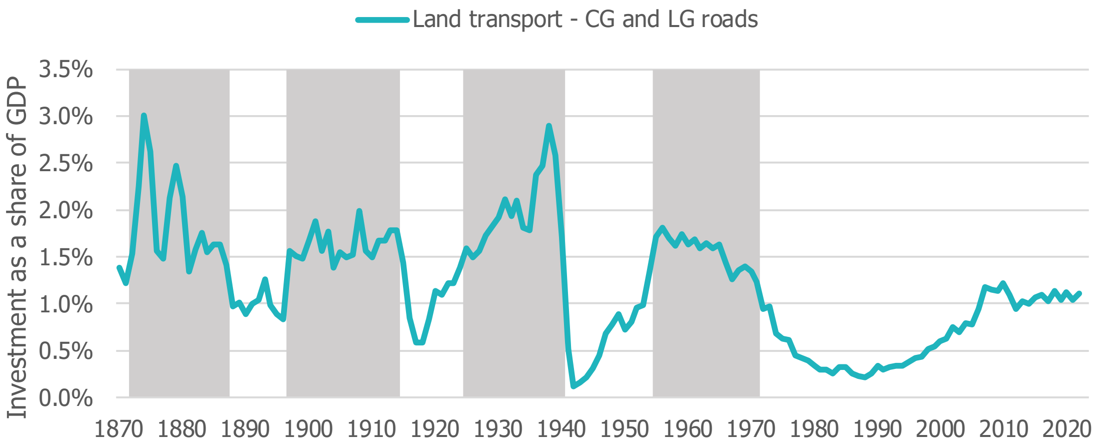
Prior to the 1920s, road investment was undertaken by local government and central government through the public works fund. Starting in 1925, central government began to collect fuel excise duty and use this money to invest directly in state highways (originally called main highways). This approach has continued, under various institutional arrangements, to the present day. Local governments continue to invest in roads (and other local transport infrastructure), funded out of a mix of local revenues (like rates) and co-funding from central government.

Figure 15 shows road investment as a share of GDP over time, highlighting four sectoral investment booms. We invested an average of 1.2% of GDP in roads over the entire 1870–2022 period. Capital investment averaged 1.9% of GDP during the first boom period

[11] https://www3.stats.govt.nz/New_Zealand_Official_Yearbooks/1950/NZOYB_1950.html#idchapter_1_129077

(1872–1887), 1.6% of GDP during the second boom (1897–1914), 2.0% of GDP during the third boom (1925–1940), and 1.6% of GDP during the fourth boom (1955–1971).

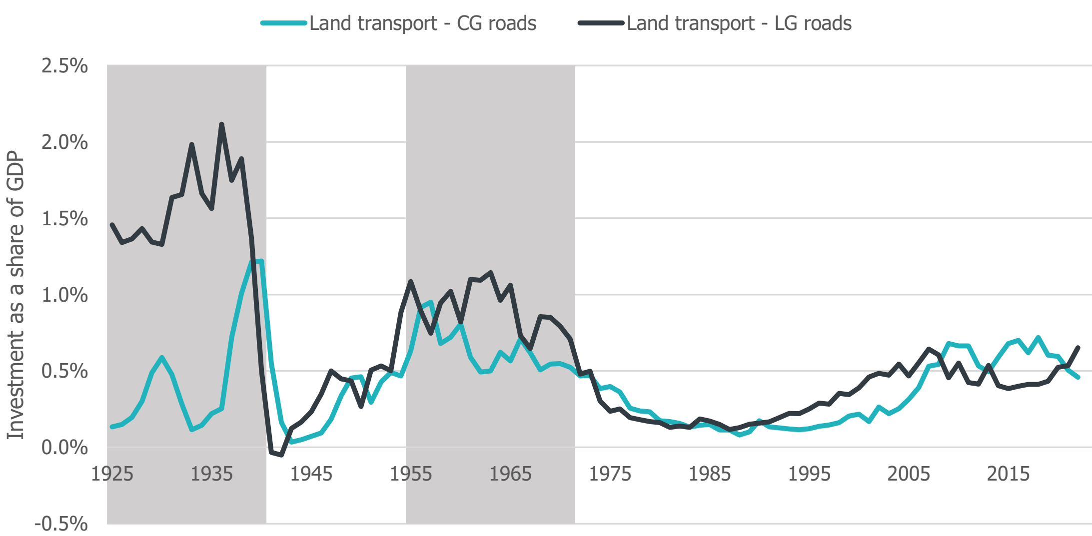
Figure 15: Capital investment in roads as a share of GDP, 1870–2022



Source: New Zealand Infrastructure Commission estimates. Note: Investment boom periods are highlighted in grey.

Figure 16 shows the composition of road investment by local and central government for years where we have available data. State highway investment has been significantly above its long-run average over the last 15 years. However, because local road investment has been below its long run average.

Figure 16: Capital investment in central and local government roads as a share of GDP, 1925–2022

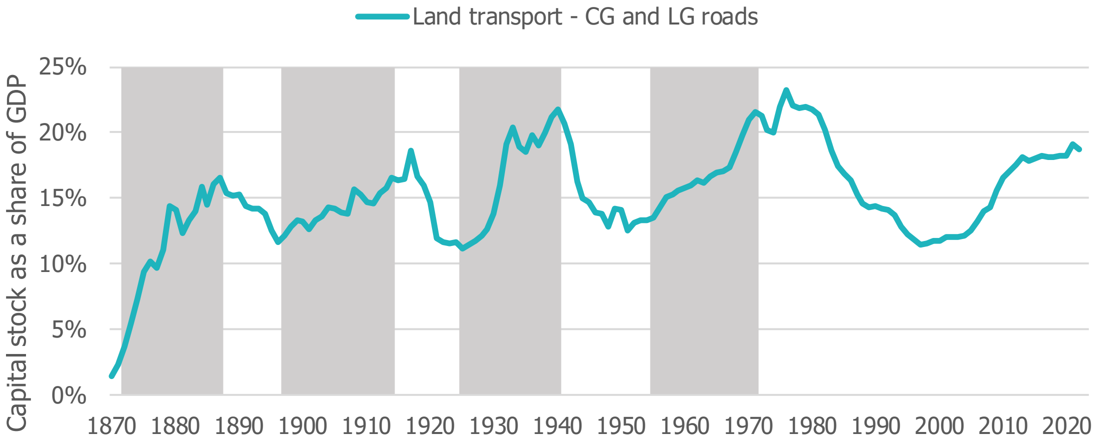


Source: New Zealand Infrastructure Commission estimates. Note: Investment boom periods are highlighted in grey.

Figure 17 shows the estimated value of road capital stock relative to GDP. Road capital-to-output ratios have tended to rise significantly during investment booms and decline after booms end.

Over the last century, we estimate that the value of road assets has varied from a low of around 11% of GDP to a high of around 23%. Road asset values have averaged around 16% of GDP over this time. Over the last decade, the value of road assets has stabilised at around 18% of GDP, slightly above the long-term average.

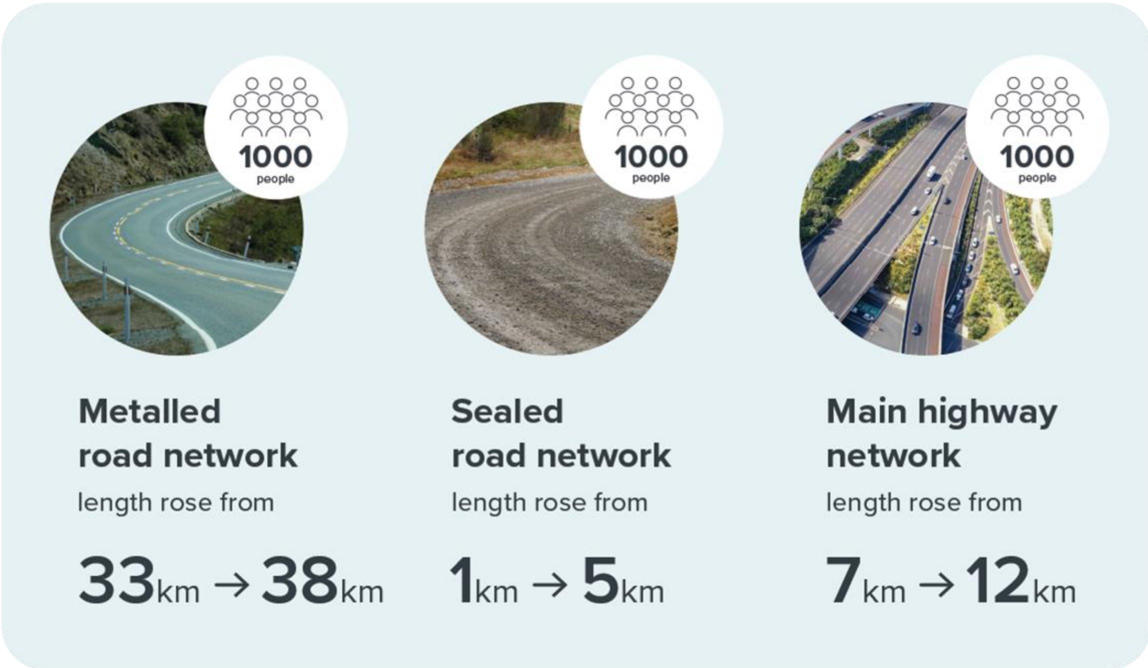
Figure 17: Estimated value of road capital stock as a share of GDP, 1870–2022



Source: New Zealand Infrastructure Commission estimates. Note: Investment boom periods are highlighted in grey.

Figure 18 shows how the physical size of New Zealand's road network expanded through the third and fourth booms (1925–1940 and 1955–1971). We do not have network size data for the pre-1925 period. We observe rapid increases in network size and quality in post-1925 booms.

In the third boom, New Zealand completed its network of basic metalled roads, began to expand the higher-quality sealed road network, and developed a new category of central-government funded main highways (a subset of which were later designated as the modern state highway network). During this time:



- metalled road network length rose from 33 km per 1000 people to 38 km
- sealed road network length rose from less than 1 km per 1000 people to 5 km
- main highway network length rose from 7 km per 1000 people to 12 km.

At the end of this boom, the total quantity of metalled and paved roads per capita peaked and began to decline. At this point, the country had finished building a basic road network that provided service to almost all New Zealanders. Further investment would be directed towards incrementally expanding the network in response to population growth and improving the quality of the network.

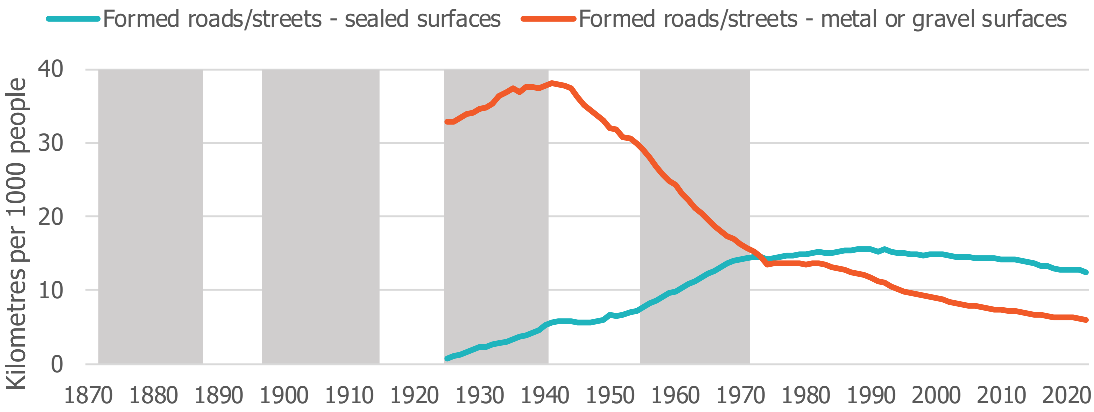
In the fourth boom, New Zealand significantly improved the quality of its road network by extending the sealed road network and building a high-capacity motorway network in some cities. During this time:

- sealed road network length rose from 8 km per 1000 people to 14.5 km, with a parallel reduction in metalled roads per capita
- motorway/expressway network length rose from 8 km per 1 million people to 37 km.

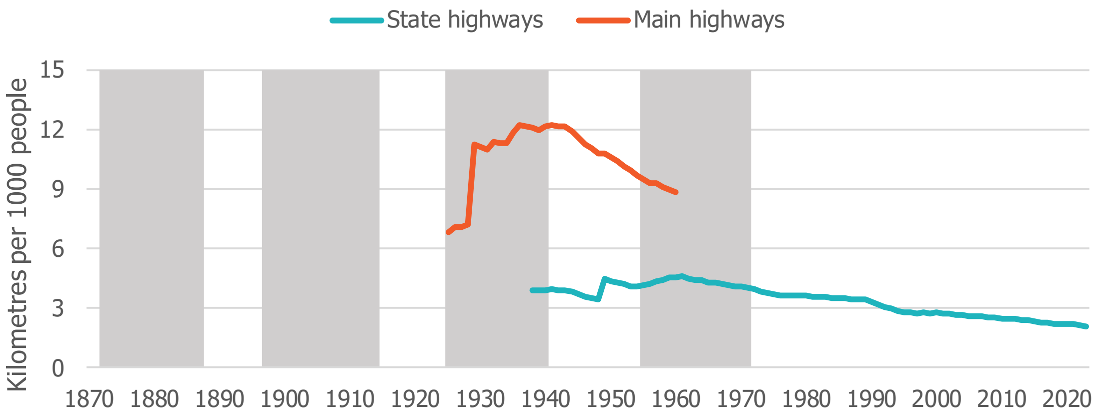
At the end of this boom, sealed road network per capita had reached 92% of its peak level, with slower increases in subsequent decades. Motorways per capita stabilised from the early 1970s to the late 2000s, with incremental increases to the network in line with population growth. However, since 2007 the quantity of motorways per capita has doubled, coinciding with a period of significantly higher investment in state highways.

Figure 18: Per-capita size of New Zealand's road network, 1925–2022

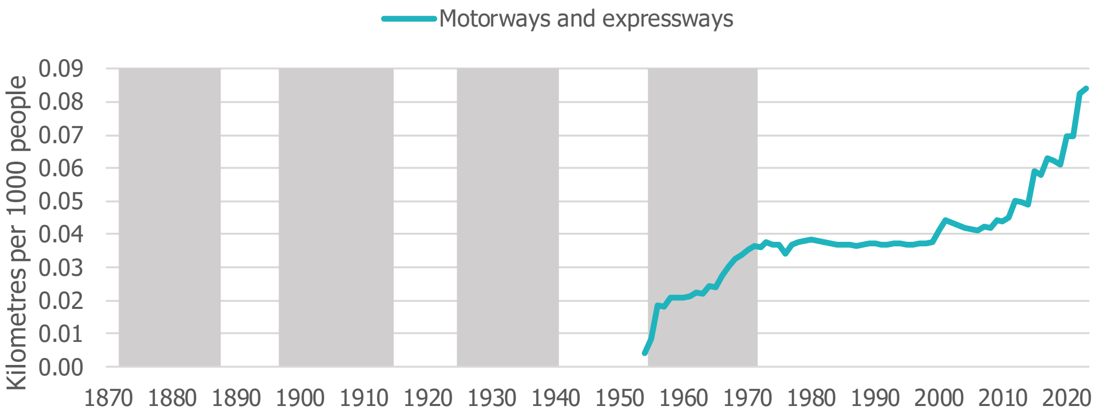
Panel A: Total sealed and metalled road network



Panel B: Main highway and state highway network



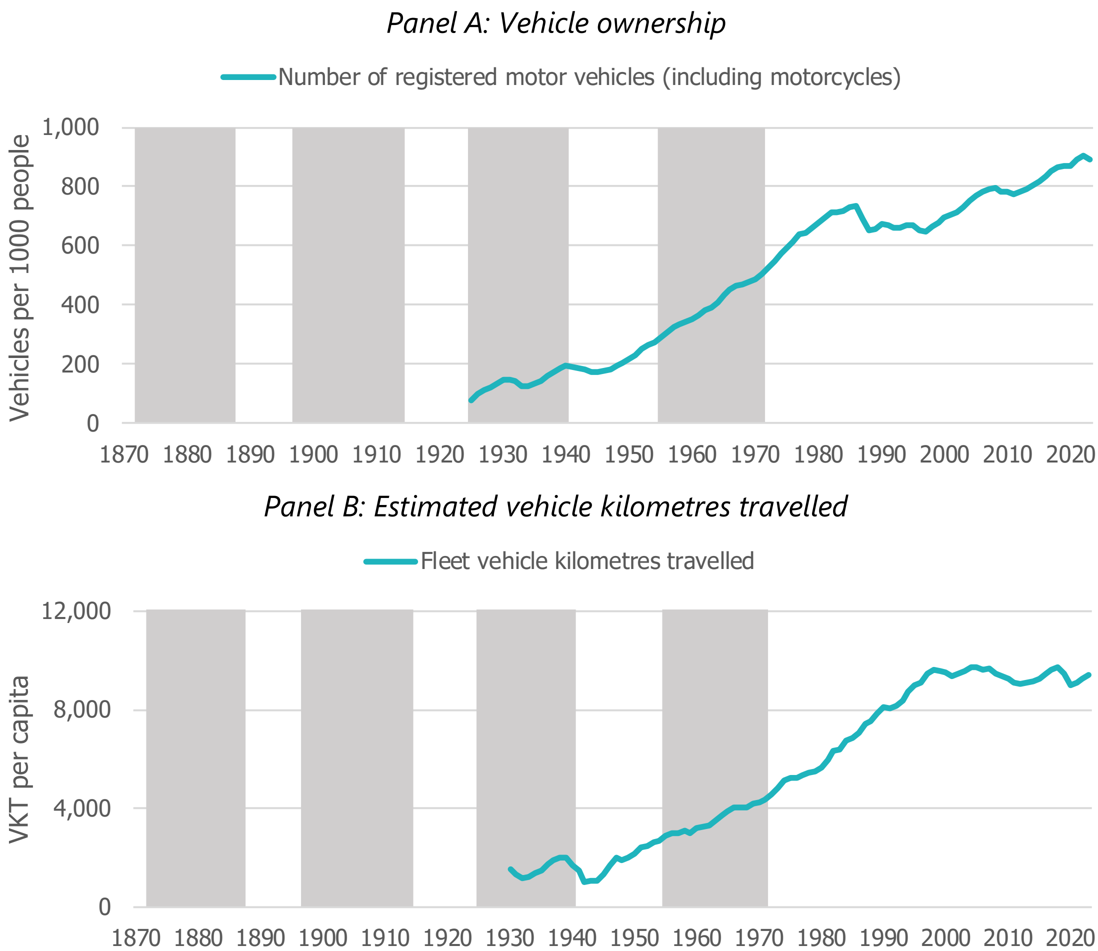
Panel C: Motorways and expressways



Source: New Zealand Infrastructure Commission estimates. Note: Investment boom periods are highlighted in grey.

Figure 19 shows that, although significant expansion of the extent of New Zealand's road network ceased after the end of the fourth investment boom, per-capita usage continued to rise for several more decades. Per-capita vehicle ownership stabilised in the 1980s and 1990s but has since increased further. Conversely, vehicle kilometres travelled grew throughout the 1980s and 1990s before stabilising from the early 2000s to the present. Ongoing growth in usage appears to have been accommodated through incremental network upgrades, plus increasing congestion on some urban road networks (New Zealand Infrastructure Commission, 2022b).

Figure 19: Per-capita usage of New Zealand's road network, 1925–2022



Source: New Zealand Infrastructure Commission estimates. Note: Investment boom periods are highlighted in grey.

Electricity and gas: Powering New Zealand

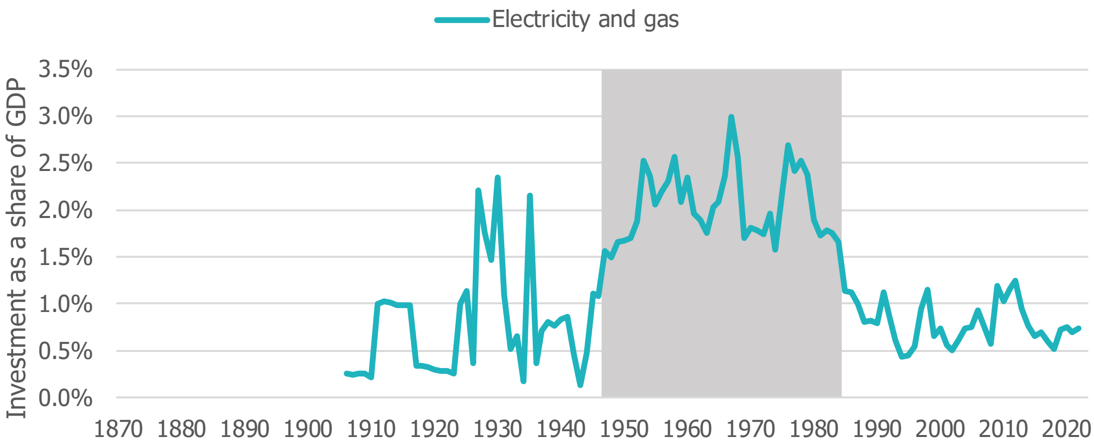
Institutional arrangements for undertaking electricity and gas capital investment have changed significantly since the early 1900s.

Prior to 1907, there was a small amount of investment by private companies (starting in Reefton in 1888). Local governments started investing in significant electricity generation and distribution schemes in 1907 (Dunedin City Council's Waipori scheme), followed by significant central government investment starting in 1910 (the Lake Coleridge scheme). From the end of the First World War to the late 1980s, both local and central governments played significant roles. The sector was corporatised and restructured in the late 1980s, and part-privatised in the 1990s. Today, investment is done by a mix of state-owned enterprises or mixed-ownership model companies, private companies involved in either generation or distribution, and council-owned electricity distribution companies.

Figure 20 shows that there has been one investment boom in electricity and gas, from 1947 to 1984. This includes the post-war period of growth and electricity-driven industrialisation and ends with the 'Think Big' period of state-sponsored major energy and industrial megaprojects (Boshier, 2022). During this investment boom, capital investment in electricity and gas averaged 2.1% of GDP, above the long-run average of 1.2%.

There are also some signs of a smaller but less consistent investment boom in the 1920s, when electricity distribution networks were being built by local power boards. This appears to have been cut short by the Great Depression.

Figure 20: Capital investment in electricity and gas as a share of GDP, 1906–2022

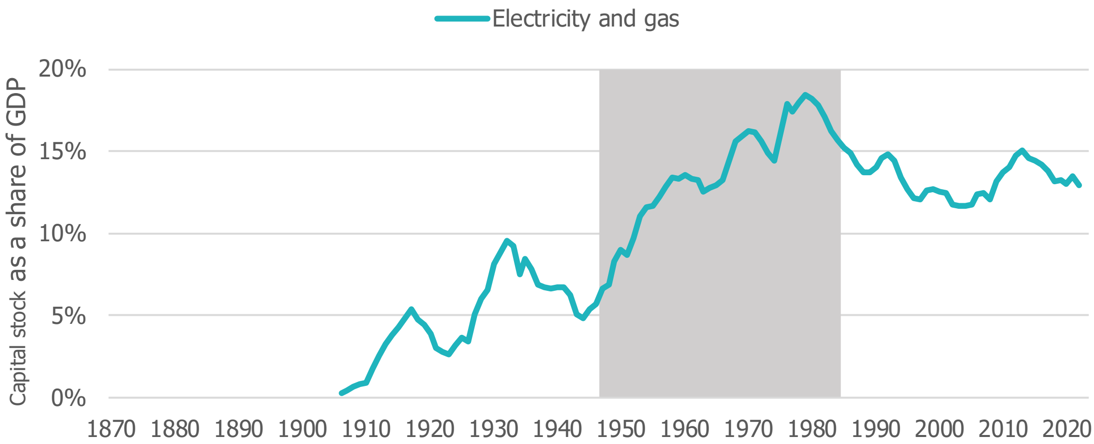


Source: New Zealand Infrastructure Commission estimates. Note: Investment boom periods are highlighted in grey.

Figure 21 shows the estimated value of electricity and gas capital stock relative to GDP. Capital-to-output ratios in this sector rose dramatically through the long boom period but declined somewhat after the end of the boom.

Over the last century, we estimate that the value of electricity and gas assets rose from around 3% to a peak of around 18%. Over the last decade, the value of these assets has averaged around 14% of GDP.

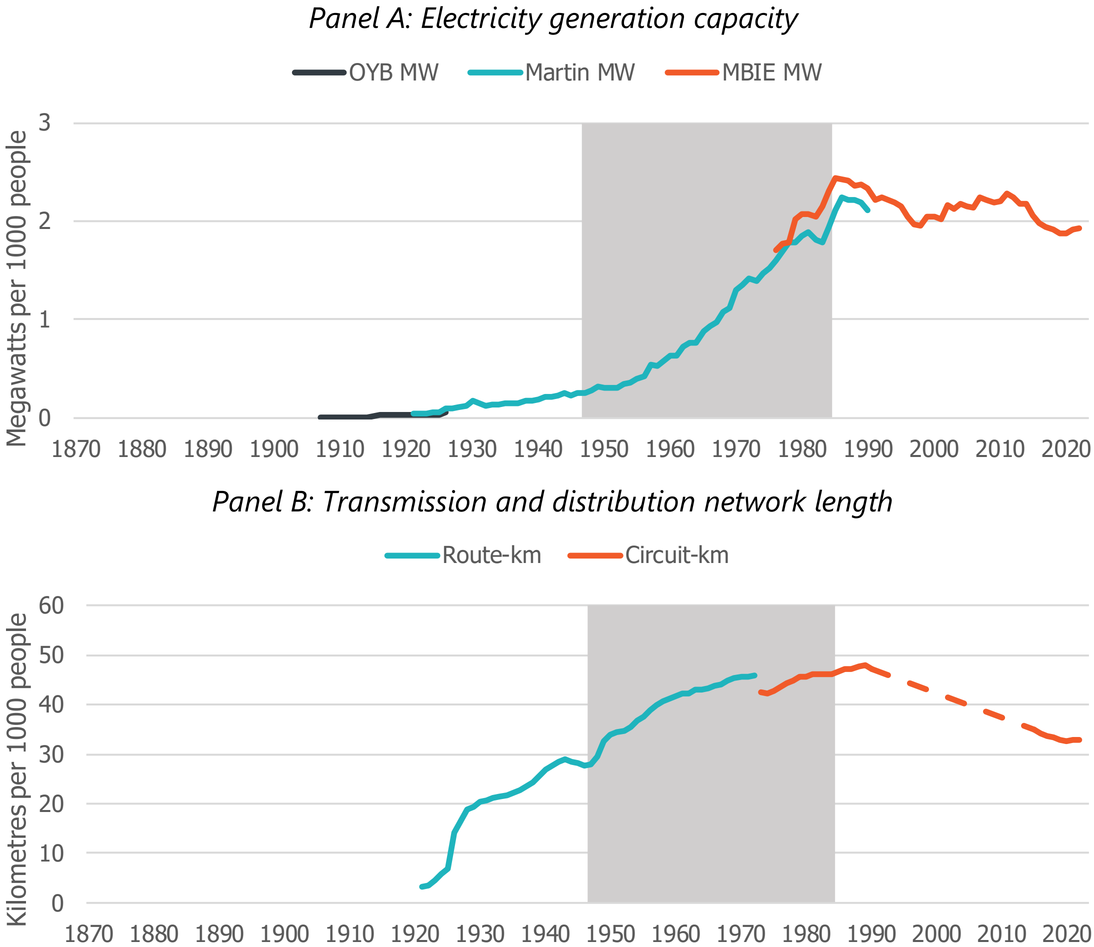
Figure 21: Estimated value of electricity and gas capital stock as a share of GDP, 1870–2022



Source: New Zealand Infrastructure Commission estimates. Note: Investment boom periods are highlighted in grey.

Figure 22 shows that the physical size of the electricity network expanded significantly during the boom and achieved its peak levels around the end of this investment boom. Electricity generation capacity rose from around 0.3 MW per 1000 people to around 2.3 MW, while the per-capita length of transmission and distribution lines almost doubled. Since the end of this investment boom, per-capita generation capacity has been stable or slightly declining.

Figure 22: Per-capita size of New Zealand's electricity network, 1921–2022



Source: New Zealand Infrastructure Commission estimates. Note: Investment boom periods are highlighted in grey.

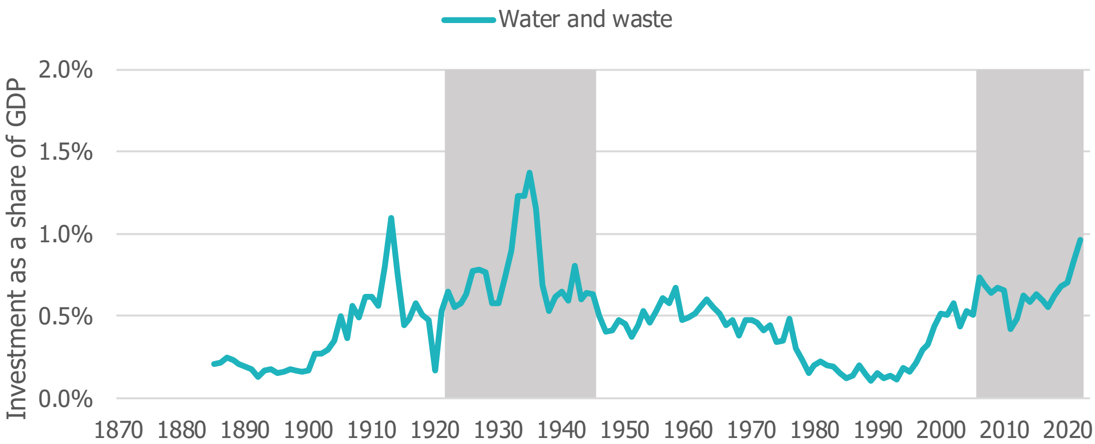
Water and waste: Expanding and (sometimes) maintaining networks

Water and waste capital investment has mainly been undertaken by local government throughout the period we studied, although there has been a trend towards private involvement in waste infrastructure in recent decades. Water network assets – covering drinking water supply, wastewater, and stormwater and flood control – are currently owned and operated by local governments or council-controlled organisations. However, the structure of the local government sector has changed significantly over time, with a trend towards establishment of new local government bodies in the first half of the 20th century followed by significant local government amalgamation in 1989 and (in the Auckland region) 2010.

Figure 23 shows that there have been two investment booms in water and waste. The first, from 1909 to 1943, corresponds to a period of significant improvement to water supply and sewers in New Zealand towns and cities (Frost, 1991; Schrader, 2016). During this period, capital investment in water and waste averaged 0.8% of GDP, above the long-run average of 0.5%. The second boom, from 2006 to 2022, corresponds to a recent period of asset renewal and improvements to health and environmental standards, with capital investment averaging 0.7% of GDP.

Also notable is a period of significantly below-trend investment from the mid-1970s to the late 1990s, which may have led to a maintenance and renewal backlog on water networks.

Figure 23: Capital investment in water and waste as a share of GDP, 1885–2022

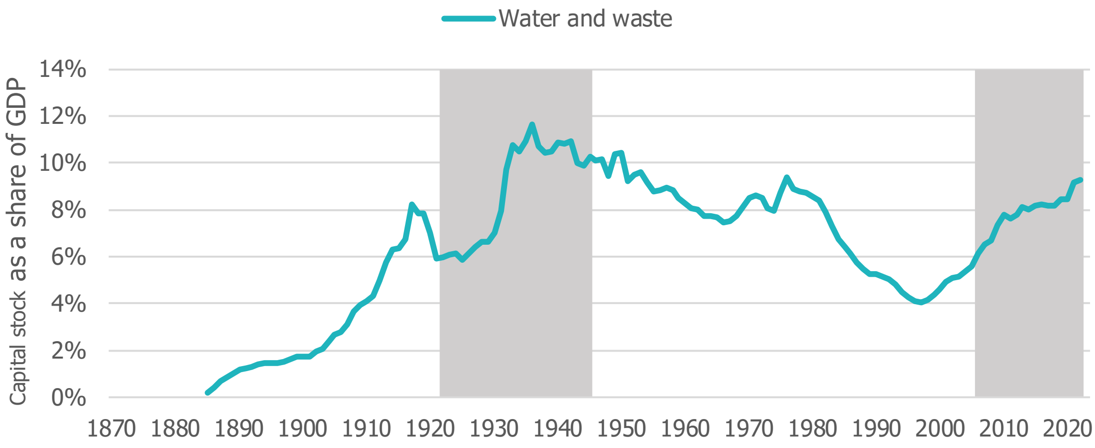


Source: New Zealand Infrastructure Commission estimates. Note: Investment boom periods are highlighted in grey.

Figure 24 shows the estimated value of water and waste capital stock relative to GDP. The capital-to-output ratio in this sector rose substantially during boom periods, and slowly declined after the end of the first boom.

Over the last century, we estimate that the value of water and waste assets has varied from a low of around 4% of GDP to a high of around 12%. Asset values have averaged around 8% of GDP over this time. Over the last decade, the value of water and waste assets has averaged around 8% of GDP, after recovering from a low point in the mid-1990s.

Figure 24: Estimated value of water and waste capital stock as a share of GDP, 1870–2022



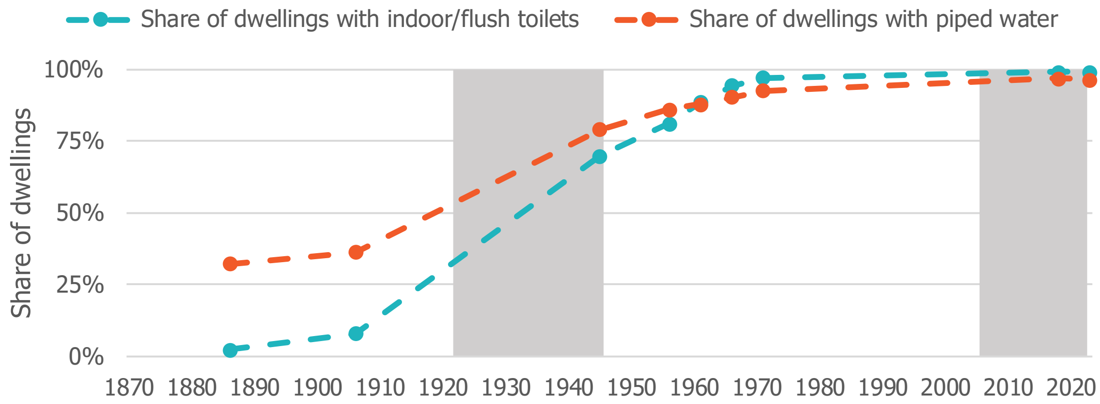
Source: New Zealand Infrastructure Commission estimates. Note: Investment boom periods are highlighted in grey.

Figure 25 shows that the coverage of water and sewer networks expanded significantly during the first investment boom. In 1906, we estimate (based on various historical data sources) that less than 30% of New Zealand homes had piped water and less than 10% had indoor flush toilets connected to sewers.[12] At the end of this period, in 1945, 79% of homes had piped water and 70% had indoor flush toilets. Network coverage continued growing at a slower rate through the early 1970s.

However, water networks did not significantly expand during the second investment boom, as the coverage of piped water and flush toilets was nearly universal at this point. Investment during this period is likely to have been directed towards improving the quality or condition of the network rather than significantly expanding it. This is borne out by our estimates of capital stock value, which suggest that the network was considerably 'run down' by the mid-1990s.

[12] These estimates should not be considered overly reliable, but we note that they correspond with data from the United States for a similar period (Gordon, 2016). Frost (1991) notes similar patterns of water and sewer network expansion in cities in New Zealand and the western United States during this period.

Figure 25: Per-capita size of New Zealand's water network, 1886–2023

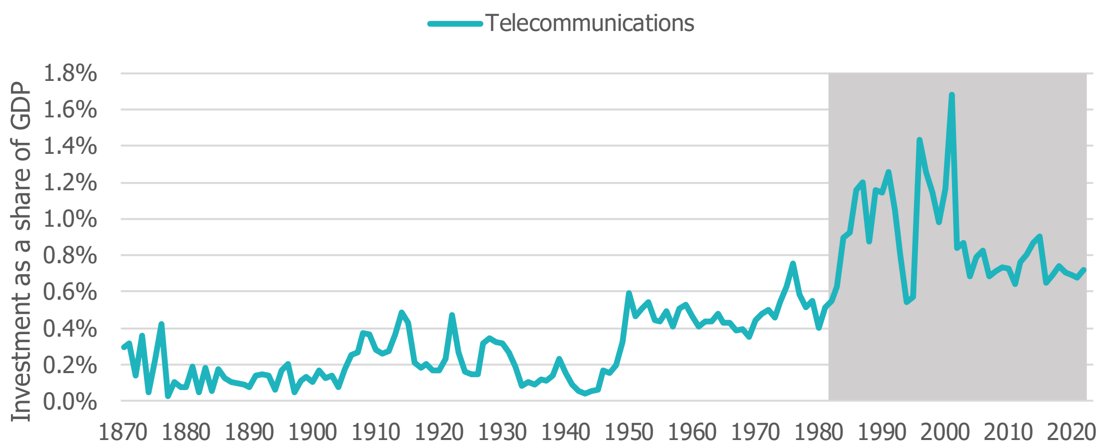


Source: New Zealand Infrastructure Commission estimates. Note: Investment boom periods are highlighted in grey. Data sources are not perfectly comparable over time; see Appendix for details.

Telecommunications: Responding to rapid technology change

Figure 26 indicates that there have been several historical 'level shifts' in capital investment in telecommunication, corresponding to the completion of the telegraph network in the 1910s and the expansion of the telephone network from the 1950s onwards. However, by our definition only the most recent period, from 1982 to 2022, is categorised as an investment boom. During this investment boom, investment averaged 0.9% of GDP, relative to a long-run average of 0.4%.

Figure 26: Capital investment in telecommunications as a share of GDP, 1870–1922



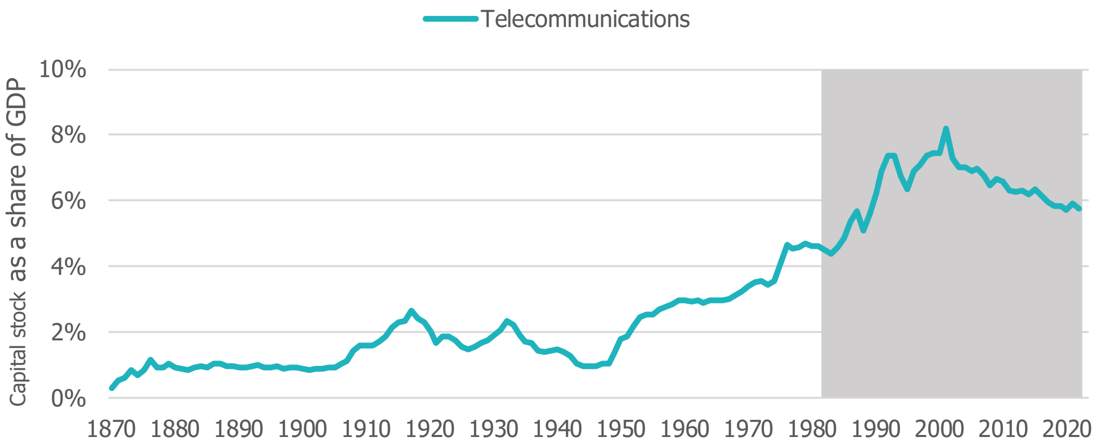
Source: New Zealand Infrastructure Commission estimates. Note: Investment boom periods are highlighted in grey.

Figure 27 shows the estimated value of telecommunications capital stock relative to GDP. The capital-to-output ratio in this sector rose consistently from around 1950 to around

2000, but has declined somewhat since then even though capital investment has remained substantially above its long-term average.

Over the last century, we estimate that the value of telecommunications assets rose from around 2% of GDP to a peak of around 8% of GDP, subsequently declining to around 6%. This suggests that the New Zealand economy has become much more 'telecommunications-intensive' over time.

Figure 27: Estimated value of telecommunications capital stock as a share of GDP, 1870–2022



Source: New Zealand Infrastructure Commission estimates. Note: Investment boom periods are highlighted in grey.

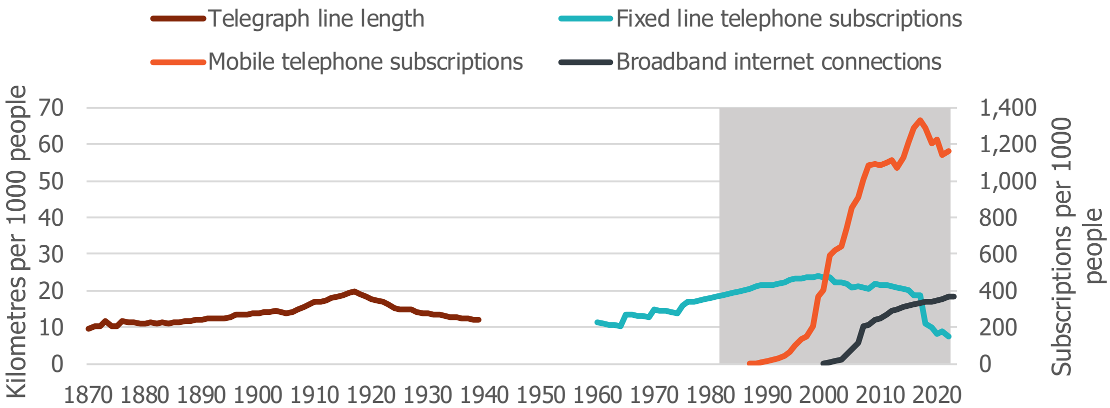
Figure 28 shows how New Zealand's telecommunications networks expanded (and in one case contracted) during this investment boom. It uses network uptake, in terms of subscribers per 1000 people, as a proxy for physical network size.[13] During this time:

- Coverage of the fixed-line telephone network rose to its highest-ever level, and then declined as this network was supplanted by newer technologies.
- Mobile telephone subscriptions rose from 0 to over 1300 subscriptions per 1000 people, and then fell back slightly.
- Broadband internet subscriptions rose from 0 to over 360 subscriptions per 1000 people.

Growth in uptake of mobile and broadband internet networks appears to have slowed or even reversed slightly. Capital investment as a share of GDP has also fallen back from its peak levels. This may suggest that the telecommunications investment boom has tapered off.

[13] We do not have data on physical network size for all of these networks. However, more recent data on ultra-fast broadband roll-out shows that physical network size and user uptake are closely related, with a slight lag between network roll-out and user uptake.

Figure 28: Per-capita uptake of New Zealand's telecommunications networks, 1960–2023



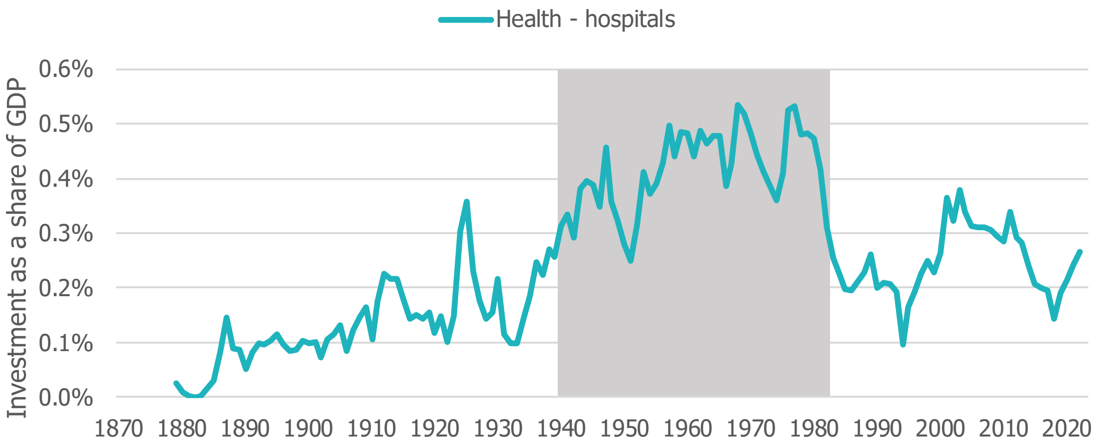
Source: New Zealand Infrastructure Commission estimates. Note: Investment boom periods are highlighted in grey.

Hospitals: Changing models of care

Institutional arrangements for hospital provision have changed significantly from the 1800s to today. Hospitals were originally provided locally by hospital boards, followed by a move to central government provision starting in the 1930s. While central government continues to play a leading role in hospital provision, organisational structures for doing so have been reformed several times since the 1990s. In addition, some hospital provision is done by the private sector.

Figure 29 shows that there has been one investment boom in hospitals, from 1940 to 1983. This overlaps with the Second World War, which saw the need for considerable new hospital capacity, and overlaps with the post-war period of population and income growth. During this investment boom, capital investment in hospitals averaged 0.4% of GDP, above the long-run average of 0.2%.

Figure 29: Capital investment in hospitals as a share of GDP, 1879–2022

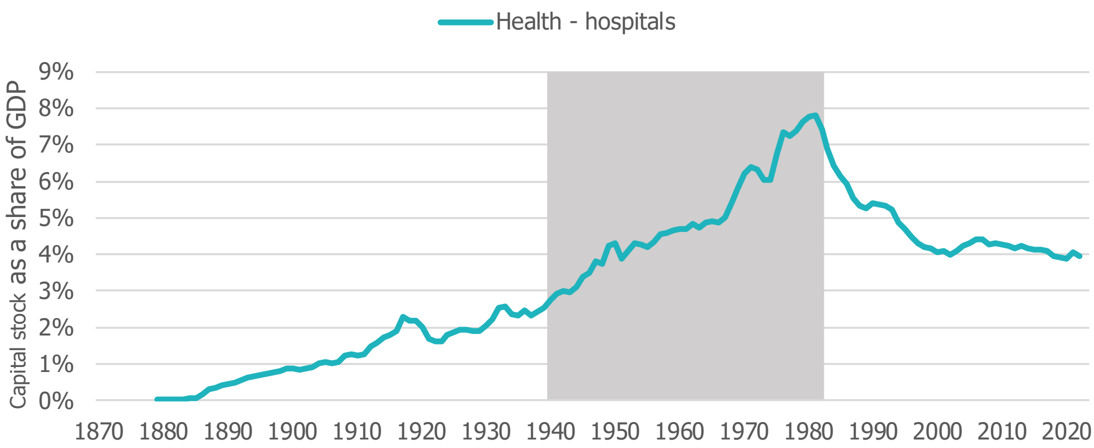


Source: New Zealand Infrastructure Commission estimates. Note: Investment boom periods are highlighted in grey.

Figure 30 shows the estimated value of hospital capital stock relative to GDP. The capital-to-output ratio in this sector rose substantially during its long boom, and subsequently declined significantly.

Over the last century, we estimate that the value of hospital assets rose from around 2% of GDP to a peak of around 8% of GDP, subsequently declining to around 4% of GDP. Over the last two decades, the value of hospital assets has been stable at this level.

Figure 30: Estimated value of hospital capital stock as a share of GDP, 1870–2022

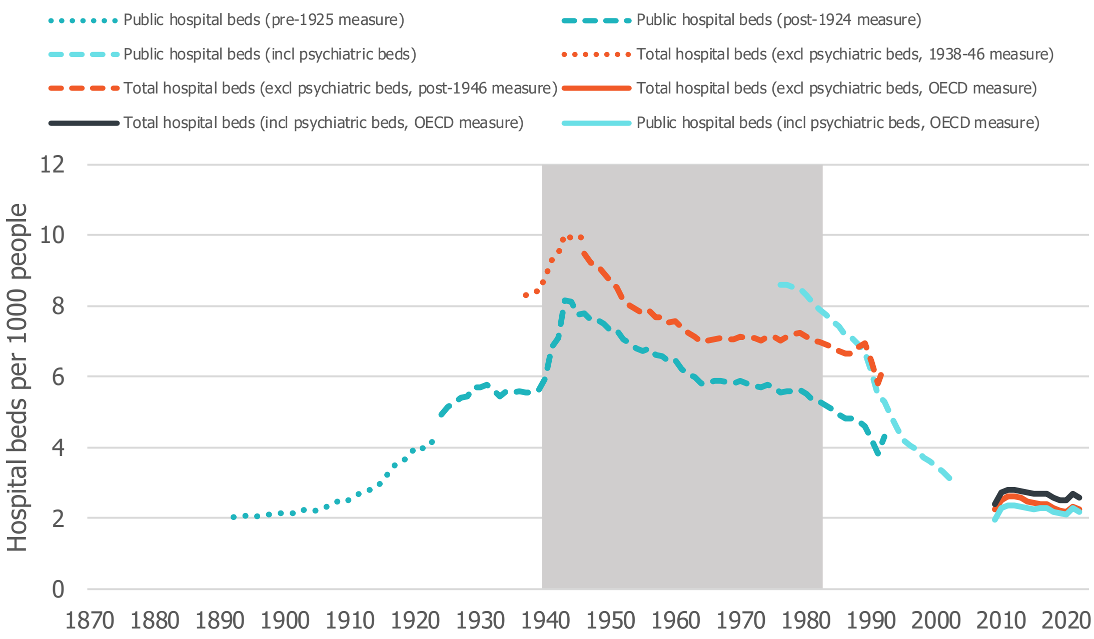


Source: New Zealand Infrastructure Commission estimates. Note: Investment boom periods are highlighted in grey.

Figure 31 shows how the per-capita size of the hospital network evolved over this period. Hospital beds per 1000 people increased rapidly during the Second World War, peaked around 1945, and then gradually declined through the rest of the boom period. This holds true for both public hospital beds (blue dashed line) and total public and private hospital beds (orange dashed line). Further declines occurred after the end of the investment boom period.

This data suggests that investment was directed mainly towards improving the quality of hospitals, potentially by reconfiguring them to provide a different mix of services or to take advantage of new medications and surgical techniques. However, we do not have long-run data on hospital quality or mix of services to test this hypothesis against.

Figure 31: Per-capita size of New Zealand's hospital network, 1892–2022



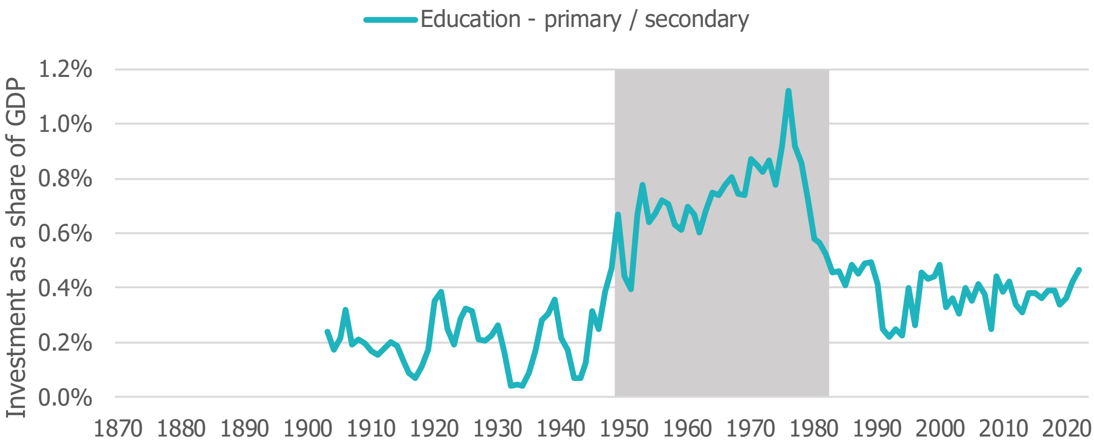
Source: New Zealand Infrastructure Commission estimates. Note: Investment boom periods are highlighted in grey.

Primary and secondary education: Demographics and new services

Primary and secondary education infrastructure and services is primarily provided by central government, with a small role for private schools.

Figure 32 shows that there has been one investment boom in primary and secondary education, from 1949 to 1982. This coincides with the post-Second World War baby boom, which led to a temporary increase in the school-aged share of the population. During this investment boom, capital investment in schools averaged 0.7% of GDP, above the long-run average of 0.3%.

Figure 32: Capital investment in primary and secondary education as a share of GDP, 1903–2022

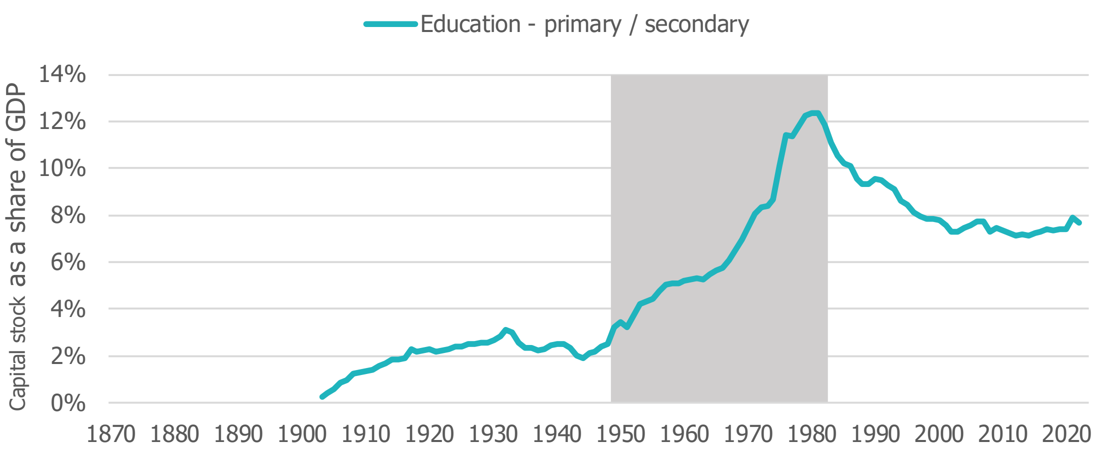


Source: New Zealand Infrastructure Commission estimates. Note: Investment boom periods are highlighted in grey.

Figure 33 shows the estimated value of primary and secondary education capital stock relative to GDP. The capital-to-output ratio in this sector rose sharply during its long boom, and subsequently declined from the peak.

Over the last century, we estimate that the value of school assets rose from around 2% of GDP to a peak of around 12% of GDP, subsequently declining to slightly under 8% of GDP. Over the last two decades, the value of hospital assets has been stable at this level.

Figure 33: Estimated value of primary and secondary education capital stock as a share of GDP, 1870–2022



Source: New Zealand Infrastructure Commission estimates. Note: Investment boom periods are highlighted in grey.

Figure 34 shows how the primary and secondary school system grew and changed in per-capita terms over this period. It uses student numbers per 1000 people as a proxy for the total size of the school network relative to New Zealand's population (Panel A), and supplements this with information on the number of schools per 1000 people (Panel B).

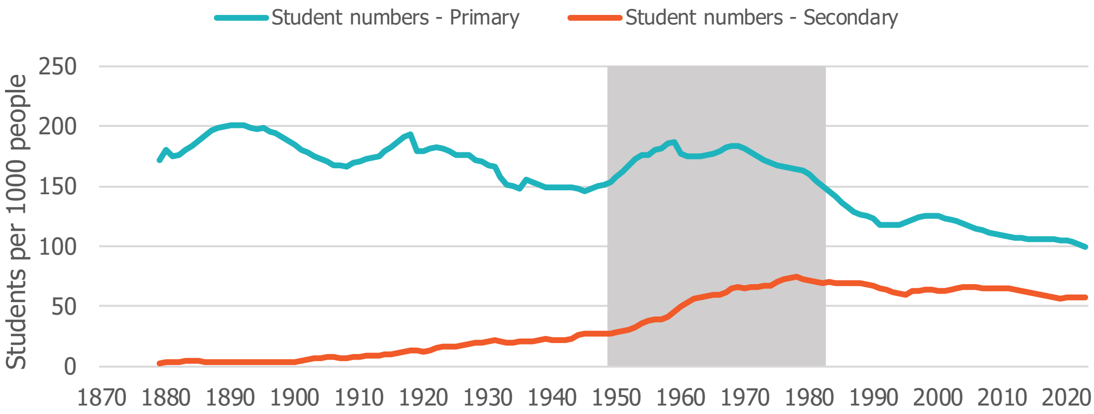
Taken together, this data suggests that there were significant changes in the capacity and quality of the school network over the investment boom period:

- Primary students per capita rose, peaked, and then declined, followed by ongoing declines after the investment boom period.
- Secondary students per capita rose to a new, higher level throughout this period, and stabilised at this level after the investment boom period.
- The number of primary schools per 1000 people declined from 1.3 to 0.8, continuing a long-term trend, while the number of secondary schools per 1000 people was stable at slightly more than 0.1 per 1000 people.

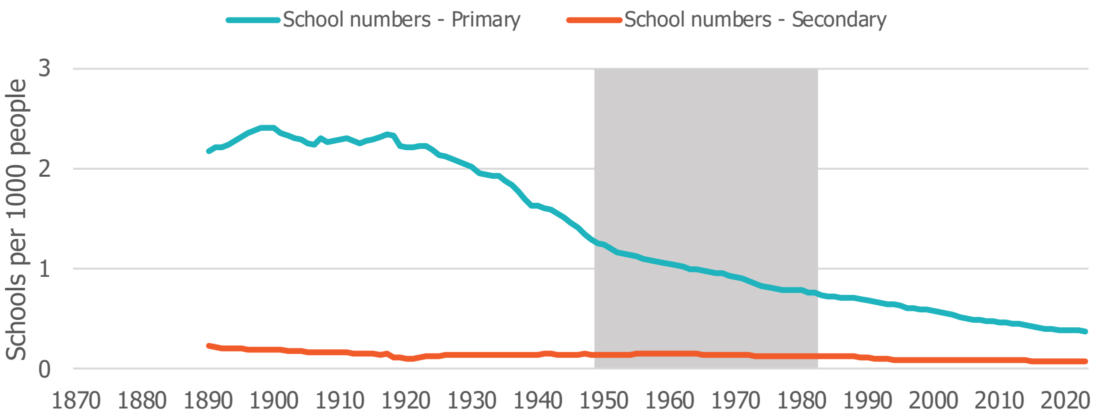
Taken together, this suggests that the school network was expanding to serve a greater share of the population, providing a different mix of services (more secondary education), and providing services through fewer, larger schools. Relative to the number of school-aged children, participation in primary education appears to have been constant (and universal) over this period, while participation in secondary education doubled.

Figure 34: Per-capita size of New Zealand's primary and secondary education system, 1879–2023

Panel A: Primary and secondary school students



Panel B: Number of primary and secondary schools



Source: New Zealand Infrastructure Commission estimates. Note: Investment boom periods are highlighted in grey.

Conclusions

We conclude by summarising some key lessons from the historical data and implications for how we think about scenarios for future infrastructure investment trends.

Total infrastructure investment varies within a range

In this report, we consider a roughly 150-year period that includes many fundamental economic, technological, and policy changes that have affected infrastructure investment, as well as society in general. This includes large changes, like world wars, global depressions, transformative new technologies, and shifts to voting rights and voting systems, as well as little changes, like year-to-year fluctuations in population and economic growth.

Through all these changes, the 'share of our wallet' spent on infrastructure capital investment has been reasonably consistent over time. Investment has averaged around 5.6% of GDP over the entire period, and there is no clear upwards or downwards trend in investment as a share of GDP.

Focusing on the last century, where data quality is higher, investment levels have never been higher than 7.3% of GDP on average over a 30-year period (1949–1978 average) nor lower than 5.0% over a 30-year period (1978–2007 average). We see higher or lower investment in some individual years, but investment tends to revert to the 5% to 7% range.

In recent decades, infrastructure investment as a share of GDP has been close to the long-run average. From 2003 to 2022, overall infrastructure investment averaged 5.8% of GDP, slightly higher than the long-run average, but with less year-to-year volatility than we observe in previous decades.

Going forward, we can reasonably expect to continue investing somewhere between 5% and 7% of GDP in all types of infrastructure, on average. A large shock – bigger than the changes we've seen over the last 150 years – would be needed to push us substantially out of the historical range.

We will face some novel challenges that will necessitate shifts in investment, like mitigating and adapting to climate change. But most future challenges facing infrastructure networks, such as demographic change, economic growth, technology change, and political and policy change, have historical precedents. How we've responded to past challenges can help guide our thinking about the future.

Our mix of infrastructure has evolved over time

While overall infrastructure investment has varied within a relatively narrow range, the mix of investment has varied significantly over time. Infrastructure networks have become more diverse and complex as our economy, and the technology that underpins it, has evolved.

In the late 1800s and early 1900s, land transport – road and rail assets – accounted for almost all infrastructure assets by value, as well as most new investment.

Infrastructure networks diversified substantially from 1900 to 1960, with the development and growth of electricity infrastructure, substantial growth in water infrastructure, the expansion of school and hospital networks, and significant investment in social housing. To accomplish this, we increasingly directed investment towards new types of infrastructure, while continuing to maintain and incrementally improve what was already there.

Our infrastructure asset base has diversified further in recent decades. From 1980 to 2022, telecommunication networks and tertiary education assets grew as a proportion of total asset value, while social housing declined in relative terms. Water and land transport assets declined as a share of total infrastructure asset values between 1980 and 2000 but have increased as a share of the total since then. Once again, developing and expanding new infrastructure networks, or re-investing in existing networks, required the mix of investment to shift.

We can reasonably expect the mix of infrastructure investment to continue shifting in the future. Even in periods where overall investment is reasonably stable, we tend to increase investment in some networks and reduce it in others so that we can meet changing needs.

Investment booms lead to rapid growth in network size or quality

There are some sustained periods where we invest a lot more than the long-term average in a certain type of infrastructure. We identify 14 of these sector-level investment booms, spread across nine different infrastructure sectors.

Investment booms tend to follow fundamental technological and economic changes that create demand for new or substantially improved networks. For example, we built electricity networks in response to the invention of the electric dynamo and paved the road network in response to the invention of the automobile.

Sector-level investment booms lead to rapid, one-off increases in the coverage or quality of infrastructure networks. At the start of a boom, we tend to have unfinished networks that are only serving part of the population or providing lower levels of service. By the end of a boom, networks are much larger, serving most potential users, or much higher quality.

However, investment booms do not last forever. The median boom lasts for around 21 years. In the median boom, capital investment is 67% higher, as a share of GDP, relative to the long-run average for that sector. At the end of the boom, investment tends to drop down to a lower level.

This is because there are limits to how much infrastructure people can productively use, meaning that the per-capita size and value of infrastructure networks cannot keep rising indefinitely. And once network expansion slows down, so too does investment. It costs more to build a network from scratch than it does to maintain the network and incrementally upgrade it to serve new growth.

We may see more investment booms in the future if changes to technology or the structure of our economy create demand for new types of infrastructure. Significantly higher investment in a specific sector will only be sustainable if users are willing to pay for a significantly bigger or better network.

Infrastructure investment responds to fundamental drivers

A final lesson is that, in the long run, capital investment in infrastructure reflects fundamental factors, like demographic change, economic growth, asset renewal needs, and technology changes. When demand for infrastructure services grows, investment tends to respond.

New Zealand now invests more in infrastructure, in inflation-adjusted dollar terms, than it did in the past. This reflects the growing needs and expanding budget of a larger and wealthier population. We can reasonably expect overall investment demand to keep growing in the future, in dollar terms, as our population and incomes rise and as we continue maintaining, renewing, and building resilience into our infrastructure networks.

How we've responded to past challenges can help guide our thinking about how we can respond to future challenges through infrastructure investment.

For example, if New Zealand's population and incomes grow faster, we can expect this to push up investment demands a bit in existing networks, to accommodate growth. Slower population and income growth would have the opposite effect.

However, the big investment demands tend to come along when we need to build entirely new infrastructure networks. This is most likely to happen in response to a fundamental technology change, like the automobile or computer. Several recent technology changes are worth watching to understand their effects on infrastructure investment demand.

First, in recent years batteries and electric motors have experienced transformational improvements that make them useful for many more applications. Forecasters like the International Energy Agency and Ministry of Business, Innovation and Employment expect this to boost demand for electricity infrastructure, relative to fossil fuel energy sources.[14] Second, and more recently, the development of generative artificial intelligence, such as large language models trained on large text databases to understand, generate, and manipulate language, has boosted demand for datacentres and supporting infrastructure.

How did we pay for all of this?

While this report outlines what we have spent on infrastructure over time and how our infrastructure networks have grown as a result, it does not explore how we have paid for investment. Further work is needed to address several questions in this area.

First, has infrastructure investment mainly been done on a 'pay as you go' basis, or have we financed investment by taking on public (or private) debt that must be repaid over time? When we have used debt, how hard has it been to repay the loans?

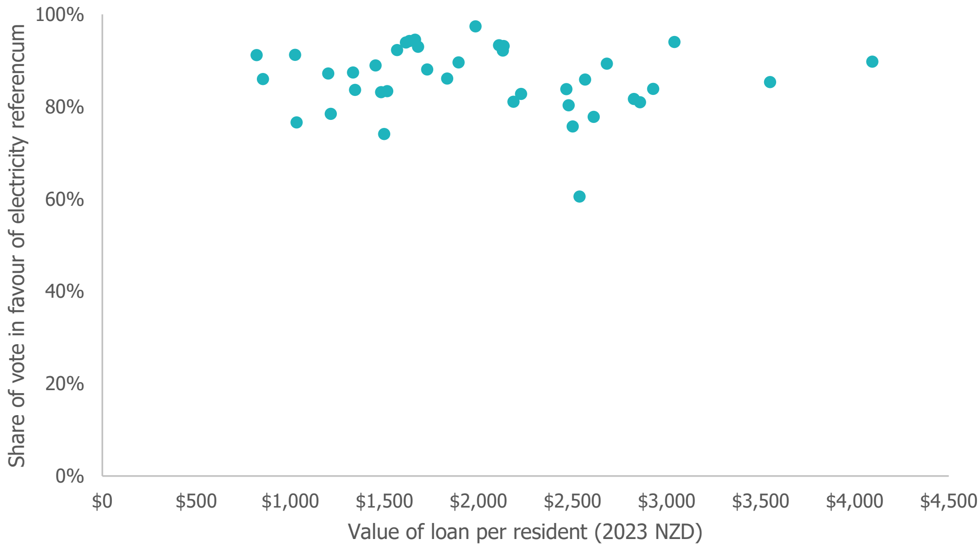
We previously gathered and analysed long-run data on overall central and local government debt ratios (New Zealand Infrastructure Commission, 2024c). This data highlights that debt ratios tended to be stable, or even declining, through periods of high infrastructure investment from the 1880s onwards. At a broad level, this suggests that increases in debt were matched with increases in revenues during these periods.

More work is needed to understand how specific projects and investment programmes were financed. While compiling data for this report, we ran across some interesting case studies, like the system of local referendums used to approve investment in local electricity generation and distribution schemes in the 1910s and 1920s (Figure 35). In these referendums, voters were asked to approve a loan to finance electric power supply, along with targeted rates to repay the loan.

The 1931 Official Yearbook reports on 45 electricity supply referendums that were held between 1919 and 1929. These schemes served almost a million people and required total borrowing equal to almost 7% of New Zealand's 1930 GDP. Despite the high cost, all referendums passed, with an average of 85% of electors voting in favour. This highlights high willingness to take on debt to provide new or fundamentally improved infrastructure networks in the past.

[14] https://www.iea.org/reports/electricity-2025; https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-modelling/electricity-demand-and-generation-scenarios

Figure 35: Results of 1920s electricity power board referenda



Source: 1931 New Zealand Official Yearbook.

Second, how have we raised the money to pay for investment or repay debt? How much has come from user charges like petrol tax and electricity charges, how much from rates, and how much from general central government tax revenues?

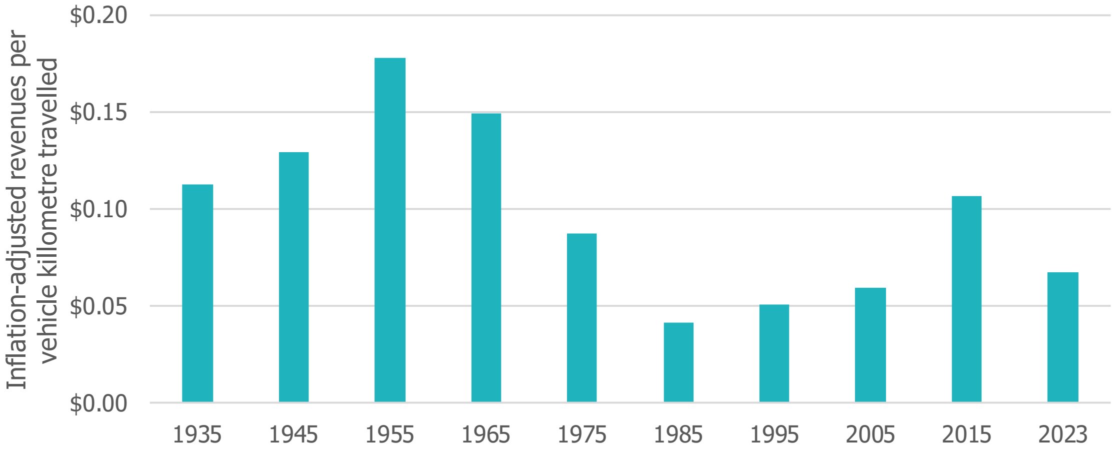
More work is needed to understand the mix of revenue sources that was used to pay for investment. Once again, we ran across some relevant information while researching this report. For example, data from Official Yearbooks suggests that from 1925 onwards, central government mostly used petrol taxes, road user charges, and vehicle registration and licence fees to pay for road networks.

Figure 36 shows that charges levied on road users (petrol tax, road user charges, vehicle registration and licence fees, and other miscellaneous road user charges) per kilometre driven were considerably higher in the past. They were particularly high during mid-century road investment booms. Adjusted for inflation, motorists paid twice as much per kilometre in 1955 than they do today, even though incomes are nearly three times higher today.

While the network was being built, funding top-ups from general tax revenues seem to have been limited, accounting for only 6% of total road fund revenues in 1955 and 3% in 1965. This meant that high road investment did not displace tax-funded investment in other types of public infrastructure, like schools and hospitals.

This example highlights that users can be willing to pay high charges when networks are being built or significantly improved. However, users' willingness to pay seems to decline after networks are completed. After road network coverage and quality reached maturity in the early 1970s, average user charges declined and the focus for investment shifted to other infrastructure networks.

Figure 36: Estimated road-user revenues hypothecated to land transport fund per vehicle kilometres travelled, 2025 NZD



Source: New Zealand Infrastructure Commission estimates based on road user revenue data from Stats NZ Official Yearbook and NZ Transport Agency, plus historical vehicle kilometres travelled estimates. The decline in per-kilometre user charges in 2023 reflects the impact of a temporary fuel tax cut.

Appendix: Sources and methods

This Appendix outlines how we compiled long term estimates of infrastructure capital investment, capital stock, and construction prices. We emphasise that these are **estimates**, corresponding as closely as possible to modern definitions, but that the underlying data sources are not compiled in a consistent way over time.

Summary of methodology

Key sources

Our estimates are based upon data from four key sources:

- The **New Zealand Infrastructure Commission's (2024a)** previous re-analysis of Stats NZ National Accounts – Capital Accounts statistics for the 1990–2022 period (*NZIC*): These provide data on capital investment, depreciation, and capital stock for public and private infrastructure sectors, which are defined using a combination of ANZSIC industry and sector of ownership.
- **Stats NZ National Accounts** – Capital Accounts statistics (*SNZ NA*): These provide data for the 1972-2023 period on ANZSIC industry capital investment and on net capital stock price deflators for asset types.
- **Mulcare's (1994) long-term estimates for public investment** (*Mulcare*): These provide estimates of construction price indices, capital investment, and capital stock for a set of public infrastructure sectors, for years ranging from 1846 through to 1989.
- **New Zealand Official Yearbook** (*OYB*): These provide various types of information, including information on capital investment or non-current spending for infrastructure sectors that were historically in public ownership, for years between the late 1800s and late 1900s. We manually transcribed relevant data from the Official Yearbook, correcting and re-analysing it where needed.

This Appendix explains how we have combined these data sources to produce long-term estimates for key infrastructure sectors.

Sectors that we produce capital investment and capital stock estimates for

Table A1 summarises the sectors that we provide capital investment estimates for, the time periods for which we can provide estimates, and the key sources used in estimates for each sector.

In most cases, we are able to extend capital investment estimates back in time to the date of the first significant capital investment (for example, the early 1900s for the electricity sector or the mid-1930s for state housing) or at least back to the early 1900s or late 1800s.

We were unable to obtain any relevant pre-1972 estimates for tertiary education and were unable to obtain any relevant pre-1990 estimates for the residual 'other public capital' category. Other public capita is a broad category of public infrastructure and includes items such as stadiums and sports facilities as well as community and arts facilities.

Table A1: Summary of sector and temporal coverage of capital investment estimates

Sector	Years	Source
Transport – road	1870–2022; 1925–2022 for CG/LG breakdown	Mulcare/OYB/NZIC
Transport – rail	1870–2022	OYB/NZIC
Electricity and gas	1906–2022	OYB/NZIC
Water and waste	1885–2022	OYB/SNZ NA/NZIC
Telecommunications	1870–2022	OYB/NZIC
Education – primary/secondary	1903–2022	Mulcare/NZIC
Education – tertiary	1972–2022	Mulcare/SNZ NA/NZIC
Health – hospitals	1878–2022	Mulcare/NZIC
Public administration and safety	1903–2022	Mulcare/NZIC
Social housing	1938–2022	OYB/NZIC
Other public capital	1990–2022	NZIC

Note: Sectors are defined using a combination of ANZSIC industry and sector of ownership, as outlined in NZIC.

Reporting units

New Zealand changed to decimal currency on 10 July 1967 with a conversion rate of $2 per £1. For ease of interpretation, we convert pre-1967 currency into dollar equivalents.

New Zealand adopted metric units (kilometres and metres) in the early 1970s, completing the conversion on 14 December 1976. For ease of interpretation, we convert pre-1976 imperial units into metric units.

We report capital investment, capital stock, and unit cost values in nominal New Zealand dollars, real New Zealand dollars (deflated using a GDP deflator for the overall NZ economy), and as a share of GDP (production measure). We report prices as indices.

We report physical capital stock measures in quantity terms (using metric units where appropriate) and in per-capita terms.

Reliability of data

We present the best available estimates for capital investment and capital stock over time, but the reliability of these estimates can vary.

Post-1990 capital investment and capital stock estimates, which are based on Stats NZ National Accounts data coded to a consistent sectoral classification, should be treated as **most reliable**.

In general, pre-1990 capital investment and capital stock estimates should be treated as **less reliable** than post-1990 estimates, and the reliability of capital investment and capital stock estimates for the period from the 1870s to the 1920s should be treated as **less reliable** than estimates for later years.

Methodology for estimating capital investment

We construct sector-level long-term infrastructure capital investment estimates using pre-1990 data from Mulcare (1994), the New Zealand Official Yearbook, and Stats NZ National Accounts, and post-1990 data from the New Zealand Infrastructure Commission (2024a).

To the extent possible, these estimates are based on consistent concepts. We attempt to measure capital investment based on a gross fixed capital formation concept, using a broadly consistent set of sectoral definitions, as outlined in Table A1 above. Construction of these estimates has required us to splice together different datasets and, in some cases, estimate or interpolate between them.

Some capital investment estimates, and the resulting capital stock estimates, are based on an underlying data source that reports data on capital investment or a closely related concept (for example, gross fixed capital formation or gross capital formation). Other estimates are based on underlying data sources that do not perfectly correspond to the capital investment concept (for example, annual construction costs) and which therefore require supplementary imputation or estimation.

Because the exact approach varies between sectors, depending upon data availability, we explain sources and methods in more detail at a sectoral level, below.

Methodology for estimating the value of capital stock

We construct sector-level long-term infrastructure capital stock estimates by combining post-1990 data from the New Zealand Infrastructure Commission (2024a) with pre-1990 estimates created with a perpetual inventory model of capital stocks. We join the pre-1990 estimates with the post-1990 data, ensuring that the two series paste smoothly onto each other.

A perpetual inventory model of capital stocks sums up accumulated capital investment, revalues it for changes in prices for relevant investment goods, and subtracts off accumulated depreciation and asset writedowns (if any). Stats NZ uses this method to estimate the value of capital stocks in National Accounts statistics (Statistics New Zealand, 2014).

Equation 1 defines the perpetual inventory model. $K_{i,t}$ is the nominal value of capital stocks for infrastructure sector i in year t; $p_{i,t}$ is the price index for that infrastructure sector; $\delta_{i,t}$ is the depreciation rate for that infrastructure sector in year t; $w_{i,t}$ is the share of capital stock 'written down' in that year, for example, due to unexpected obsolescence or unplanned destruction; and $I_{i,t}$ is the nominal value of capital investment for that infrastructure sector in year t.

The first term in this equation ($K_{i,t-1} * \left(\frac{p_{i,t}}{p_{i,t-1}}\right)$) reflects the revaluation of the existing capital stock for changes in prices. The second term $(1 - \delta_{i,t} - w_{i,t})$ reflects the adjustment of the existing capital stock for depreciation and writedowns. The third term ($I_{i,t} * (1 - 0.5\delta_{i,t})$) reflects the addition of new investment to the capital stock, minus depreciation on the portion of that investment that started incurring 'wear and tear' during the year.

Equation 1: Perpetual inventory model of capital stocks

$$K_{i,t} = K_{i,t-1} * \left(\frac{p_{i,t}}{p_{i,t-1}}\right) * (1 - \delta_{i,t} - w_{i,t}) + I_{i,t} * (1 - 0.5\delta_{i,t})$$

We implement the perpetual inventory model using our investment series for each infrastructure sector, plus some supplementary data sources and assumptions. In most cases, the investment series starts at or near the beginning of significant capital investment in that sector, meaning that we do not need to estimate the value of capital stocks in the starting year.

To revalue existing capital stock, we construct a long-run price series for infrastructure construction using estimates from Mulcare (1994) and Stats NZ National Accounts data. This series is explained at the end of this appendix.

For depreciation rates, we start with 1990–2022 sector-level estimates from the New Zealand Infrastructure Commission (2024a). These are estimated based on Stats NZ National Accounts data on consumption of fixed capital (a proxy for routine depreciation) as a share of capital stock, with an adjustment for depreciation on the flow of new investment through the year. In most cases, we use the simple average of annual depreciation rates over the 1990–2022 period as our estimate of historical depreciation rates in previous years. In cases where depreciation rates appear to be trending upwards or downwards over the 1990–2022 period, we use the average over the earlier part of the period.

In most cases, this results in perpetual inventory model capital stock estimates that are close to the 1990–2022 estimates previously published in New Zealand Infrastructure Commission (2024a). However, in some cases, the perpetual inventory model estimates are significantly higher than estimates from New Zealand Infrastructure Commission (2024a). In these cases, we add in additional capital stock writedown assumptions that best match known information on when networks may have experienced unplanned obsolescence, asset disposals, or other writedowns that are not captured in depreciation rates.

Because the exact approach varies between sectors, depending upon data availability, we explain sources and methods in more detail at a sectoral level, below.

Finally, because our estimates are potentially sensitive to choices about the price index used to revalue infrastructure goods from year to year, we sensitivity test an alternative price index (the GDP deflator) to understand whether this materially affects the level or time trends of our capital stock estimates.

Methodology for estimating the physical size of infrastructure networks

We supplement capital investment and stock estimates with data on the physical size of infrastructure networks, based on historical data from the New Zealand Official Yearbook and more recent data from relevant central government agencies and other sources as needed.

Depending upon sector, we gathered data on the physical size of infrastructure networks (for example, kilometres of open rail line or number of schools), the quality of those networks (for example, the length of sealed road network relative to metalled road network), or usage/uptake of networks (for example, the number of telephone subscribers). We explain data sources in more detail at a sectoral level, below.

For some sectors, we can use spending data and data on the physical size of infrastructure networks to estimate unit cost trends for infrastructure goods – generally capital cost per added unit or maintenance cost per unit of network size. These provide some additional context on sectoral trends.

Historical population and GDP estimates

Table A2 summarises the sources we use for historical population and GDP estimates. We use these to normalise infrastructure investment and capital stock relative to population or GDP. Estimates are available for the full 1870–2022 period analysed in this paper. The relevant SNZ series paste smoothly onto the NZIER historical data series.

Table A2: Sources for historical population and economic data

Economic variable	Source
Population (as at December)	1870–1990: NZIER Data1850 1991–2024: Stats NZ Estimated Resident Population (Annual-December), series DPE058AA
Nominal Gross Domestic Product (expenditure measure)	1870–1971: NZIER Data1850 1972–2025: Stats NZ Gross Domestic Product (Expenditure measure), nominal (Annual-March), series SNE023AA
Real Gross Domestic Product (production measure)	1870–1977: NZIER Data1850 1978–2025: Stats NZ Gross Domestic Product (Production measure), chain volume (Annual-March), series SNE053AA
GDP deflator (2025 base year)	Calculated by dividing nominal GDP by real GDP, then adjusting from a 2010 base year to a 2025 base year.

Sources: NZIER Data1850 and Stats NZ Population Estimates and National Accounts.

Transport – Roads

Context

Road capital investment is largely undertaken local and central governments. We provide estimates for total road capital investment and for the share of the total that is undertaken by local government (for local roads) and central government (for state highways).

Prior to the 1920s, road investment was undertaken by local government and central government through the public works fund. Starting in 1925, central government began to collect fuel excise duty and use this money to invest directly in state highways (and the predecessor category of main highways, which were co-funded by local governments). This approach has continued, under various institutional arrangements, to the present day. Local governments continue to invest in roads (and other local transport infrastructure), funded out of a mix of local revenues (like rates) and co-funding from central government.[15]

Capital investment estimates

We construct a capital investment series for both central government and local government roads by combining data from Mulcare and NZIC. This series covers the 1870–2022 period. We then use data from the OYB and NZIC to estimate the split between central government roads (state highways) and local government roads.

Table A3: Sources used to construct capital estimates for transport-roads

Years	Source	Notes
1870–1989	Mulcare	Estimates of gross capital formation for roads. Based on various underlying data sources as described on pages 5-6 of Mulcare.
1990–2022	NZIC	Estimates of gross fixed capital formation for central government and local government roads, based on Stats NZ National Accounts – Capital Accounts data.

[15] https://teara.govt.nz/en/roads

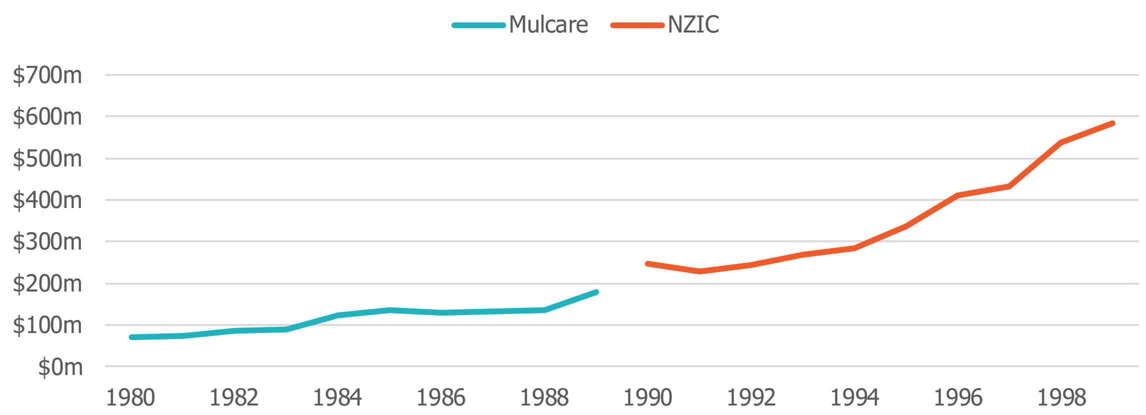
Table A4: Sources used to estimate capital investment for main/state highways and local roads

Years	Source	Notes
1925–1989	OYB/Mulcare	OYB provides data on main/state highway construction and renewal expenditure out of the National Roads Fund, starting with the 1926 Yearbook. We collate this data, clean it where needed, including interpolating data for 1926 and 1927, and use it as an estimate of capital investment in main/state highways owned by central government. We estimate local road capital investment by subtracting main/state highway investment from total road gross capital formation from Mulcare. OYB also provides data on main/state highway maintenance expenditure, which we record but do not count as capital expenditure.
1990–2022	NZIC	Estimates of gross fixed capital formation for central government roads and local government roads, based on Stats NZ National Accounts – Capital Accounts data.

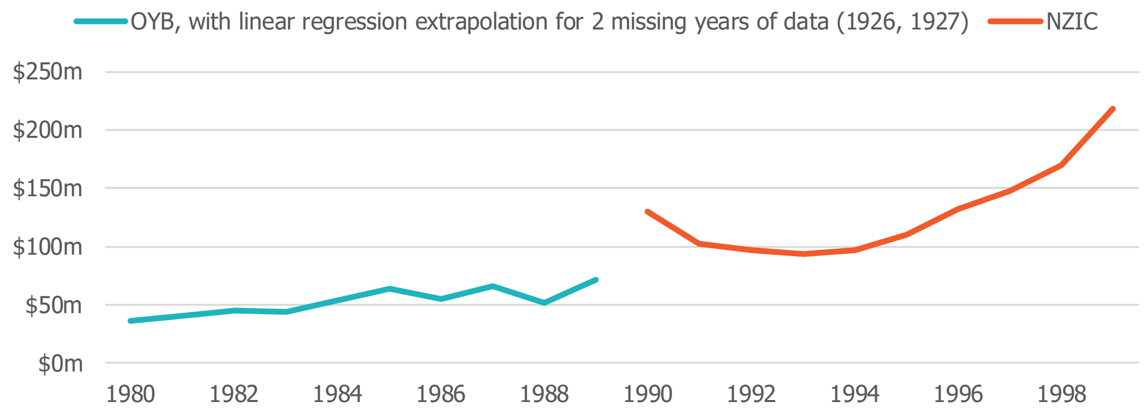
As there is no overlap between the NZIC and Mulcare series, we examine how these series compare to each other in the ten years before and after the break between the series. Figure A1 shows that while the pre-1989 and post-1990 input series do not perfectly align, there is no sharp difference between them either in terms of levels or trends. It is possible that the pre-1989 OYB series under-estimates central government road investment somewhat, and hence over-estimates local government road investment by an equal amount.

Figure A1: Comparison of input series for road investment (nominal NZD)

Panel A: Central government and local government road investment



Panel B: Central government road investment



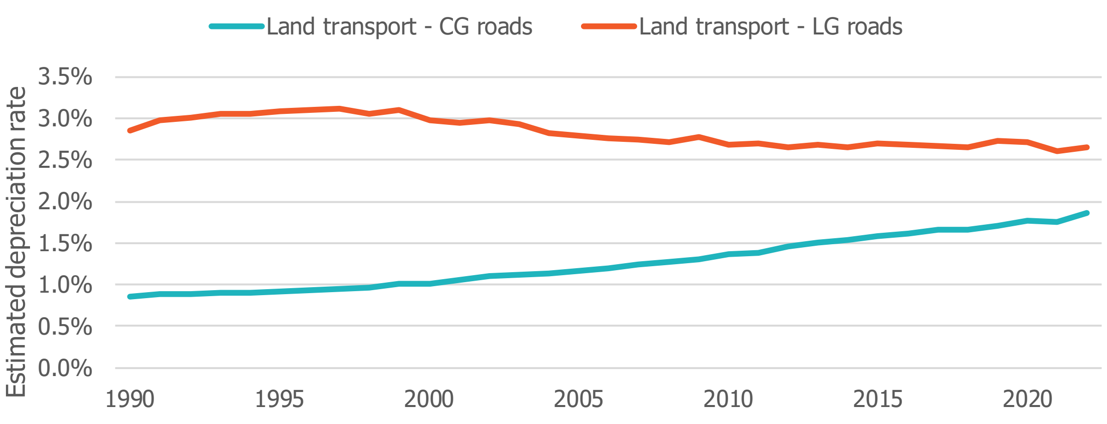
Source: New Zealand Infrastructure Commission analysis.

Capital stock estimates

We provide capital stock estimates for all roads from 1870 to 2022, for central government roads (main highways and state highways) from 1925 to 2022, and for local government roads from 1925 to 2022. To do so, we use separate investment series for central government and local government roads from 1925 onwards, as well as the total road investment series available from 1870 onwards. We use the composite infrastructure construction price index presented below to revalue the capital stock from year to year.

Average depreciation rates differ for central government and local government roads, which seem to reflect the fact that central government roads are built to a higher standard of durability. Figure A2 summarises annual estimates of depreciation rates for the 1990-2022 period. Over this period, depreciation rates averaged 2.84% for local government roads and 1.26% for central government roads. These imply an average asset life of around 35 years for local government roads and around 80 years for central government roads.

Figure A2: Estimated depreciation rates for road capital stock, 1990–2022



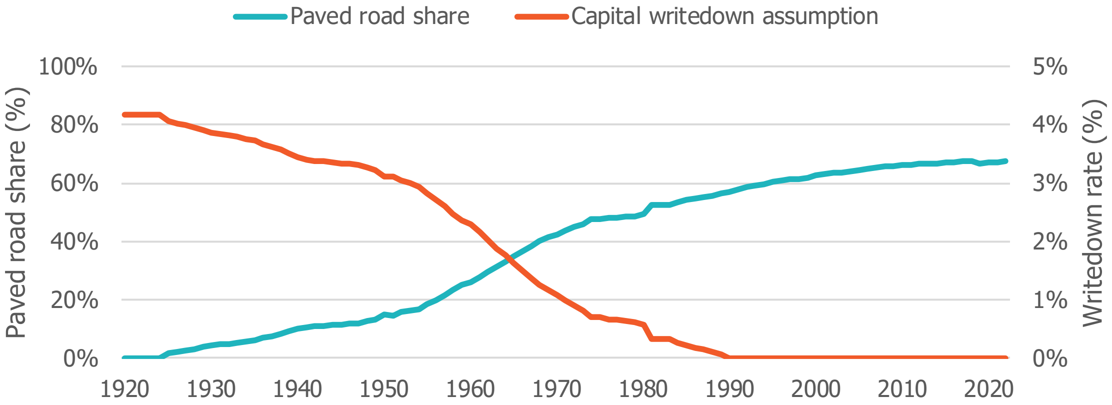
Source: Estimated using data from NZIC.

We use 1990–2022 average depreciation rates as a starting basis for the pre-1989 period but add writedown assumptions on top of base depreciation rates to account for the fact that roads were less durable in the past due to a lower average standard of construction.

We construct a proxy estimate using information on the share of the road network that was paved over time (based on physical stock information described below). Roads with metalled or unmetalled surfaces are likely to deteriorate faster than paved roads. We apply higher writedowns when paved roads make up a smaller share of the total road network, calibrating the magnitude of these writedowns to ensure that perpetual inventory model capital stock estimates closely align with 1990–2022 capital stock estimates from NZIC.

Figure A3 summarises our capital writedown assumptions, which are added to the base depreciation rates described above. In the mid-1920s, when less than 2% of the road network was paved, annual writedowns are assumed to be around 4% of the value of capital assets. When combined with depreciation rates, this implies average asset lives of around 14 years for local roads and 19 years for central government roads in the mid-1920s. Writedowns decline over time as the road network is paved.

Figure A3: Capital writedown assumptions for roads

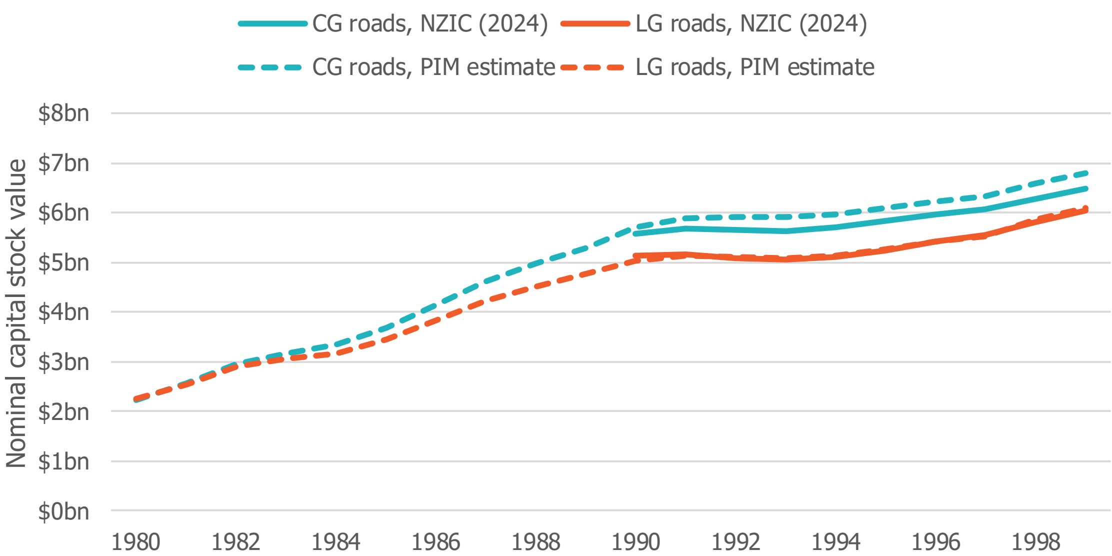


Source: New Zealand Infrastructure Commission analysis.

Figure A4 shows that the resulting perpetual inventory model estimates are close to post-1990 estimates from NZIC. Dashed lines indicate perpetual inventory model estimates and solid lines indicate post-1990 estimates based on Stats NZ National Accounts data. In 1990, our capital stock estimate for all road types is within 0.3% of observed data, with a slight over-estimate for central government roads and a slight under-estimate for local government roads.

Our final capital stock series splices together the pre-1990 perpetual inventory model capital stock estimates described here with the 1990–2022 data presented by NZIC.

Figure A4: Comparison of perpetual inventory model capital stock estimates with post-1990 data for roads



Source: New Zealand Infrastructure Commission analysis.

Physical network size data

We gather data on the length of the road network, broken down by road surface and road category (main/state highways and motorways/expressways). We supplement this with information on network usage (registered vehicles, vehicle kilometres travelled, and petrol consumption for land transport).

Table A5: Road network size and quality metrics

Metric	Years	Unit	Sources
Length of formed roads with sealed surfaces	1925–2023	Kilometres	1925–2008: OYB publishes annual data on road network length, broken down by surface category. 2011–2023: NZTA publishes annual data on road network length, broken down by surface category.[16] 2009–2010: Straight line imputation between OYB and NZTA series.
Length of formed roads with metalled surfaces	1925–2023	Kilometres	Same as above.
Length of formed roads with unmetalled surfaces	1925–1980	Kilometres	1925–1980: OYB publishes annual data on road network length, including roads with unmetalled surfaces. Series discontinued after 1980.
Length of bridges	1925–1987; 2011–2023	Metres	1925–1987: OYB publishes annual data on bridge length. 2011–2023: NZTA publishes annual data on bridge length.[17]
Main highway length	1925–1960	Kilometres	1925–1960: OYB publishes annual data on main highway length. Series discontinued after 1960.
State highway length	1938–2023	Kilometres	1938–2008: OYB publishes annual data on state highway length, with some missing years (1954–1960, 1990–1993) that had to be interpolated. 2011–2023: NZTA publishes annual data on road network length, broken down by surface category.[18] 2009–2010: Straight line imputation between OYB and NZTA series.
Motorway/ expressway length	1954–2023	Kilometres	1954–1987; 2005: OYB publishes annual data on motorway network length. 2023: NZTA road network length database.[19] 1988–2022: Data on motorway construction from the New Zealand Infrastructure Commission (2022) used to impute growth in network length between known points.

Note: All data sourced from OYB required some minor data cleaning, including correcting seeming transcription errors and imputing one or two years of missing data.

Table A6: Road network usage metrics

Metric	Years	Unit	Sources
Number of registered motor vehicles (including motorcycles)	1925–2023	Number	1925–1998: OYB publishes annual data on number of registered motor vehicles. 2000–2023: MoT publishes annual data on number of registered motor vehicles.[20] 1999: Straight line imputation between OYB and MoT series.
Fleet vehicle kilometres travelled	1976, 1980–2023	Billion kilometres	1930–1979: VKT trend estimated using historical petrol consumption data (see below) combined with long-run fuel economy trend assumptions for the US vehicle fleet, which is assumed to be similar to the NZ vehicle fleet (Sivak & Tsimhoni, 2009). Note that fuel economy was flat or slightly declining over this period. 1980–2000: MfE publish historical VKT data.[21] 2001–2023: MoT publishes annual VKT data.[22] Note: There is a slight series break between the MoT and MfE series.
Petrol consumption for land transport	1930–2023	Million litres	1930–1973: OYB publishes annual data on volume of petrol ('motor spirits') used by motor vehicles travelling on public roads. 1974–2023: MBIE publishes data on kilotonnes of oil consumed for domestic land transport, which we convert to litres using MBIE conversion factors.[23]

[16] NZTA, 'Physical statistics – roads'. Accessed at https://www.nzta.govt.nz/planning-and-investment/learning-and-resources/transport-data/data-and-tools/

[17] NZTA, 'Physical statistics – bridges'. Accessed at https://www.nzta.govt.nz/planning-and-investment/learning-and-resources/transport-data/data-and-tools/

[18] NZTA, 'Physical statistics – roads'. Accessed at https://www.nzta.govt.nz/planning-and-investment/learning-and-resources/transport-data/data-and-tools/

[19] Cross-checked against Wikipedia: https://en.wikipedia.org/wiki/List_of_motorways_and_expressways_in_New_Zealand

[20] Ministry of Transport, 'Annual fleet statistics', Table 1.1. Accessed at https://www.transport.govt.nz/statistics-and-insights/fleet-statistics/annual-fleet-statistics/

[21] Ministry for the Environment, 'Environment New Zealand 2007: Chapter 4: Transport'. Accessed at https://environment.govt.nz/publications/environment-new-zealand-2007/chapter-4-transport/

[22] Ministry of Transport, 'Annual fleet statistics', Table 1.4b. Accessed at https://www.transport.govt.nz/statistics-and-insights/fleet-statistics/annual-fleet-statistics/

[23] MBIE, 'Oil Statistics', 'Oil supply, transformation and consumption' table. Accessed at https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/oil-statistics.

Unit costs

We calculate a simple measure of unit costs for main/state highways by dividing annual main/state highway maintenance expenditure by the length of main/state highways. This provides some information on how the cost to maintain the road network evolved over time. However, it should not be seen as a true price index as it does not control for changing traffic volumes or changing quality of road surfaces. This measure is available for the 1929–1989 period.

Transport – Rail

Context

Rail capital investment has mainly been undertaken by central government since 1876, except for a period of full or partial private ownership from 1993 to 2008. The rail network is currently owned and operated by a State-Owned Enterprise.[24] We provide estimates for total rail capital investment for the 1870-2022 period, abstracting from ownership arrangements.

Capital investment estimates

We construct a capital investment series for rail by combining historical data from the Official Yearbook with more recent data from NZIC. This series covers the 1870-2022 period. As noted in the following table, the OYB does not include capital investment or construction cost estimates for the pre-1893 period, and there are also gaps in the data in the late 1960s and late 1980s. We impute capital investment estimates for years with missing data.

[24] https://teara.govt.nz/en/railways

Table A7: Sources used to construct capital investment estimates for transport – rail

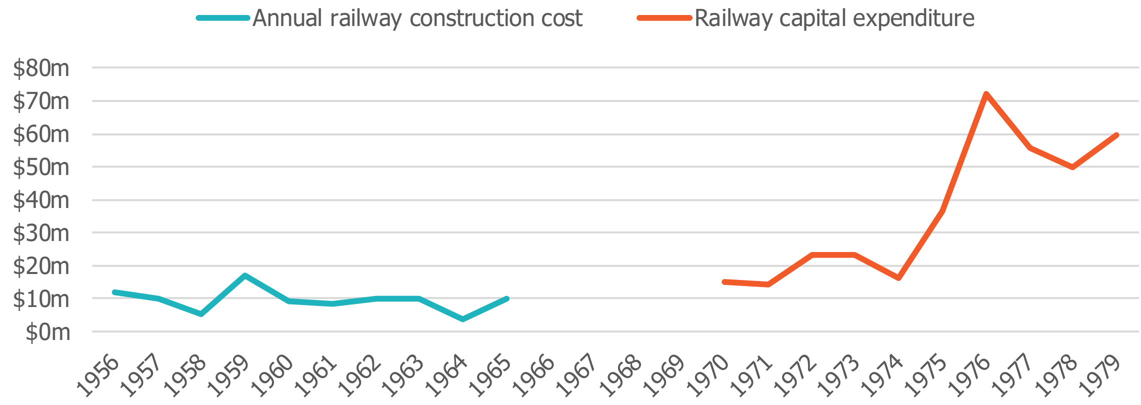
Years	Source	Notes
1870–1893	OYB	OYB publishes data on cumulative rail construction costs as of 1893, as well as annual data on the length of open rail lines for 1870 to 1893. We use this to estimate annual railway construction costs during this period. We spread cumulative construction costs as of 1893 based on the annual length of new lines that were opened over the 1878–1893 period, with straight-line imputation for the 1870–1877 period where many new lines were under construction but not yet completed. This imputation adjusts for changes in prices over this period using a GDP deflator series published by NZIER.[25] OYB also provides data on railway maintenance expenditure (ways, works, and signals) for the 1906–1984 period, which we record but do not count as capital expenditure.
1894–1965	OYB	OYB publishes annual data on cumulative railway construction expenditure for the 1893–1965 period. We collate this data, clean it where needed, and use it to estimate annual capital investment in railways.
1966–1969	Interpolation	OYB does not publish data on railway capital expenditure or construction costs during this period. We linearly interpolate between the pre-1965 and post-1970 series.
1970–1984	OYB	OYB publishes annual data on cumulative railway construction expenditure for the 1970–1984 period. We collate this data, clean it where needed, and use it as an estimate of annual capital investment.
1985–1989	Interpolation	OYB does not publish data on railway capital expenditure for this period. We linearly interpolate between the pre-1984 and post-1990 series.
1990–2022	NZIC	Estimates of gross fixed capital formation for rail, based on Stats NZ National Accounts – Capital Accounts data.

As there is no overlap between the two OYB series and the NZIC series, we examine how these series compare to each other in the ten years before and after each break. Figure A5 shows that there is no sharp difference between these series either in terms of levels or trends.

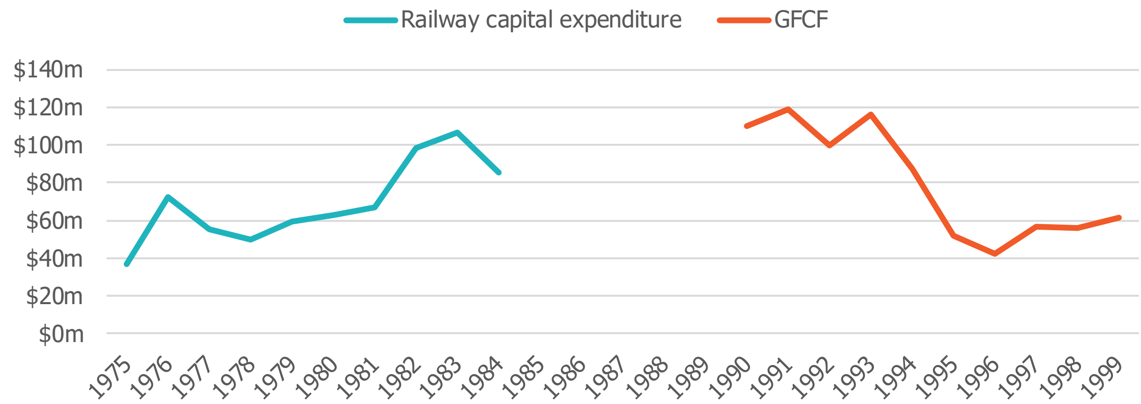
[25] To do so, we observe that cumulative capital cost as of time T (K_T) can be written as a function of the flow of investment over time $t=0,1,\ldots,T$. Investment at time t is equal to the number of units constructed (n_t), the real per-unit cost (c_t), and the price index (p_t). If we assume that real per-unit costs are constant over this period (i.e., $c_t=c$), and we have estimates for K_T, n_t, and p_t, we can calculate the real per-unit cost as $c = \frac{K_T}{\sum_{t=0}^{T} n_t p_t}$. After calculating c we can then estimate annual investment for each year of the imputation period.

Figure A5: Comparison of input series for rail investment (nominal NZD)

Panel A: Comparison of two OYB series



Panel B: Comparison of OYB series and NZIC series

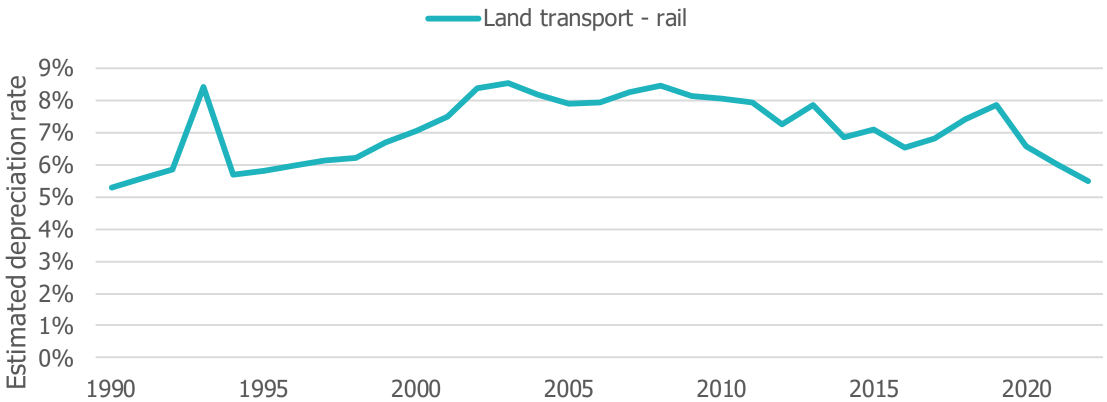


Capital stock estimates

We provide capital stock estimates for rail from 1870 to 2022. To do so, we use the above rail investment series available from 1870 onwards. Prior to this point, the value of New Zealand's rail network was assumed to be negligible (only 74 kilometres of open track, equal to around 1% of the peak size of the network). We use the composite infrastructure construction price index presented below to revalue the capital stock from year to year.

Figure A6 summarises annual estimates of depreciation rates for the 1990–2022 period. Over this period, depreciation rates averaged 7.08% for rail assets. This implies an average asset life of around 14 years.

Figure A6: Estimated depreciation rates for rail capital stock, 1990–2022



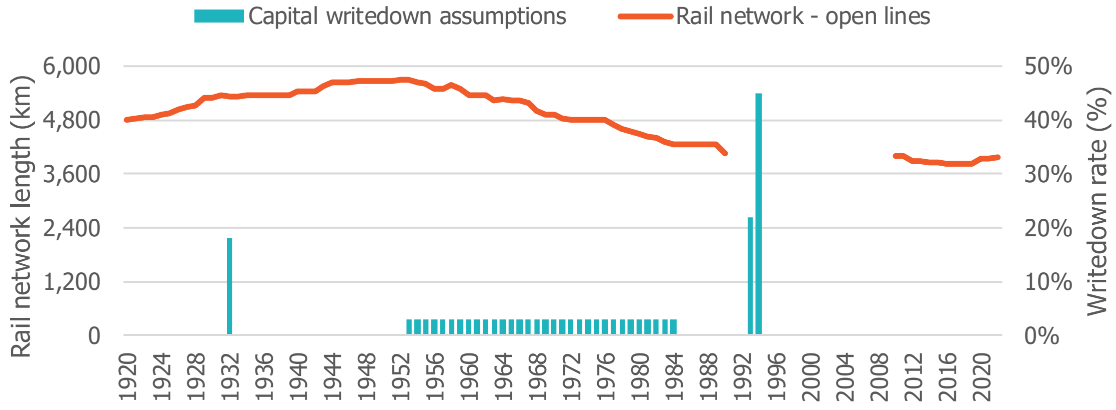
Source: Estimated using data from NZIC.

We use 1990–2022 average depreciation rates as a starting basis for the pre-1989 period but add writedown assumptions on top of base depreciation rates to account for the fact that the rail network experienced significant line closures from the 1950s onwards, as well as significant asset writedowns that coincided with network privatisation in the early 1990s.

We estimate writedowns using three sources of information. First, the OYB provides information on a significant one-off capital writedown that occurred in 1932, when approximately 18% of cumulative construction costs were written down. Second, post-1990 data suggests significant writedowns occurred in 1993 and 1994, equal to around 22% of asset value in 1993 and a further 45% in 1994. Third, we estimate that significant writedowns occurred from roughly 1953 to 1984, when the total length of the rail network declined due to line closures. We calibrate the magnitude of the 1953–1984 writedowns to ensure that perpetual inventory model capital stock estimates closely align with 1990–2022 capital stock estimates from NZIC. This results in annual writedowns of around 3.1% of asset value over this whole period.

Figure A7 summarises our capital writedown assumptions, which are added to the base depreciation rates described above. It also shows how our writedown assumptions they compare with changes in the length of the rail network.

Figure A7: Capital writedown assumptions for rail

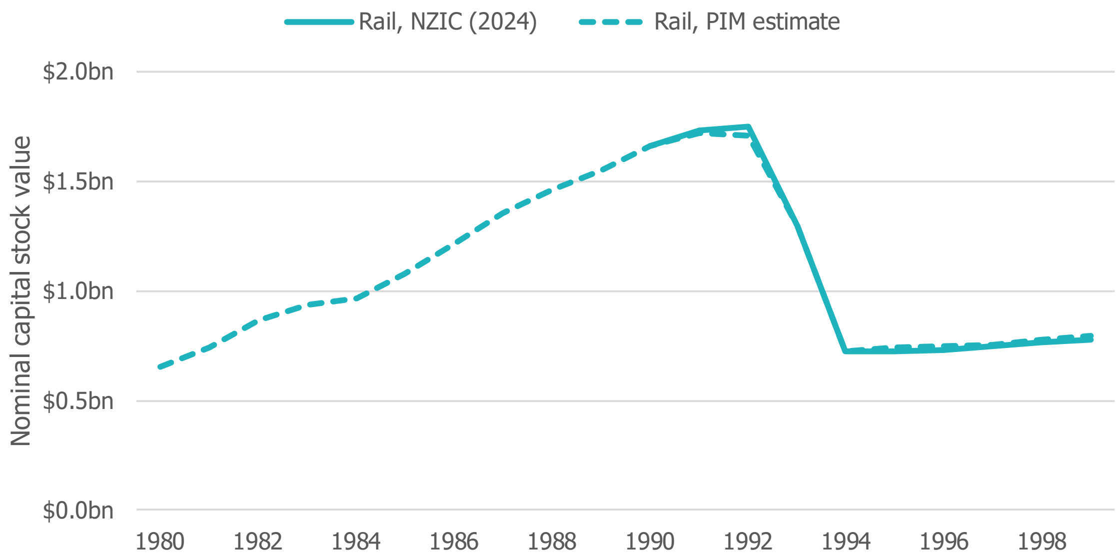


Source: New Zealand Infrastructure Commission analysis.

Figure A8 shows that the resulting perpetual inventory model estimates are close to post-1990 estimates from NZIC. Dashed lines indicate perpetual inventory model estimates and solid lines indicate post-1990 estimates based on Stats NZ National Accounts data. In 1990, our capital stock estimate for rail is within 0.1% of observed data.

Our final capital stock series splices together the pre-1990 perpetual inventory model capital stock estimates described here with the 1990–2022 data presented by NZIC.

Figure A8: Comparison of perpetual inventory model capital stock estimates with post-1990 data for rail



Source: New Zealand Infrastructure Commission analysis.

Physical network size data

We gather data on the length of the rail network over time.

Table A8: Rail network size metrics

Metric	Years	Unit	Sources
Rail network length	1870–2022	Kilometres	1870–1990: OYB publishes annual data on length of open rail lines, with some missing years (1871–1875, 1877–1879, 1985–1986) that had to be interpolated. 2010–2023: OECD-ITF publishes annual data on length of member country rail networks.[26]

Unit costs

We calculate a simple measure of unit costs for railways by dividing annual maintenance expenditure by the length of open railway lines. This provides some information on how the cost to maintain the rail network evolved over time. However, it should not be seen as a true price index as it does not control for changing usage or changing quality of infrastructure. This measure is available for the 1906–1984 period.

[26] OECD-ITF, 'Transport data and statistics', 'Annual length of inland transport infrastructure' table. Accessed at https://www.itf-oecd.org/transport-data-and-statistics

Water and waste

Water and waste capital investment has mainly been undertaken by local government throughout this period, although there has been a trend towards private involvement in waste infrastructure in recent decades. Water network assets – covering drinking water supply, wastewater, and stormwater and flood control – are currently owned and operated by local governments or council-controlled organisations. However, the structure of the local government sector has changed significantly over time, with a trend towards establishment of new local government bodies in the first half of the 20th century followed by significant local government amalgamation in 1989 and (in the Auckland region) 2010.[27]

Capital investment estimates

We provide estimates for total water and waste capital investment for the 1885–2022 period, abstracting from changes in institutional structure.

We construct a capital investment series for water and waste by combining historical data from the Official Yearbook and Stats NZ National Accounts with more recent data from NZIC. This series covers the 1885–2022 period. To construct this series, we started with data on total local government public works expenditure (covering both capital expenditure and maintenance spending) and estimate the share of this spending that is related to capital investment in water and waste infrastructure.

[27] https://teara.govt.nz/en/sewage-water-and-waste/page-5

Table A9: Sources used to construct capital investment estimates for water and waste

Years	Source	Notes
1885–1971	OYB	Water and waste infrastructure investment is included within the broader category of local government expenditure. OYB provides data on local government expenditure that can be used to estimate water and waste capital expenditure. There are three basic steps in this calculation: (1) we identify total works and utilities spending (including both capital investment and maintenance expenditure) by local government entities that provide water infrastructure; (2) we estimate the capital expenditure share of total works and utilities spending; and (3) we estimate the share of these councils' capital expenditure that is related to water infrastructure. Further details on data sources and calculations are provided below.
1972–1989	SNZ NA	Stats NZ National Accounts – Capital Accounts provide data on annual gross fixed capital formation for ANZSIC industry D28/29 Water Supply, Sewerage and Drainage Services and Waste Collection, Treatment and Disposal Services. This corresponds to the sectoral definition used in the NZIC series for 1990–2022.
1990–2022	New Zealand Infrastructure Commission (2024)	Estimates of gross fixed capital formation for water and waste infrastructure, based on Stats NZ National Accounts – Capital Accounts data.

Figure A9 shows the OYB data that we draw upon for the first two steps of the calculation. Data is shown on a log scale (base 10) to make it easier to interpret in light of the compounding effects of inflation and economic growth.

Panel A shows data on total local authority spending (1885–1983), local authority works and utilities spending (1892–1973), and local authority capital expenditure (1967–1972). As expected, works and utilities spending accounts for a large share of total local authorities spending – rising from around 50% of the total in the 1890s to around 75% in the 1960s and 70s.

Between 1967 and 1972, capital expenditure averaged around 41% of total local authority works and utilities spending. However, it is reasonable to expect that it was higher in the late 1800s, when local authorities had less infrastructure to maintain. Based on data from borough council works and utilities spending (1903–1912) and from two other networks at a similar stage of development (local electricity boards, 1925–1934; railways, 1906–1915), we estimate that this ratio might have been around 62% around 1900.[28] We assume a similar ratio for the pre-1900 period and a straight-line path from 1900 to 1967.

Panel B shows data on works and utilities spending by all local governments, and by local governments that provide water services (1892–1973). The share of local government works and utilities spending undertaken by water service-providing entities rose from less than 30% in the 1890s to a high of around 60% in the 1920s, and then declined gradually to a bit under 50% by the 1970s.

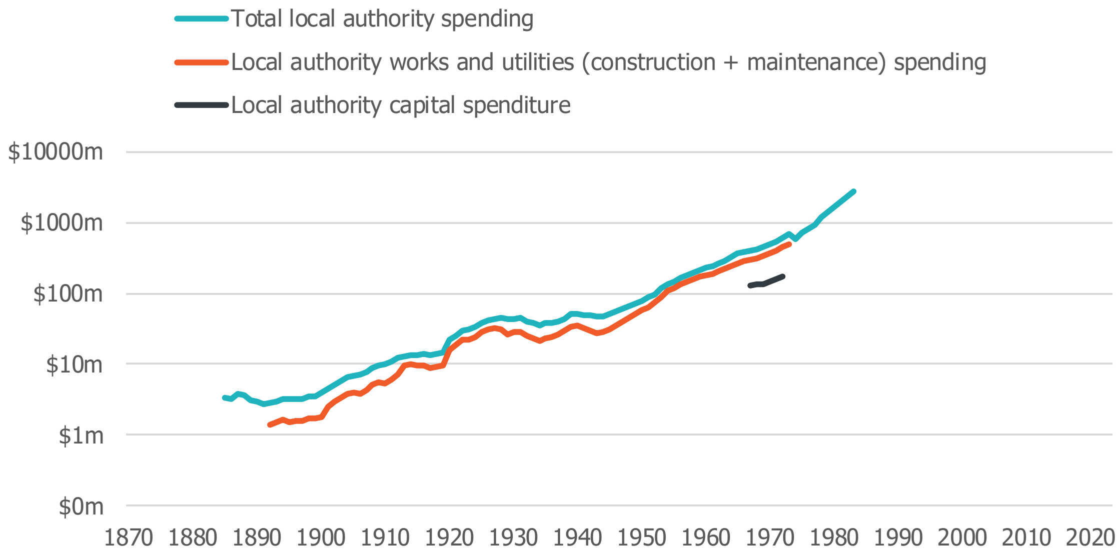
As we do not have data on works and utilities spending for the 1885–1891, we extrapolate this based on the trend in total local authority spending over this period.

Based on these data sources, we estimate total local authority capital expenditure, and capital expenditure by local government entities that provide water services, for the 1885–1973 period.

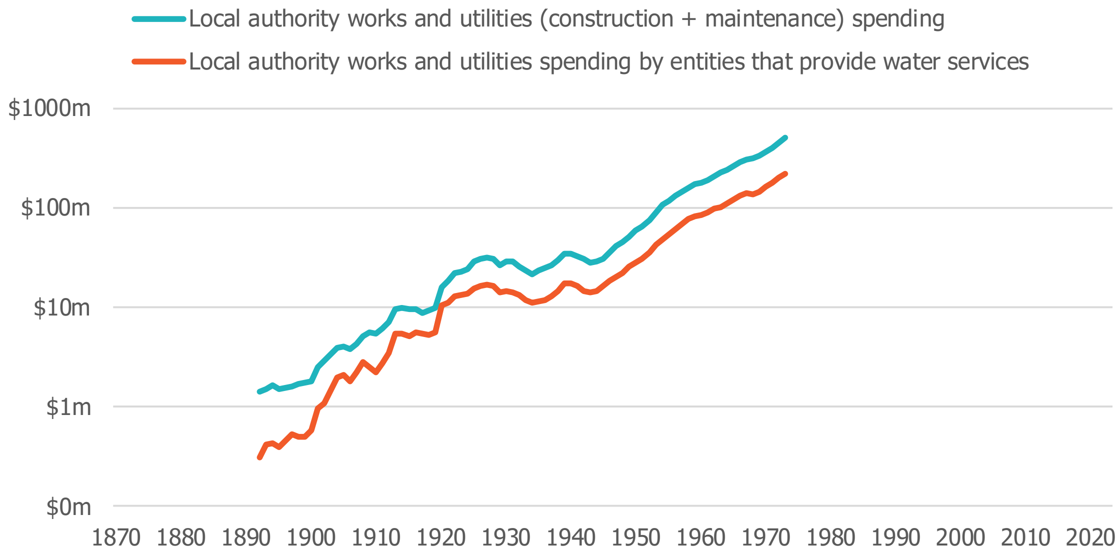
[28] From 1903 to 1912, the value of new works financed from loan money (the primary mechanism for building new local government infrastructure at this point) was equal to 61% of total borough council works and utilities spending. From 1906 to 1915, construction investment accounted for 66% of total railways construction and maintenance spending. From 1925 to 1934 (i.e., early in the development of the electricity networks) capital investment accounted for 59% of local electricity boards' total works and utilities spending.

Figure A9: OYB data series used to estimate local authority capital investment

Panel A: Total local authority spending, works and utilities spending, and capital expenditure



Panel B: Local authority works and utilities spending

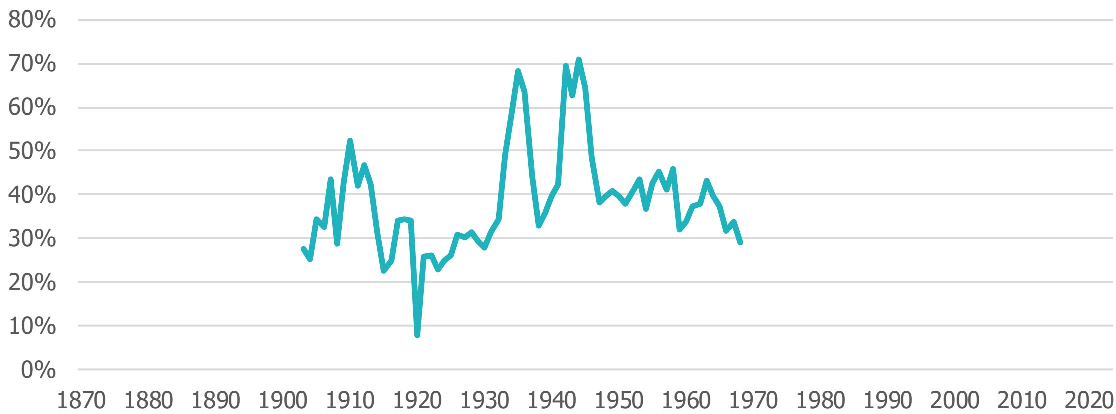


Note: Prior to the 1989 local government reforms, 'local authorities that provide water services' included several kinds of general-purpose local authorities (borough and city councils; town districts; native townships) and single-purpose local authorities (river districts; catchment districts; land-drainage districts; water-supply districts; urban drainage districts; underground-water authorities). Borough councils accounted for over 90% of total spending by local authorities that provide water services. Several other types of local governments (most notably county councils and roads districts) were able to provide water services, but the available information suggests that their primary focus was on road investment.

Figure A10 shows the OYB data that we use for the third step of the calculation, in which we estimate the share of capital expenditure by local government entities that provide water services that is related to water and waste infrastructure. The reason this is necessary is that some local government entities that provide water and waste infrastructure, such as borough councils, also provide other types of infrastructure. Following Mulcare (1994), we use OYB data on borough council expenditure on new works out of loan money (available 1903-1968) for this purpose.

The water and waste share of loan-financed new works varies over time but does not trend up or down over the whole 1903–1968 period. It is slightly lower in the 1910s and 1920s, and higher in the 1930s and late 1940s. We extrapolate ratios for 1885–1902 based on the average ratio over the 1903–1922 period (33%), and for 1969–1973 based on the average ratio over the 1949–1968 period (38%).

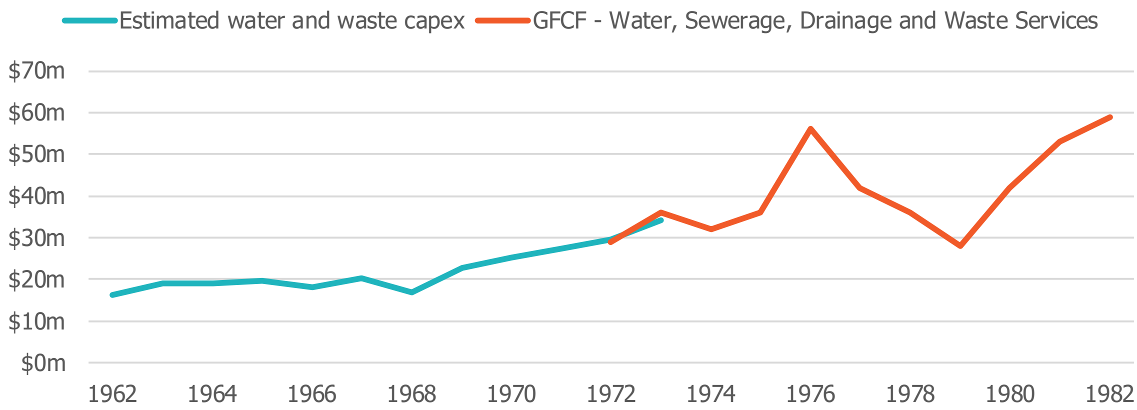
Figure A10: Water and waste infrastructure as a share of boroughs' loan-financed new works



Note: Water and waste infrastructure is categorised as 'Water-supply' and 'Drainage and Sewerage/Sanitation'. There is no separate category for landfills.

We compare the resulting series for water and waste infrastructure investment with the SNZ NA series. Figure A11 shows how these series compare for two years in which they overlap (1972 and 1973), and ten years before and after the join between the series. There is a close (although not exact) match between the two series in the overlap years, and no sharp difference in trends close to the join.

Figure A11: Comparison of input series for water and waste investment (nominal NZD)

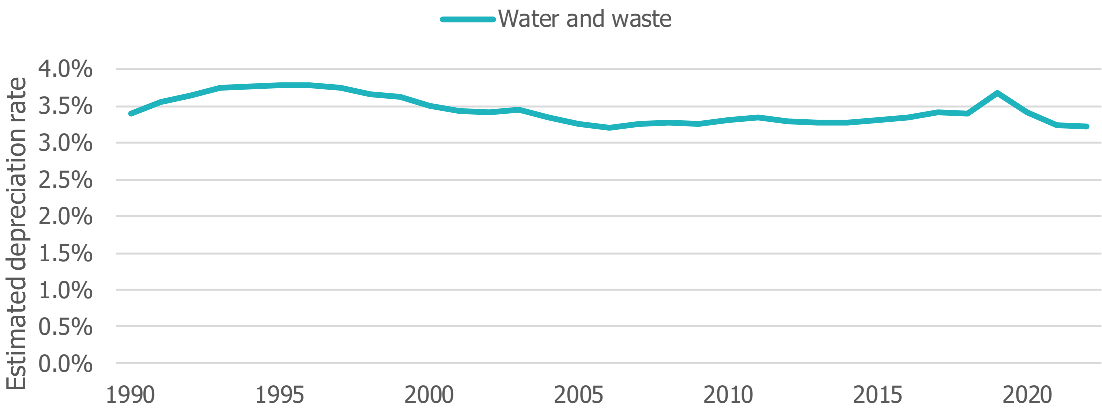


Capital stock estimates

We provide capital stock estimates for water and waste from 1885 to 2022. To do so, we use the above water and waste investment series available from 1885 onwards. Prior to this point, the value of New Zealand's water network was assumed to be negligible, although we note that some cities had started constructing waterworks. We use the composite infrastructure construction price index presented below to revalue the capital stock from year to year.

Figure A12 summarises annual estimates of depreciation rates for the 1990–2022 period. Over this period, depreciation rates averaged 3.44 % for water and waste assets. This implies an average asset life of around 29 years.

Figure A12: Estimated depreciation rates for water and waste capital stock, 1990–2022



Source: Estimated using data from NZIC.

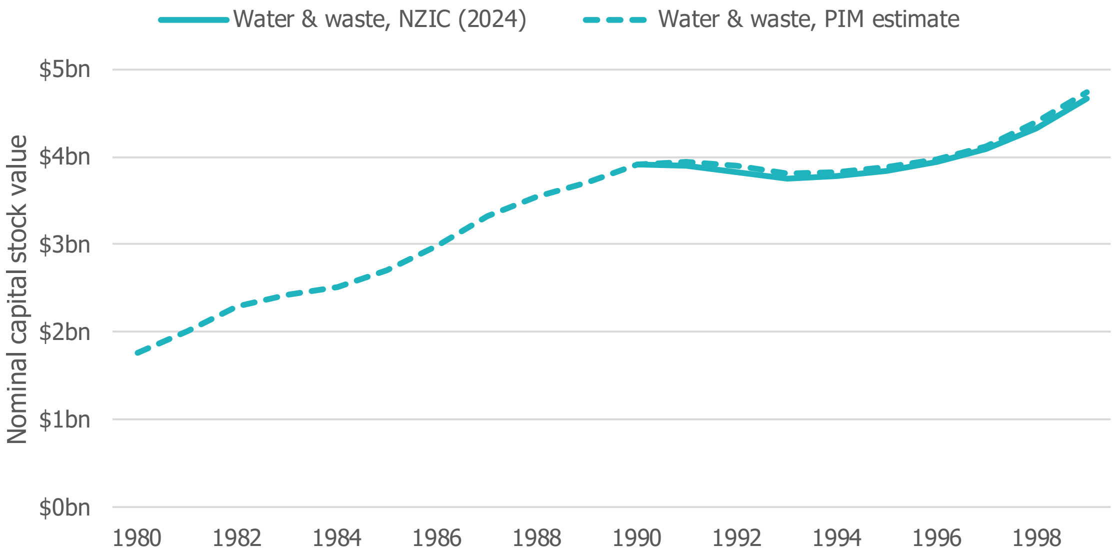
We use the 1990–2022 average depreciation rate as a starting basis for the pre-1989 period. However, in the absence of any adjustment this results in a perpetual inventory model estimate of capital stock that is 10% higher than post-1990 estimates from NZIC.

As a result, we add an additional writedown rate of 0.43% on top of base depreciation. In the absence of any information that would enable us to identify the time path of additional writedowns or depreciation, we assume that this applies equally to every year in the pre-1990 period. This implies a slightly shorter average asset life of around 25 years in the pre-1990 period.

Figure A13 shows that the resulting perpetual inventory model estimates are close to post-1990 estimates from NZIC. Dashed lines indicate perpetual inventory model estimates and solid lines indicate post-1990 estimates based on Stats NZ National Accounts data. In 1990, our capital stock estimate for water and waste infrastructure is within 0.1% of observed data.

Our final capital stock series splices together the pre-1990 perpetual inventory model capital stock estimates described here with the 1990–2022 data presented by NZIC.

Figure A13: Comparison of perpetual inventory model capital stock estimates with post-1990 data for water and waste



Source: New Zealand Infrastructure Commission analysis.

Physical network size data

We provide proxy measures of network coverage based on Stats NZ Census data (for the 1945–1971 and 2018–2023 periods) and estimates based on the best available historical data for the 1880s and early 1900s. We estimate network coverage based on the share and number of dwellings with indoor/flush toilets and the share and number of dwellings with access to piped drinking water or safe drinking water.

Table A10: Water network coverage metrics

Metric	Years	Unit	Sources
Dwellings with indoor/flush toilets	1886, 1906, 1945, 1956, 1961, 1966, 1971, 2018, 2023	Percentage and number	1886, 1906: New Zealand Infrastructure Commission estimate of share of dwellings with indoor toilets based on multiple historical data sources. See below for details. 1945–1971: OYB publishes Census data on amenities in dwellings (availability of flush toilet, either shared or individual). We calculated the share of dwellings that stated a response that had access to a flush toilet.[29] 2018, 2023: Census questions on access to basic amenities in occupied private dwellings (availability of toilet). We calculated the share of dwellings that stated a response that had access to a toilet.
Dwellings with piped water/safe drinking water	1886, 1906, 1945, 1956, 1961, 1966, 1971, 2018, 2023	Percentage and number	1886, 1906: New Zealand Infrastructure Commission estimate of share of dwellings in borough councils that provide piped drinking water based on multiple historical data sources. See below for details. 1945–1971: OYB publishes Census data on amenities in dwellings (availability of piped water, either shared or individual). We calculated the share of dwellings that stated a response that had access to piped water. 2018, 2023: Census questions on access to basic amenities in occupied private dwellings (availability of 'tap water that is safe to drink').[30] We calculated the share of dwellings that stated a response that had access to safe drinking water.

We note that data for the 1930s could be obtained from the returns of the 1937 Housing Survey, which was undertaken to identify the condition of housing in New Zealand. This survey included questions about basic amenities in dwellings, including toilets or other forms of sanitation. Some information from the Housing Survey is published in the 1940 OYB, but not in a way that would allow us to identify the share of dwellings that have access to flush toilets.[31]

[29] We gathered this data from the 1950, 1961, 1966, 1971, and 1976 OYBs.
[30] Accessed on Aotearoa Data Explorer:
https://explore.data.stats.govt.nz/vis?tm=census%20basic%20amenities&pg=0&snb=8&df[ds]=ds-nsiws-disseminate&df[id]=CEN23_TBT_001&df[ag]=STATSNZ&df[vs]=1.0&dq=.2013%2B2018%2B2023&ly[rw]=CEN23_TBT_DWD_001&ly[cl]=CEN23_YEAR_001&to[TIME]=false
[31] https://www3.stats.govt.nz/New_Zealand_Official_Yearbooks/1940/NZOYB_%201940.html#idsect2_1_179546

We estimate the share of dwellings that had access to an indoor/flush toilet in the mid-1880s (1886 Census year) and early 1900s (1906 Census year) by first estimating the share of dwellings in large borough councils (Auckland, Wellington, and Christchurch) that had access to indoor toilets, and then weighting this by the share of all dwellings that are in borough councils. This calculation assumes that these three cities are representative of indoor toilet uptake in all borough councils, and that dwellings outside of borough councils are not served by sewage networks. On balance, this is likely to lead to an over-estimate of sewage network coverage.

Table A11 summarises our estimates. We estimate that around 2% of all dwellings had indoor toilets in 1886, rising to around 8% by 1906. Our estimates are similar to but slightly lower than historical US data reported by Gordon (2016), which suggest that between 10 and 20% of US dwellings had access to indoor/flush toilets in the 1890s and 1900s. Frost (1991) shows that urban development and infrastructure trends in New Zealand were similar to those in the western US during this period.

Table A11: Estimated share of dwellings with indoor/flush toilets, 1886 and 1906

Census year	Estimated share of dwellings in boroughs with indoor toilets	Borough share of all dwellings	Estimated share of all dwellings with indoor toilets
1886	5.3%	42%	2.2%
1906	16.9%	47%	7.9%

Notes: 1886 estimate of the share of borough dwellings with indoor toilets based on simple average of Wellington (1891 estimate), Christchurch (1884), Auckland (1878). 1906 estimate based on simple average of Wellington (1906 estimate) and Christchurch (1901). Data on the share of national dwellings that are in borough councils is from the 1886 and 1906 Censuses.

We gathered data on urban dwellings with indoor toilets from three sources. For Wellington City, Isaacs (2023) provides data on the share of newly consented dwellings that had indoor toilets in 1893 (8% of newly consented dwellings), 1896 (20%), and 1899 (37%). We combine these with Census dwelling totals to make a rough estimate of the share of total Wellington City dwellings that had flush toilets in 1891 (8%) and in 1906 (18%). The 1891 estimate should be treated as an upper bound as it assumes that the consenting trends observed in 1893 were similar for earlier years. The 1906 estimate should be treated as a lower bound as it assumes that the share of newly consented dwellings with indoor toilets did not continue to increase after 1899.

For Christchurch, Wilson (1989) cites historical data on the number of dwellings in the Christchurch Drainage Board area (which included the Christchurch borough council and several adjacent local government areas) that had indoor toilets ('water closets'), and the number of properties connected to the sewer network. In 1884 293 dwellings had indoor toilets; by 1901 this had risen to 1915 dwellings. Based on Census data, we estimate that there were roughly 9000 dwellings in the Drainage Board area in 1886 and 12,000 in 1901. This suggests that around 3% of Christchurch dwellings had indoor toilets in 1886, rising to around 16% in 1901.

For Auckland, Watercare cites historical data showing that 150 dwellings in Auckland had indoor toilets ('water closets') in 1878, out of a total of 3,000 dwellings.[32] This suggests that around 5% of Auckland dwellings had indoor toilets by the 1880s.

We estimate the share of dwellings located in council areas that provide piped drinking water in 1886 and 1906 using Census data on the number of dwellings in each borough and various historical sources for the date that borough councils constructed their first waterworks/piped water supply. We gather data on the 20 largest boroughs by population size in each year, which accounted for 71% of total borough council dwellings in 1886 and 65% in 1906. We assume that these borough councils are representative of all borough councils, and that piped water supply is not available outside of borough councils.[33]

Table A12 summarises our estimates of the share of all dwellings that were in locations with access to piped drinking water. We estimate that around 32% of dwellings were in water-serviced areas in 1886, rising to 36% by 1906. These should be interpreted as upper-bound estimates, as not all dwellings in boroughs with water networks would have been connected to the network.

Our estimates are similar to historical US data reported by Gordon (2016), which suggest that around 25% of US dwellings had access to piped drinking water by 1890, rising to 40% by 1910. Higher uptake of piped drinking water relative to sewage networks is consistent with historical evidence offered by Frost (1991) and Schrader (2016).

Table A12: Estimated share of dwellings in locations with access to piped drinking water, 1886 and 1906

	20 largest boroughs				
Census year	**Total dwellings**	**Dwellings in boroughs with piped water supply**	**Share in boroughs with piped water supply**	**Share of all dwellings in borough councils**	**Estimated share of all dwellings with access to piped drinking water**
1886	35,281	27,023	77%	42%	32%
1906	58,276	45,372	78%	47%	36%

Table A13 summarises key data for the 20 largest borough councils. Shaded cells indicate councils that had not yet constructed drinking water networks in each year. Most councils constructed waterworks or piped water networks between the 1860s and 1880s. By 1886, only 6 of the largest 20 councils lacked a piped water network, and by early 1906, only three councils still lacked piped water networks. Christchurch was the last large council to develop a piped water network, in 1909. This reflected the city's access to aquifer water (which allowed residents to self-supply from wells) as well as its low-lying swampy terrain, which meant that it placed higher priority on drainage and sewer networks earlier on in its development (Wilson, 1989).

[32] https://promising-sparkle-d7f0c0cfc9.media.strapiapp.com/wastewater_history_4e14dc0522.pdf

[33] Available information suggests that these are reasonable assumptions. Among the largest 20 borough councils, there is no systematic correlation between population size and date of waterworks construction. Timing of piped water supply appears to be more dependent on hilly terrain (which raises the cost of piped water supply) and availability of aquifer water (which reduces the need for piped water supply). Outside of borough councils, supplying dwellings from rainwater or streams appeared to be more prevalent.

Table A13: Summary of 20 largest borough councils by population size, 1886 and 1906

1886			1906		
Borough council	Number of dwellings	Date of waterworks/ piped water construction	Borough council	Number of dwellings	Date of waterworks/ piped water construction
Auckland	6806	1866	Wellington	11005	1874
Wellington	4672	1874	Christchurch	10591	1909
Dunedin	4842	1867	Auckland	6918	1866
Christchurch	3021	1909	Dunedin	7741	1867
Sydenham	1924	1909	Palmerston North	2131	1889
Napier	1442	1876	Napier	1944	1876
Nelson	1412	1863	Wanganui	1717	1874
Oamaru	1150	1880	Nelson	1725	1863
Invercargill	987	1888	Timaru	1490	1881
St. Albans	1020	1909	Invercargill	1458	1888
Wanganui	958	1874	Petone	1351	1903
Parnell	896	1877	Grey Lynn	1185	1888
Caversham	871	1867	Gisborne	1182	1909
Thames	1029	1876	Waihi	1282	1905
Lyttelton	710	1877	Roslyn	1227	1904
South Dunedin	810	1867	Parnell	1040	1877
Timaru	743	1881	New Plymouth	1131	Late 1906
Roslyn	663	1904	Devonport	1073	1894
Maori Hill	643	1904	Oamaru	1083	1880
North-east Valley	682	1881	Masterton	1002	1900

Note: Waterworks/piped water supply dates are gathered from a range of historical sources and may not always be exact. Note that some councils were established or merged over this period. For instance, St Albans and Sydenham amalgamated with Christchurch between 1886 and 1906, and Caversham, Maori Hill, and North-east Valley amalgamated with Dunedin.

Electricity and gas

Institutional arrangements for undertaking electricity and gas capital investment have changed significantly since the early 1900s.

Prior to 1907, there was a small amount of investment by private companies (starting in Reefton in 1888). Local governments started investing in significant electricity generation and distribution schemes in 1907 (Dunedin City Council's Waipori scheme), followed by significant central government investment starting in 1910 (the Lake Coleridge scheme). From the end of the First World War to the late 1980s, both local and central governments played significant roles. The sector was corporatised and restructured in the late 1980s, and part-privatised in the 1990s. Today, investment is done by a mix of state-owned enterprises or mixed-ownership model companies, private companies involved in either generation or distribution, and council-owned electricity distribution companies.[34]

Capital investment estimates

We provide estimates for total electricity and gas capital investment for the 1906–2022 period, abstracting from ownership arrangements.

We construct a capital investment series for electricity and gas by combining historical electricity capital investment data from the Official Yearbook and Stats NZ National Accounts with more recent data from NZIC. As noted in the following table, the OYB does not provide annual capital investment data for the pre-1924 period, so we impute an investment trend for this period. As the OYB does not provide consistent information on gas investment, we impute this based on a comparison of SNZ NA and OYB data for the 1972–1977 period (pre-Maui).

[34] https://teara.govt.nz/en/energy-supply-and-use/page-5

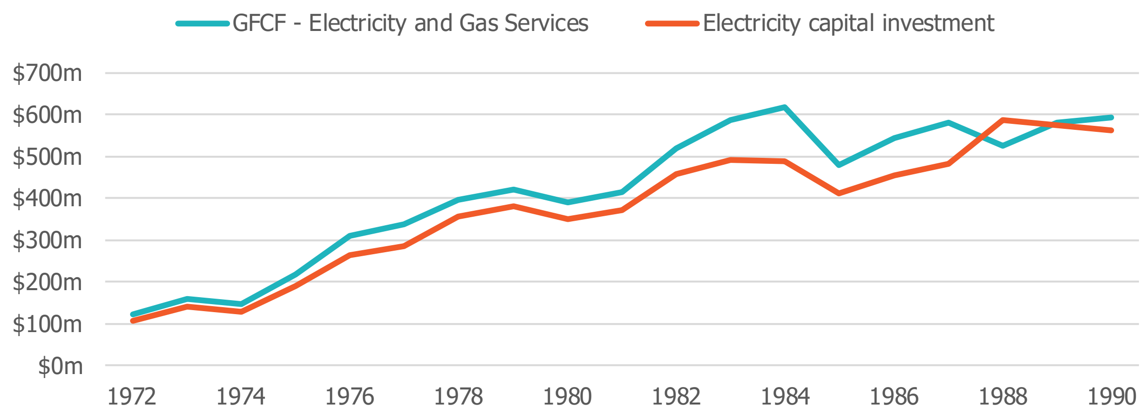
Table A14: Sources used to construct capital investment estimates for electricity and gas

Years	Source	Notes
1906–1923	OYB	OYB publishes data on cumulative electricity capital outlay as of 1923, as well as data that can be used to estimate installed electricity generation capacity available for public supply for 1906 to 1923. We use this to estimate annual electricity capital investment during this period. We spread cumulative capital outlay as of 1923 based on growth in generation capacity over the 1906–1923 period. We spread new generation capacity opened by 1910 (largely the Waipori scheme) evenly over the 1906–1910 period, new generation capacity opened by 1916 (largely the Lake Coleridge scheme) evenly over the 1911–1916 period, and new generation capacity opened by 1923 evenly over the 1917–1923 period. This imputation adjusts for changes in prices over this period using a GDP deflator series published by NZIER.[35] We scale up electricity investment, which we measure, by 14% to account for minor investment in gasworks, based on the average ratio of electricity and gas GFCF to electricity capital investment over the 1972–1981 period where the OYB and SNZ NA series overlap.
1924–1971	OYB	OYB publishes annual data on new capital investment for electricity generation, transmission, and distribution for the 1924–1990 period. We use this series to estimate electricity capital investment over the 1924–1971 period. We scale this up by 14% to account for minor investment in gasworks, based on the average ratio of electricity and gas GFCF to electricity capital investment over the 1972–1981 period where the OYB and SNZ NA series overlap (pre-Think Big and largely prior to the Maui gas field's opening).
1972–1989	SNZ NA	Stats NZ National Accounts – Capital Accounts provide data on annual gross fixed capital formation for ANZSIC industry D26/27 Electricity Supply and Gas Supply. This corresponds to the sectoral definition used in the NZIC series for 1990–2022.
1990–2022	NZIC	Estimates of gross fixed capital formation for central government and local government roads, based on Stats NZ National Accounts – Capital Accounts data.

The OYB and SNZ NA series overlap for 19 years (from 1972 to 1990). Figure A14 shows that these two series track closely together over this period. The SNZ NA series is slightly higher, due to the fact that it captures gas networks as well as electricity networks. As expected, the gap between the two series is largest in the early to mid-1980s when significant investment was occurring to develop gas networks.

[35] To do so, we observe that cumulative capital cost as of time T (K_T) can be written as a function of the flow of investment over time t=0,1,...,T. Investment at time t is equal to the number of units constructed (n_t), the real per-unit cost (c_t), and the price index (p_t). If we assume that real per-unit costs are constant over this period (i.e., $c_t=c$), and we have estimates for K_T, n_t, and p_t, we can calculate the real per-unit cost as $c = \frac{K_T}{\sum_{t=0}^{T} n_t p_t}$. After calculating c we can then estimate annual investment for each year of the imputation period.

Figure A14: Comparison of input series for electricity and gas investment (nominal NZD)

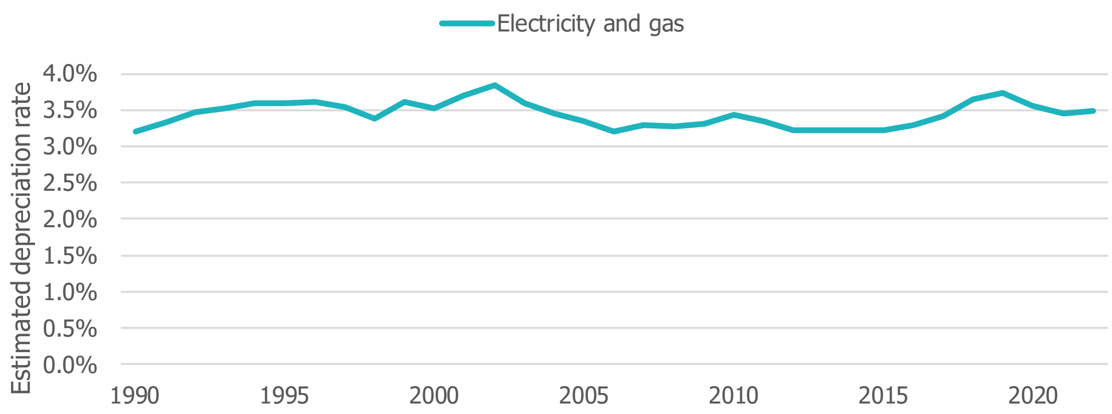


Capital stock estimates

We provide capital stock estimates for electricity and gas from 1906 to 2022. To do so, we use the above electricity and gas investment series available from 1906 onwards. Prior to this point, the value of New Zealand's energy networks was assumed to be negligible, as investment in public electricity supply only started in this year. However, this omits a small amount of local government and private sector investment in coal-gas plants. We use the composite infrastructure construction price index presented below to revalue the capital stock from year to year.

Figure A15 summarises annual estimates of depreciation rates for the 1990–2022 period. Over this period, depreciation rates averaged 3.44% for electricity and gas assets. This implies an average asset life of around 29 years.

Figure A15: Estimated depreciation rates for electricity and gas capital stock, 1990-2022



Source: Estimated using data from NZIC.

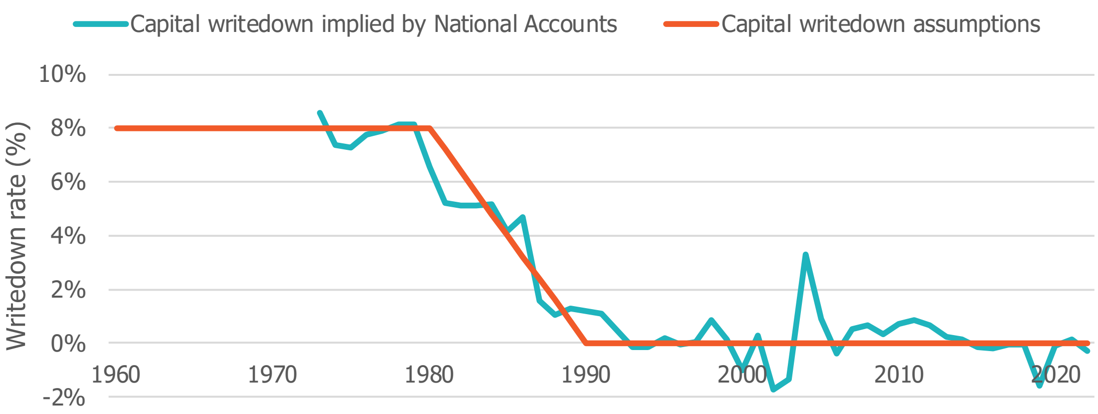
We use 1990–2022 average depreciation rates as a starting basis for the pre-1989 period but add writedown assumptions on top of base depreciation rates to account for the fact that the electricity and gas sector seemed to incur significant capital writedowns in the pre-1990 period. In the absence of any writedowns the perpetual inventory model estimate of capital stock is over twice as high as post-1990 estimates from NZIC.

We estimate the path and magnitude of writedowns using Stats NZ National Accounts data on net capital stock, gross fixed capital formation, and consumption of fixed capital, which is available for ANZSIC industry D26/27 Electricity Supply and Gas Supply from 1972 onwards. For each year from 1973 to 2022, we calculate a perpetual inventory model capital stock estimate for the sector, and then compare it against reported net capital stock. We use this to calculate the percentage writedown that must have occurred in this year.

For example, in 1984, we estimate the asset revaluations added around $280 million to the value of electricity and gas networks, and that around $620 million was invested in new or improved assets. Against this, electricity and gas networks incurred around $210 million in depreciation. Summing together revaluations and capital investment and subtracting depreciation, the nominal value of electricity and gas networks should have increased by around $690 million. However, Stats NZ reports that the value of the capital stock only increased by around $400 million. This implies asset writedowns equal to around $290 million, which is equal to approximately 5.2% of the value of the network.

Figure A16 summarises our resulting estimates of 1973-1990 capital writedowns, as well as the smoothed writedown rates that we use in this analysis. Writedowns are added to the base depreciation rates described above. We note that these writedown assumptions imply that a significant share of pre-1990 electricity and gas capital investment was unproductive or inefficient.

Figure A16: Capital writedown assumptions for electricity and gas

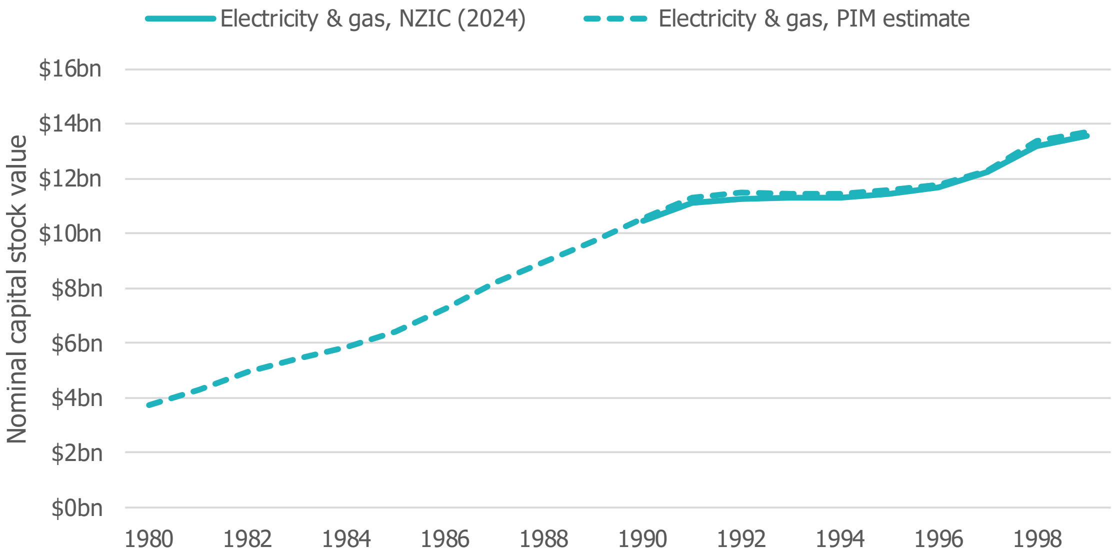


Source: New Zealand Infrastructure Commission analysis.

Figure A17 shows that the resulting perpetual inventory model estimates are close to post-1990 estimates from NZIC. Dashed lines indicate perpetual inventory model estimates and solid lines indicate post-1990 estimates based on National Accounts data. In 1990, our capital stock estimate for electricity and gas is within 0.8% of observed data.

Our final capital stock series splices together the pre-1990 perpetual inventory model capital stock estimates described here with the 1990–2022 data presented by NZIC.

Figure A17: Comparison of perpetual inventory model capital stock estimates with post-1990 data for electricity and gas



Source: New Zealand Infrastructure Commission analysis.

Physical network size data

We gather data on the size of the electricity network, including total installed generation capacity (three overlapping series covering the 1906–1922 period) and transmission and distribution network length (two overlapping series covering most years from 1921 to 2022). We also gather a partial measure of network quality, in terms of transmission and distribution losses as a share of total generation output (two series covering the 1934–2023 period).

Table A15: Electricity network size and quality metrics

Metric	Years	Unit	Sources
Electricity generation capacity (1)	1906–1927	Megawatts	1906–1927: OYB publishes data that can be used to calculate annual electricity generation capacity available for public supply.
Electricity generation capacity (2)	1921–1990	Megawatts	1921–1990: Stats NZ LTDS republishes annual generation capacity data from Martin (1991).[36]
Electricity generation capacity (3)	1976–2022	Megawatts	1976–2022: MBIE publishes annual data on operational generation capacity.[37] Note that this series overlaps with but does not exactly line up with the earlier series. We present both together rather than splicing them.
Transmission and distribution route-km	1921–1972	Kilometres	1921–1972: Stats NZ LTDS republishes annual T&D route-kilometre data from Martin (1991).[38]
Transmission and distribution circuit-km	1973–1990; 2015–2022	Kilometres	1973–1990: Stats NZ LTDS republishes annual T&D route-kilometre data from Martin (1991).[39] 2015–2022: Sum of ComCom annual information disclosure data for electricity distribution businesses[40] and Transpower.[41]
Transmission and distribution losses as a % of generation (1)	1934–1991	Percentage	1934–1991: OYB publishes data on total electricity output and electricity lost in transmission, etc (both in MWh). We divide one into the other to obtain estimated T&D losses as a percentage of electricity output.
Transmission and distribution losses as a % of net generation (2)	1990–2023	Percentage	1990–2023: MBIE publishes data on net generation and T&D line losses (both in GWh).[42] We divide one into the other to obtain estimated T&D losses as a percentage of net output. Note that this series overlaps with but does not exactly line up with the earlier series. We present both together rather than splicing them.

[36] Stats NZ, 'Long-term data series: 14.1 Capacity of electricity and electricity generated'. Accessed at https://statsnz.contentdm.oclc.org/digital/collection/p20045coll35/id/217/rec/209.
[37] MBIE, 'Electricity Statistics', 'Table 7 – Plant type (MW)'. Accessed at https://www.mbie.govt.nz/building-and-

Unit costs

We calculate a simple measure of unit costs for electricity generation investment based on an Electricity Authority dataset on cost and capacity for electricity generation schemes opened between 1907 and 2013. We sum up the quantity of added generation capacity (in megawatts) and the nominal cost of new generation capacity added in each year during this period. In some years, no new generation capacity is opened. We then calculate the average unit cost (in nominal NZD per megawatt) for each year. We exclude years in which a small amount of new generation capacity (defined as less than 0.2% of total capacity) is opened, as small generation schemes often have atypical costs.

energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/electricity-statistics.

[38] Stats NZ, 'Long-term data series: 14.1 Capacity of electricity and electricity generated'. Accessed at https://statsnz.contentdm.oclc.org/digital/collection/p20045coll35/id/217/rec/209.

[39] Stats NZ, 'Long-term data series: 14.1 Capacity of electricity and electricity generated'. Accessed at https://statsnz.contentdm.oclc.org/digital/collection/p20045coll35/id/217/rec/209.

[40] ComCom, 'Information disclosed by electricity distributors'. Accessed at https://comcom.govt.nz/regulated-industries/electricity-lines/electricity-distributor-performance-and-data/information-disclosed-by-electricity-distributors.

[41] ComCom, 'Information disclosed by Transpower'. Accessed at https://comcom.govt.nz/regulated-industries/electricity-lines/electricity-transmission/information-disclosed-by-transpower

[42] MBIE, 'Electricity Statistics', 'Table 2 – Annual electricity generation and consumption'. Accessed at https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/electricity-statistics.

Telecommunications

Context

Institutional arrangements for undertaking telecommunications investment have changed significantly from the 1800s to today. Telecommunications technologies have also changed significantly, from telegraphs to fixed-line telephones and fixed-line data services to mobile phones and fibre broadband.

Between the 1860s and 1980s, telecommunications infrastructure was supplied by central government through the Post Office. The sector was corporatised and restructured in the late 1980s and privatised in the early 1990s. It was restructured again in the 2000s, followed by central government co-investment in ultra-fast broadband. Today, investment is primarily done by private companies.[43]

Capital investment estimates

We provide estimates for total telecommunications capital investment for the 1870–2022 period, abstracting from ownership arrangements and changes in technology.

We construct a capital investment series for telecommunications by combining historical telecommunications capital investment data from the New Zealand Official Yearbook (OYB) and Stats NZ National Accounts (SNZ NA) with more recent data from NZIC. As noted in the following table, the OYB does not provide annual capital investment data for the pre-1921 period, so we impute an investment trend for this period.

[43] https://teara.govt.nz/en/telecommunications

Table A16: Sources used to construct capital investment estimates for telecommunications

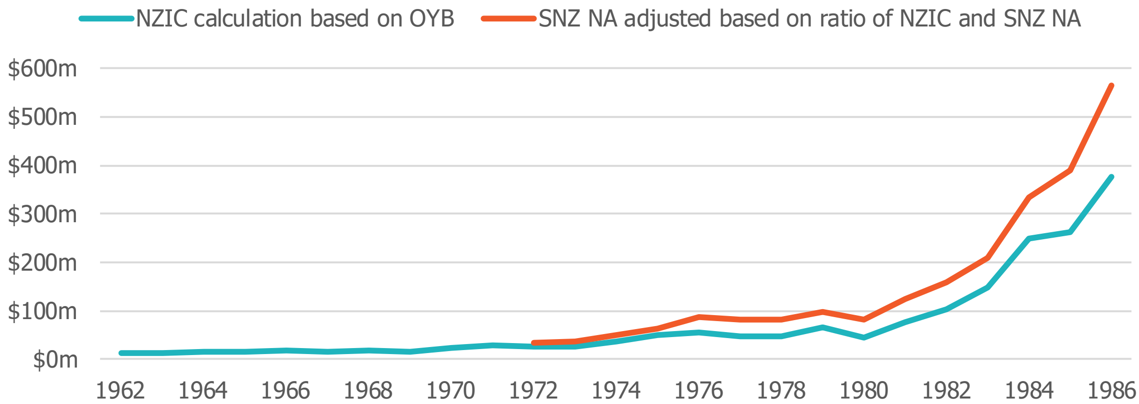
Years	Source	Notes
1870–1920	OYB	OYB publishes data on cumulative telephone capital investment as of 1893, and cumulative telegraph and telephone capital investment as of 1921. It also publishes data on network size over time, in terms of length of telegraph lines (1866 onwards) and number of telephone subscribers (1880 onwards). We use this to estimate annual telephone capital investment for the 1880-1893 period, and annual telegraph capital investment for the 1870–1920 period. We spread cumulative capital outlay at the end of each period based on annual growth in network size over the period. This imputation adjusts for changes in prices over this period using a GDP deflator series published by NZIER.[44] From 1894 to 1920, we use the OYB telephone annual capital investment series rather than imputations. We sum together telegraph and telephone capital investment estimates for each year to obtain an estimate of total telecommunications investment.
1921–1971	OYB	OYB publishes data on annual capital investment in telegraph and telephone networks from 1921 to 1968. We use this as an estimate of total telecommunications investment for this period. OYB also publishes data on annual capital investment in telephone networks only from 1894 to 1986. By the 1960s telephone network investment accounts for around 90% of the total. We therefore extrapolate total telecommunications investment over the 1969–1971 period based on growth in telephone capital investment.
1972–1989	SNZ NA	SNZ NA provide 1972–2022 data for gross fixed capital formation for ANZSIC industry J, Information Media and Telecommunications, which includes the telecommunications industry plus some other things. A comparison of the SNZ NA and NZIC series for the 1990–2022 period shows that telecommunications consistently accounts for 97% of the total. For the 1972–1989 period, we multiply the SNZ NA series by 0.97 to obtain an estimate for telecommunications capital investment.
1990–2022	New Zealand Infrastructure Commission (2024)	Estimates of gross fixed capital formation for central government and local government roads, based on Stats NZ National Accounts – Capital Accounts data.

There are 15 years of overlap between the OYB and SNZ NA series that we use to construct these estimates (from 1972 to 1986). Figure A18 shows how our estimates relate to each other for ten years prior to 1971 and for the full 15-year overlap period. This shows that while these series follow the same trend, there is a level difference between the series that gradually increases through the 1970s and 1980s. This level difference could reflect under-estimation of pre-1971 investment using the OYB data, or it could reflect the

[44] To do so, we observe that cumulative capital cost as of time T (K_T) can be written as a function of the flow of investment over time t=0,1,…,T. Investment at time t is equal to the number of units constructed (n_t), the real per-unit cost (c_t), and the price index (p_t). If we assume that real per-unit costs are constant over this period (i.e., c_t=c), and we have estimates for K_T, n_t, and p_t, we can calculate the real per-unit cost as $c = \frac{K_T}{\sum_{t=0}^{T} n_t p_t}$. After calculating c we can then estimate annual investment for each year of the imputation period.

fact that telecommunications network investment was being directed towards a broader mix of technologies and services during the post-1970s period.

Figure A18: Comparison of investment series for telecommunications

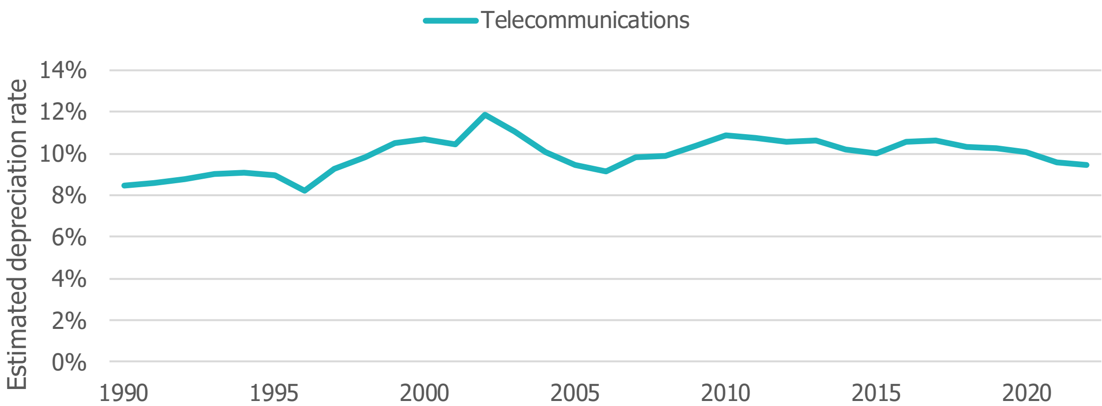


Capital stock estimates

We provide capital stock estimates for telecommunications from 1870 to 2022. To do so, we use the above telecommunication investment series available from 1870 onwards. Prior to this point, the value of New Zealand's telecommunication network was assumed to be negligible, although there had been some previous investment in telegraphs. We use the composite infrastructure construction price index presented below to revalue the capital stock from year to year.

Figure A19 summarises annual estimates of depreciation rates for the 1990–2022 period. Over this period, depreciation rates averaged 9.93% for telecommunication assets. This implies an average asset life of around 10 years.

Figure A19: Estimated depreciation rates for telecommunications capital stock, 1990–2022



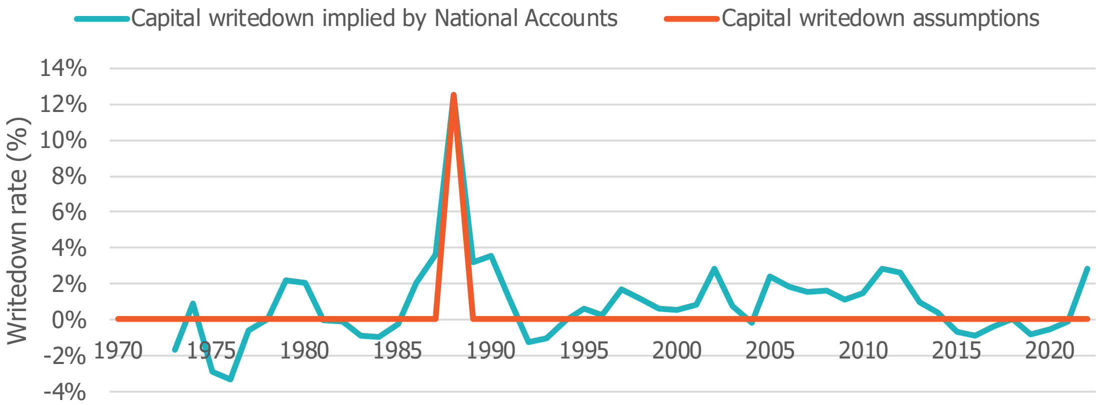
Source: Estimated using data from NZIC.

We use 1990–2022 average depreciation rates as a starting basis for the pre-1989 period, but add writedown assumptions on top of base depreciation rates to account for the fact that the telecommunications sector seemed to incur significant capital writedowns in the pre-1990 period. In the absence of any writedowns the perpetual inventory model estimate of capital stock is around 9% higher than post-1990 estimates from NZIC.

We estimate the path and magnitude of writedowns using Stats NZ National Accounts data on net capital stock, gross fixed capital formation, and consumption of fixed capital, which is available for ANZSIC industry J Information Media and Telecommunications from 1972 onwards. For each year from 1973 to 2022, we calculate a perpetual inventory model capital stock estimate for the sector, and then compare it against reported net capital stock. We use this to calculate the percentage writedown that must have occurred in this year. This is the same method as we use to estimate the path of writedowns in electricity and gas networks.

Figure A20 the writedown rates that we use in this analysis. We estimate that significant writedowns (of around 12.5% of capital stock value) occurred only in a single year, 1988. This coincides with the corporatisation of the telecommunications department. Before and after this, Stats NZ National Accounts data does not indicate any significant trend towards writedowns. Writedowns are added to the base depreciation rates described above.

Figure A20: Capital writedown assumptions for telecommunications

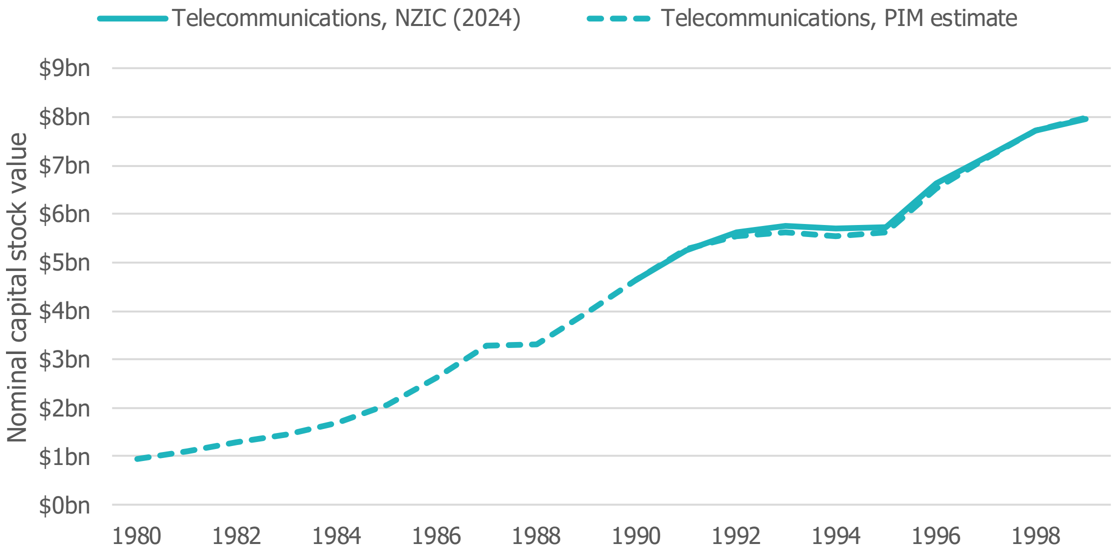


Source: New Zealand Infrastructure Commission analysis.

Figure A21 shows that the resulting perpetual inventory model estimates are close to post-1990 estimates from NZIC. Dashed lines indicate perpetual inventory model estimates and solid lines indicate post-1990 estimates based on National Accounts data. In 1990, our capital stock estimate for telecommunications is within -0.1% of observed data.

Our final capital stock series splices together the pre-1990 perpetual inventory model capital stock estimates described here with the 1990–2022 data presented by NZIC.

Figure A21: Comparison of perpetual inventory model capital stock estimates with post-1990 data for telecommunications



Source: New Zealand Infrastructure Commission analysis.

Physical network size data

We gather data on the size of different telecommunications networks that were installed and, in some cases, decommissioned over this period. This includes telegraph line length (1870–1939), fixed line telephone subscribers (three overlapping series covering the 1880-2022 period – note that there is a level difference between the World Bank and OYB series), mobile telephone subscriptions (1960–2022), and broadband network size and uptake (three series covering the 2000–2023 period). We also gather a partial measure of network quality – the length of the waiting list for a telephone connection (1950–1990; dropping to zero after this).

Table A17: Telecommunications network size and quality metrics

Metric	Years	Unit	Sources
Telegraph line length	1870–1939	Kilometres	1870–1892: Grimes (2008) publishes data on telegraph network length in the pre-1900 period.[45] 1893–1939: OYB publishes annual data on length of telegraph lines; series discontinued after 1939.
Telephone subscribers (1)	1880–1980	Number	1880: Te Ara reports that there were around 50 telephone subscriptions in 1880.[46] 1881–1892: Straight-line imputation. 1893–1980: OYB publishes annual data on number of telephone subscribers.
Telephone subscribers (2)	1980–1987	Number	1980–1987: OYB publishes annual data on number of telephone subscribers, based on a different definition to the pre-1980 series. Note that this series overlaps with but does not exactly line up with the earlier series. We present both together rather than splicing them.
Waiting list for a telephone connection	1950–1990	Number	1950–1990: OYB publishes annual data on the number of people waiting for a telephone connection.
Fixed line telephone subscriptions	1960–2022	Number	1960–2022: The World Bank publishes annual data on the number of fixed line telephone subscriptions.[47] Note that this series overlaps with but does not line up with the earlier OYB series. There is a considerable level difference between the two series. We present both together rather than splicing them.
Mobile telephone subscriptions	1987–2022	Number	1987–2022: The World Bank publishes annual data on the number of mobile telephone subscriptions.[48]
Broadband internet subscriptions	2000–2023	Number	2000–2023: The World Bank publishes annual data on the number of fixed-line broadband subscriptions.[49]
Number of end users able to connect to UFB	2011–2023	Number	2011–2021: MBIE publishes (June quarter) data on number of end users able to connect to Ultra-Fast Broadband.[50] 2022–2023: Crown Infrastructure Partners publishes annual (June quarter) data that continues the previous MBIE reporting.[51]
Number of users connected to UFB	2011–2023	Number	Same as above.

Note: All data sourced from OYB required some minor data cleaning, including correcting seeming transcription errors and imputing one or two years of missing data.

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[45] https://www.motu.nz/assets/Documents/our-work/urban-and-regional/infrastructure/Motu-note-1-Grimes.pdf
[46] https://teara.govt.nz/en/telecommunications/page-2
[47] World Bank, 'Fixed telephone subscriptions'. Accessed at https://data.worldbank.org/indicator/IT.MLT.MAIN?locations=NZ
[48] World Bank, 'Mobile cellular subscriptions'. Accessed at https://data.worldbank.org/indicator/IT.CEL.SETS?locations=NZ
[49] World Bank, 'Fixed broadband subscriptions'. Accessed at https://data.worldbank.org/indicator/IT.NET.BBND?locations=NZ
[50] MBIE, 'Quarterly Updates on Broadband Deployment'. Accessed via archive.org: https://web.archive.org/web/20240524064426/https://www.mbie.govt.nz/science-and-technology/it-communications-and-broadband/digital-connectivity-programmes/quarterly-updates-on-broadband-deployment; https://web.archive.org/web/20171101123131/http://www.mbie.govt.nz/info-services/sectors-industries/technology-communications/fast-broadband/deployment-progress/
[51] Crown Infrastructure Partners, 'Connectivity Quarterly updates'. Accessed via archive.org: https://web.archive.org/web/20240910141633/https://crowninfrastructure.govt.nz/about/publications/

Unit costs

We calculate a simple measure of unit costs for telecommunication investment by dividing annual telephone capital expenditure by the number of added telephone subscribers. We exclude a small number of years where subscribers grew by less than 1% (or contracted), mainly during the Great Depression. This provides a rough indication of how the cost to expand the telephone network evolved over time. However, it should not be seen as a true price index as it does not control for changing usage or changing quality of infrastructure, and does not account for renewal expenditure. This measure is available for the 1894–1979 period.

Health – Hospitals

Context

Institutional arrangements for hospital provision have changed significantly from the 1800s to today. Hospitals were originally provided locally by hospital boards, followed by a move to central government provision starting in the 1930s. While central government continues to play a leading role in hospital provision, organisational structures for doing so have been reformed several times since the 1990s. In addition, some hospital provision is done by the private sector.[52]

Capital investment estimates

We provide estimates for total hospital capital investment for the 1879–2022 period, abstracting from changes in ownership and provision models. We construct a capital investment series for hospitals by combining historical electricity capital investment data from Mulcare with more recent data from NZIC.

Table A18: Sources used to construct capital investment estimates for health – hospitals

Years	Source	Notes
1879–1989	Mulcare	Estimates of gross capital formation for structures (1879–1989) and non-market plant and equipment (1930–1989).
1990–2022	NZIC	Estimates of gross fixed capital formation for central government and local government roads, based on Stats NZ National Accounts – Capital Accounts data.

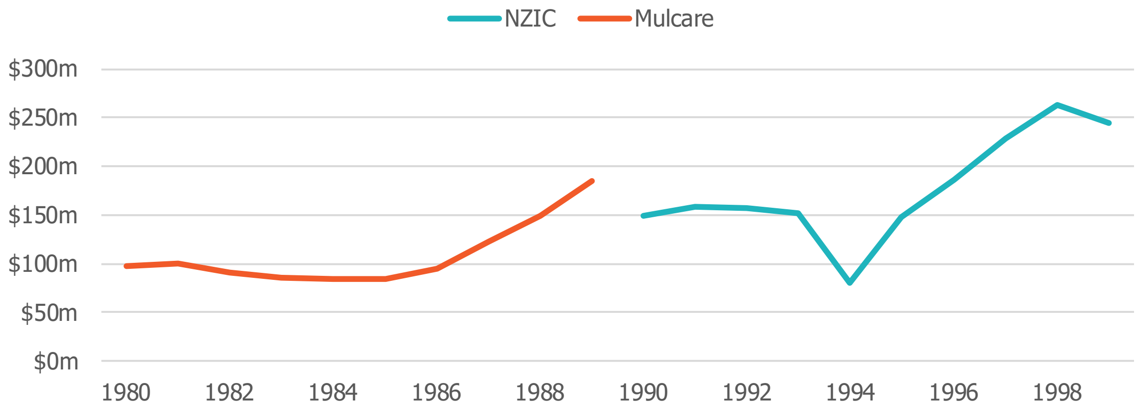
As there is no overlap between the Mulcare series and the NZIC series, we examine how these series compare to each other in the ten years before and after each break. We also examine the ratio of the Mulcare and NZIC series to the Stats NZ National Accounts series for capital investment in ANZSIC industry Q, Health Care and Social Assistance, which includes hospitals and other things.

Figure A22 shows that there is no sharp difference between these series in terms of levels or trends, when examined either in nominal NZD or as a share of capital investment in ANZSIC industry Q.

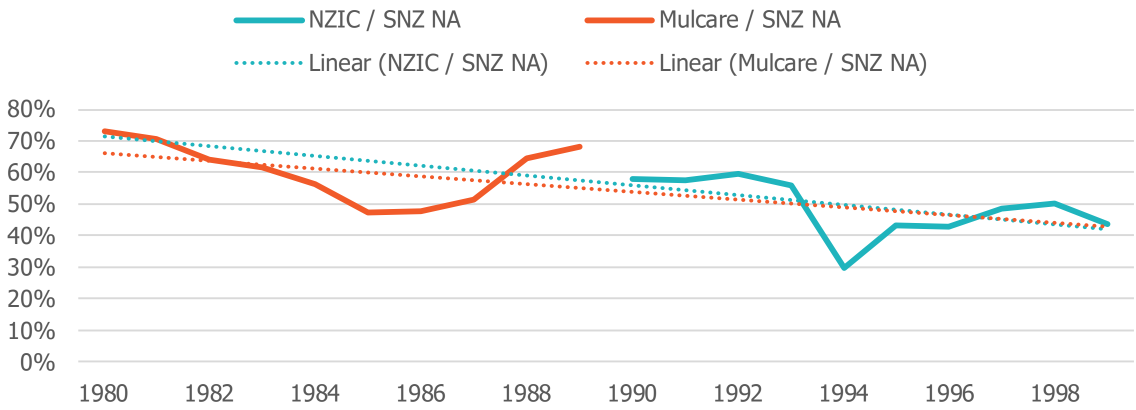
[52] https://teara.govt.nz/en/hospitals/page-6; https://www.health.govt.nz/system/files/2024-05/chronology-of-the-new-zealand-health-system-1840-to-2017_0.pdf

Figure A22: Comparison of input series for hospital investment

Panel A: Comparison of Mulcare and NZIC series in nominal NZD



Panel B: Comparison of Mulcare and NZIC series as a share of GFCF in ANZSIC industry Q

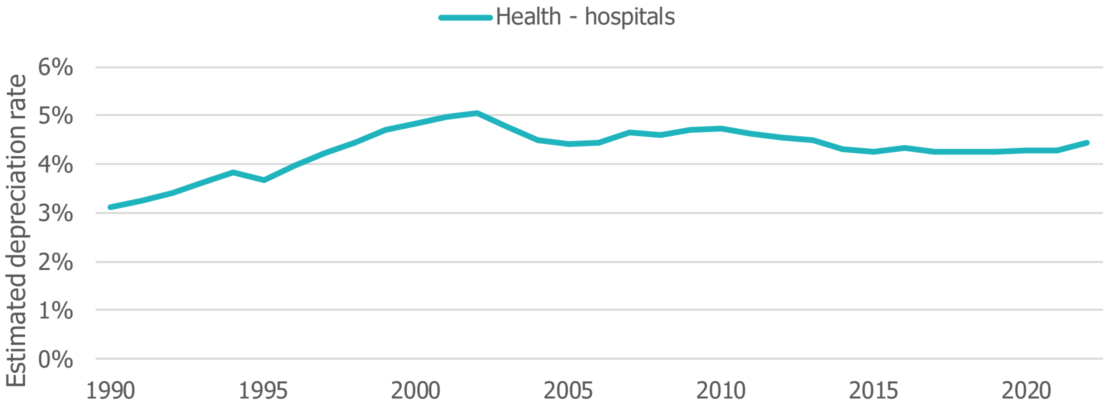


Capital stock estimates

We provide capital stock estimates for hospitals from 1879 to 2022. To do so, we use the above hospital investment series available from 1879 onwards. Prior to this point, the value of New Zealand's hospital network was assumed to be negligible, although there had been some small-scale investment by local bodies. We use the composite infrastructure construction price index presented below to revalue the capital stock from year to year.

Figure A23 summarises annual estimates of depreciation rates for the 1990–2022 period. Over this period, depreciation rates averaged 4.31% for hospital assets. This implies an average asset life of around 23 years.

Figure A23: Estimated depreciation rates for hospital capital stock, 1990-2022



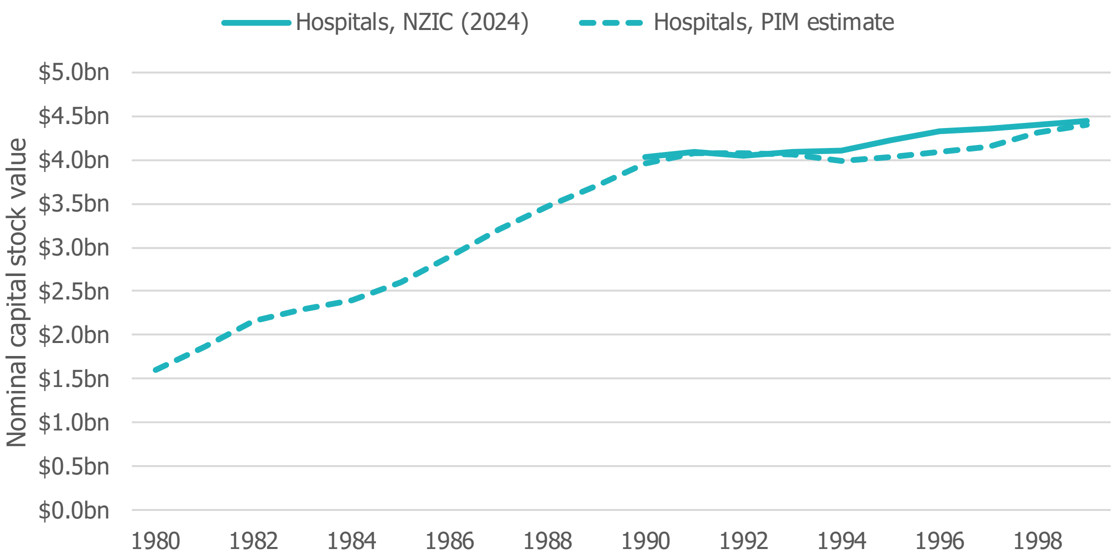
Source: Estimated using data from NZIC.

We use 1990–2022 average depreciation rates as a starting basis for the pre-1989 period. We find that this results in perpetual inventory model estimates that are very close to post-1990 estimates from NZIC. As a result, we do not apply any adjustments or supplementary assumptions about asset writedowns.

Figure A24 shows that the resulting perpetual inventory model estimates are close to post-1990 estimates from NZIC. Dashed lines indicate perpetual inventory model estimates and solid lines indicate post-1990 estimates based on National Accounts data. In 1990, our capital stock estimate for telecommunications is within -1.9% of observed data.

Our final capital stock series splices together the pre-1990 perpetual inventory model capital stock estimates described here with the 1990–2022 data presented by NZIC.

Figure A24: Comparison of perpetual inventory model capital stock estimates with post-1990 data for hospitals



Source: New Zealand Infrastructure Commission analysis.

Physical network size data

We gather data on the physical size of the hospital estate, measured in terms of bed capacity, from 1892 to 2022. How hospital beds are measured has changed over time, and as a result we report eight separate overlapping series. This includes two series for public hospital beds, excluding psychiatric beds (covering the 1892–1992 period), two series for public hospital beds, including psychiatric beds (covering the 1976–2002 and 2009–2022 periods), three series for total hospital beds, excluding psychiatric beds (covering the 1938–1992 and 2009–2022 periods), and one series for total hospital beds, including psychiatric beds (covering the 2009-2022 period).

Where these series overlap, we were unable to find information that could be used to reconcile the level differences between them.

Table A19: Hospital network size metrics

Metric	Years	Unit	Sources
Public hospital beds (excl psychiatric beds) (1)	1892–1924	Number	1892–2024: OYB publishes annual data on public hospital beds, excluding psychiatric ('mental hospital') beds.
Public hospital beds (excl psychiatric beds) (2)	1924–1992	Number	1924–1992: OYB publishes annual data on public hospital beds, excluding psychiatric ('mental hospital') beds. This series overlaps with the previous OYB series in a single year (1924), with a considerable level difference between the two series. We present both together rather than splicing them.
Public hospital beds (incl psychiatric beds) (1)	1976–2002	Number	1976–2002: OYB publishes annual data on public hospital beds, including psychiatric ('mental hospital') beds.
Public hospital beds (incl psychiatric beds) (2)	2009–2022	Number	2009–2022: OECD publishes annual data on public hospital beds, including psychiatric ('mental hospital') beds.[53] It is unclear whether this data is based on a similar definition as the earlier OYB series, so we present them separately rather than joining them into a single series.
Total hospital beds (excl psychiatric beds) (1)	1938–1946	Number	1938–1946: OYB publishes annual data on total (public and private) hospital beds, excluding psychiatric ('mental hospital') beds.
Total hospital beds (excl psychiatric beds) (2)	1946–1992	Number	1946–1992: OYB publishes annual data on total (public and private) hospital beds, excluding psychiatric ('mental hospital') beds. This series overlaps with the previous OYB series in a single year (1946), with a considerable level difference between the two series. We present both together rather than splicing them.
Total hospital beds (excl psychiatric beds) (3)	2009–2022	Number	2009–2022: OECD publishes annual data on total (public and private) hospital beds, excluding psychiatric ('mental hospital') beds.[54] It is unclear whether this data is based on a similar definition as the earlier OYB series, so we present them separately rather than joining them into a single series.
Total hospital beds (incl psychiatric beds)	2009–2022	Number	2009–2022: OECD publishes annual data on total (public and private) hospital beds, including psychiatric ('mental hospital') beds.[55]

Note: All data sourced from OYB required some minor data cleaning, including correcting seeming transcription errors and imputing one or two years of missing data.

[53] OECD, 'Hospital beds'. Accessed at https://data.oecd.org/healtheqt/hospital-beds.htm
[54] OECD, 'Hospital beds'. Accessed at https://data.oecd.org/healtheqt/hospital-beds.htm
[55] OECD, 'Hospital beds'. Accessed at https://data.oecd.org/healtheqt/hospital-beds.htm

Education – Primary/Secondary

Context

Primary and secondary education infrastructure and services is primarily provided by central government, with a small role for private schools. There is a larger role for private provision in early childhood education, but our estimates generally exclude this part of the education sector. Primary education has been compulsory since 1877, with free public provision. The school leaving age was initially set at 13, increasing to 14 in 1901, 15 in 1944, and 16 in 1989. Eligibility for public-funded education has also expanded over this time. These changes mean that the share of children attending schools has increased over time, and the nature of education services has changed.[56]

Capital investment estimates

We provide estimates for total primary and secondary education capital investment for the 1903-2022 period.

We construct a capital investment series for primary and secondary education by combining historical capital investment data from Mulcare with more recent data from NZIC.

Mulcare's description of sources and methods does not clearly state whether his estimates include or exclude tertiary education capital investment. However, comparisons with other sources, like Stats NZ National Accounts data for 1972–1989, and consideration of historical provision models for tertiary education suggest that his estimates focus solely on primary and secondary education and exclude tertiary. Consequently, we provide separate estimates for tertiary education capital investment.

Table A20: Sources used to construct capital investment estimates for primary and secondary education

Years	Source	Notes
1903–1989	Mulcare	Estimates of gross capital formation for structures (1903–1989) and non-market plant and equipment (1932–1989).
1990–2022	NZIC	Estimates of gross fixed capital formation for primary and secondary education, based on Stats NZ National Accounts – Capital Accounts data.

As there is no overlap between the Mulcare series and the NZIC series, we examine how these series compare to each other in the ten years before and after each break. We also examine the ratio of the Mulcare and NZIC series to the Stats NZ National Accounts series

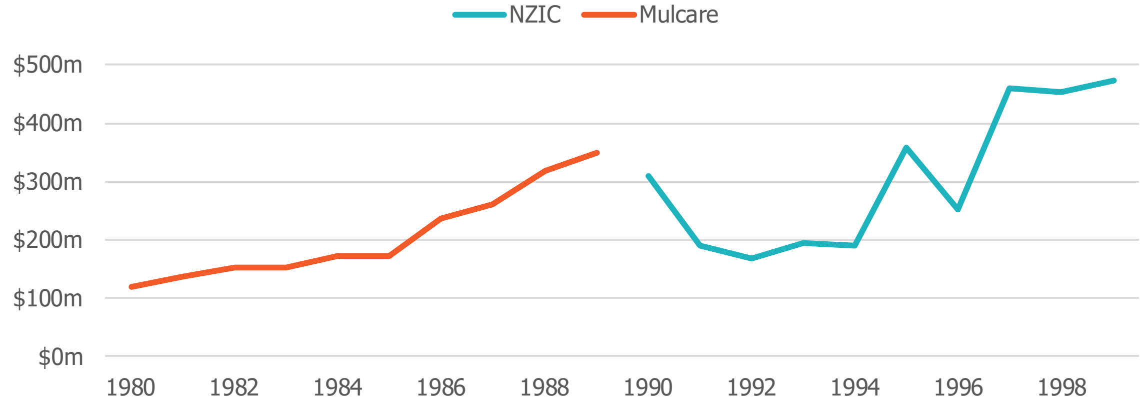
[56] https://teara.govt.nz/en/primary-and-secondary-education/page-3

for capital investment in ANZSIC industry P, Education and Training, which includes primary and secondary education as well as other things.

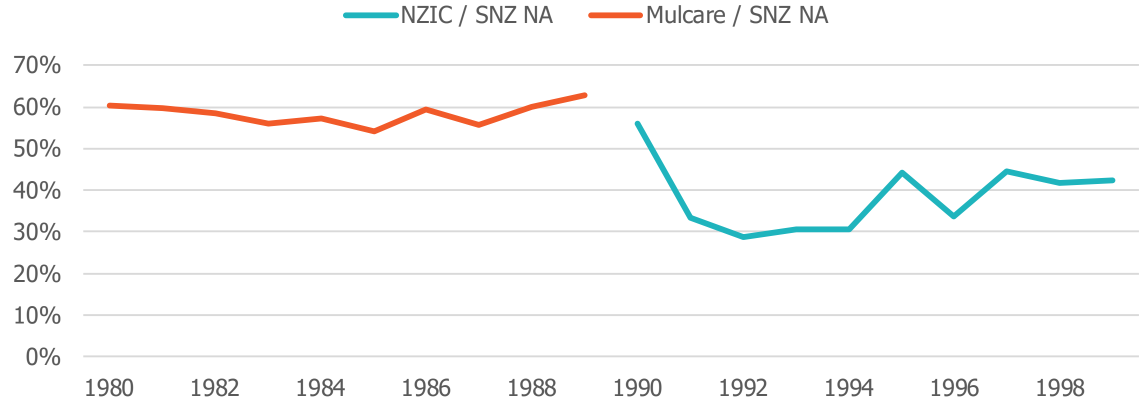
Figure A25 shows that there is no sharp difference between the series in terms of levels or trends, either in nominal NZD or as a share of capital investment in ANZSIC industry P. However, several years after 1990, capital investment in primary/secondary education drops both in dollar terms and as a share of total capital investment within ANZSIC industry P. This appears to be associated with significant expansion of the tertiary education sector after 1990.

Figure A25: Comparison of input series for primary/secondary education investment

Panel A: Comparison of Mulcare and NZIC series in nominal NZD



Panel B: Comparison of Mulcare and NZIC series as a share of GFCF in ANZSIC industry P

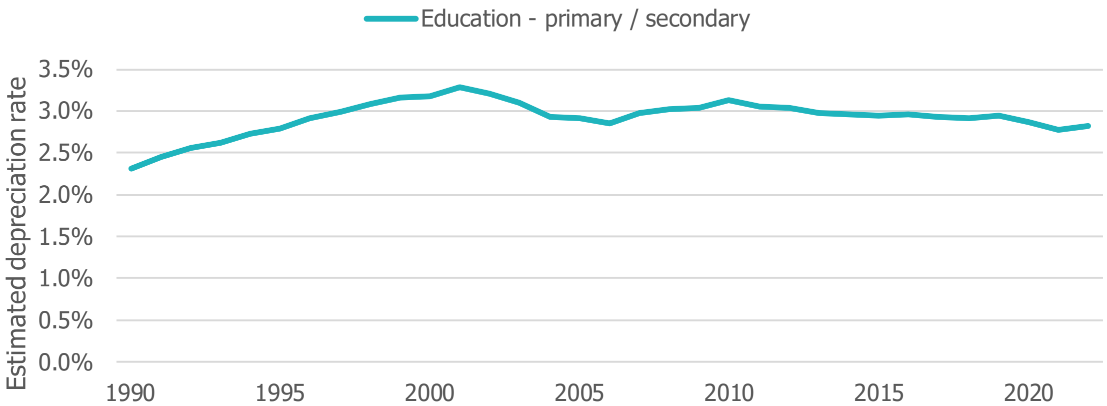


Capital stock estimates

We provide capital stock estimates for primary and secondary education from 1903 to 2022. To do so, we use the above school investment series available from 1903 onwards. The value of New Zealand's school network at this point was negligible relative to current capital stocks, although New Zealand did have an extensive primary school network at this point. We use the composite infrastructure construction price index presented below to revalue the capital stock from year to year.

Figure A26 summarises annual estimates of depreciation rates for the 1990–2022 period. Over this period, depreciation rates averaged 2.92% for primary and secondary education assets. This implies an average asset life of around 34 years.

Figure A26: Estimated depreciation rates for primary/secondary education capital stock, 1990–2022



Source: Estimated using data from NZIC.

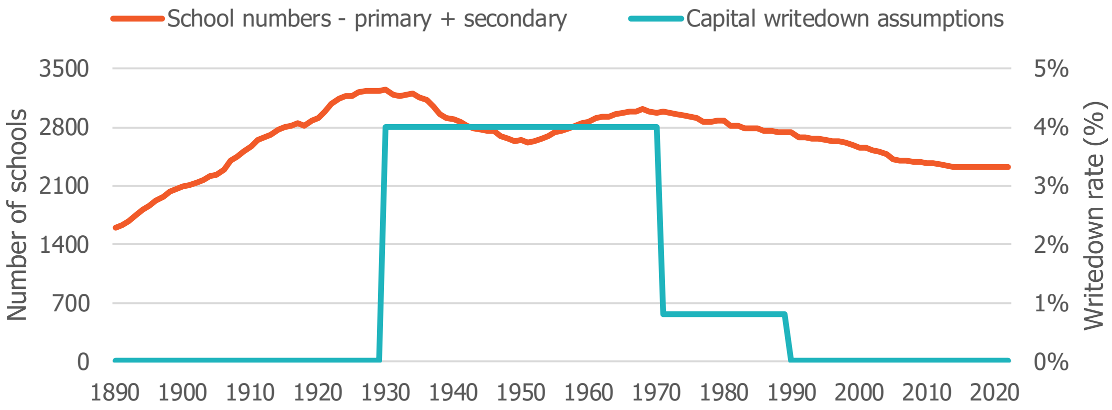
We use 1990–2022 average depreciation rates as a starting basis for the pre-1989 period but add writedown assumptions on top of base depreciation rates to account for the fact that the school network experienced significant school closures from 1930 to the present.

We estimate writedowns using two key sources of information. First, the OYB provides information on the number of primary and secondary schools from 1890 onwards. We use this to identify trends in the number of schools over time, which indicate when the education network might be experiencing closure. Second, Stats NZ National Accounts provides information on net capital stock for ANZSIC industry P Education and Training from 1972 onwards. This industry includes primary/secondary education, tertiary education, and some other things like early childhood education and private training establishments. We use this series, minus our capital stock estimates for tertiary education, to help calibrate the path of writedowns for primary and secondary education to ensure that our estimates reconcile as closely as possible with National Accounts data.

This results in annual writedowns equal to 4% of capital stock every year from 1930 to 1970 (a period during which the school network was significantly reconfigured) and annual writedowns of 0.8% from 1971 to 1989.

Figure A27 summarises our capital writedown assumptions, which are added to the base depreciation rates described above. It also shows how our writedown assumptions compare with changes in the number of primary and secondary schools over time.

Figure A27: Capital writedown assumptions for primary/secondary education

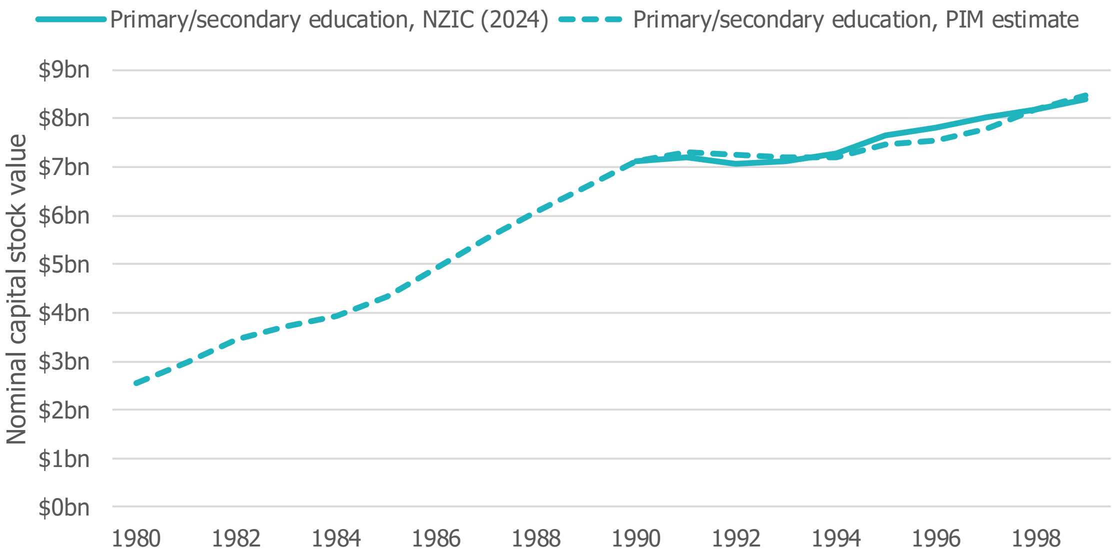


Source: New Zealand Infrastructure Commission analysis.

Figure A28 shows that the resulting perpetual inventory model estimates are close to post-1990 estimates from NZIC. Dashed lines indicate perpetual inventory model estimates and solid lines indicate post-1990 estimates based on National Accounts data. In 1990, our capital stock estimate for primary and secondary education is within -0.1% of observed data.

Our final capital stock series splices together the pre-1990 perpetual inventory model capital stock estimates described here with the 1990–2022 data presented by NZIC.

Figure A28: Comparison of perpetual inventory model capital stock estimates with post-1990 data for primary/secondary education



Source: New Zealand Infrastructure Commission analysis.

Physical network size data

We gather data on the size of the education network (in terms of number of primary and secondary schools and other school types) and usage (in terms of number of primary and secondary students). This data provides a rough indication of the changing mix of services provided over time (in terms of the ratio of primary to secondary students) as well as trends in average school size over time.

Table A21: Primary/secondary education network size and usage metrics

Metric	Years	Unit	Sources
Number of primary students	1879–2023	Number	1879–1995: SNZ LTDS republishes annual student numbers compiled from the OYB.[57] 1996–2023: Education Counts publishes annual school roll data by year, which we aggregate to primary and secondary totals.[58]
Number of secondary students	1879–2023	Number	Same as above.
Number of primary schools	1890–2023	Number	1890–1990: OYB publishes annual data on the number of schools by category, including public and private primary schools. Reporting categories change slightly over time and we group them according to a consistent definition. 1991–1995: SNZ LTDS republishes annual data on the number of schools by sector from the Ministry of Education.[59] 1996–2023: Education Counts publishes annual data on the number of schools by sector that is consistent with the SNZ LTDS series.[60]
Number of secondary schools	1890–2023	Number	Same as above.
Number of composite schools	1991–2023	Number	1991–1995: SNZ LTDS republishes annual data on the number of schools by sector from the Ministry of Education.[61] 1996–2023: Education Counts publishes annual data on the number of schools by sector that is consistent with the SNZ LTDS series.[62] Note: It is not possible to construct a longer-term data series as the OYB reporting categories cannot be aligned with more recent data.
Number of specialist schools	1991–2023	Number	Same as above.

Note: All data sourced from OYB required some minor data cleaning, including correcting seeming transcription errors and imputing one or two years of missing data.

[57] Stats NZ, 'Long-term data series: C4.1 Number of students by level'. Accessed at

Education – Tertiary

Context

Tertiary education infrastructure and services have historically been primarily provided by central government, with a small but increasing role for private training establishments. Access to and participation in tertiary education has risen over time, and from time-to-time new tertiary establishments have been set up to cater for demand.[63]

Capital investment estimates

We provide estimates for total tertiary education capital investment for the 1972–2022 period. We were unable to find data sources that would allow us to construct reliable estimates of tertiary education capital investment prior to 1972, although the first university was set up in 1869. Because tertiary student numbers were small prior to the 1960s, it is unlikely that capital investment prior to this point was particularly large.

We construct a capital investment series for primary and secondary education by combining historical capital investment data from Mulcare and Stats NZ National Accounts with more recent data from NZIC.

As described above, Mulcare's description of sources and methods does not clearly state whether his estimates include or exclude tertiary education capital investment. However, comparisons with other sources, like Stats NZ National Accounts data for 1972–1989, and consideration of historical provision models for tertiary education, suggest that his estimates focus solely on primary and secondary education and exclude tertiary. Consequently, we provide separate estimates for tertiary education capital investment.

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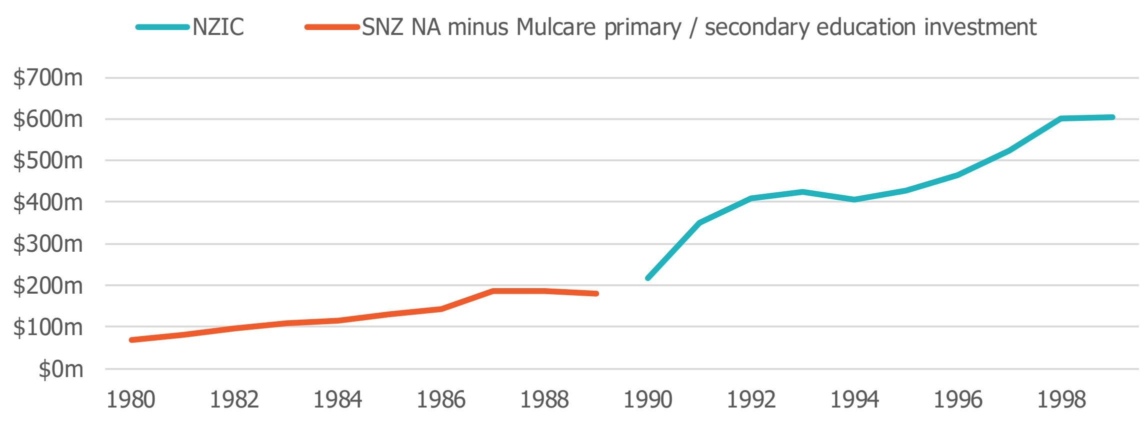
https://statsnz.contentdm.oclc.org/digital/collection/p20045coll35/id/65/rec/58.
[58] Education Counts, 'School rolls', table entitled 'Time Series Data for Trend Analysis 1996-2024'. Accessed at https://www.educationcounts.govt.nz/statistics/school-rolls
[59] Stats NZ, 'Long-term data series: C4.2 Number of Schools'. Accessed at https://statsnz.contentdm.oclc.org/digital/collection/p20045coll35/id/266/rec/59.
[60] Education Counts, 'Number of schools', table entitled 'Time series data for trend analysis 1996-2024'. Accessed at https://www.educationcounts.govt.nz/statistics/number-of-schools.
[61] Stats NZ, 'Long-term data series: C4.2 Number of Schools'. Accessed at https://statsnz.contentdm.oclc.org/digital/collection/p20045coll35/id/266/rec/59.
[62] Education Counts, 'Number of schools', table entitled 'Time series data for trend analysis 1996-2024'. Accessed at https://www.educationcounts.govt.nz/statistics/number-of-schools.
[63] https://teara.govt.nz/en/tertiary-education

Table A22: Sources used to construct capital investment estimates for tertiary education

Years	Source	Notes
1972–1989	Estimated based on SNZ NA and Mulcare	Stats NZ National Accounts provide 1972–2022 data for gross fixed capital formation for ANZSIC industry P, Education and Training, which includes primary/secondary education, tertiary education, and some other things like early childhood education and private training establishments. A comparison of the SNZ NA and NZIC series for the 1990–2022 period shows that primary/secondary and tertiary education account for 95% of the total. For the 1972–1990 period, we multiply the SNZ NA series by 0.95 and subtract Mulcare's estimates of gross capital formation for primary/secondary education to obtain an estimate for tertiary education capital investment.
1990–2022	NZIC	Estimates of gross fixed capital formation for primary and secondary education, based on Stats NZ National Accounts – Capital Accounts data.

As there is no overlap between the estimated pre-1989 series and the NZIC series, we examine how these series compare to each other in the ten years before and after each break. Figure A29 shows that there is no level difference between these series, but that there is a sharp trend difference, with tertiary education capital investment rising significantly in the early 1990s. This appears to coincide with a period of rapidly increasing tertiary enrolments.

Figure A29: Comparison of investment series for tertiary education investment (nominal NZD)



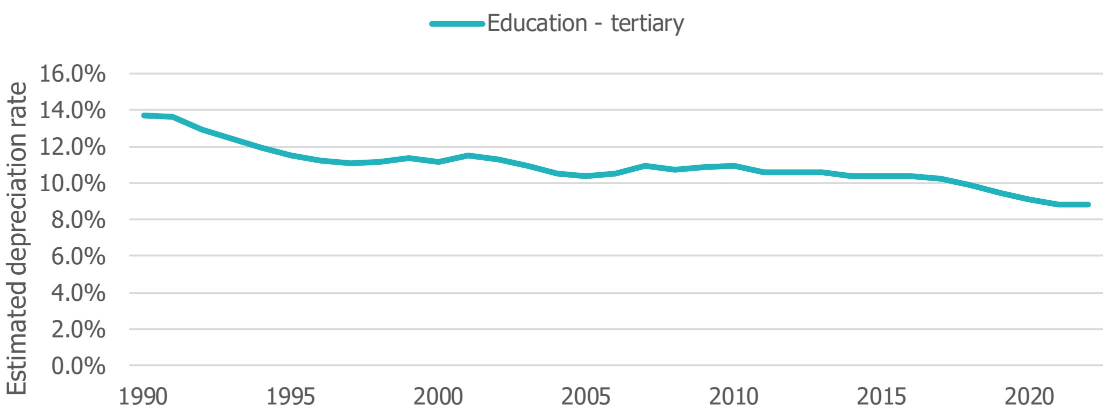
Capital stock estimates

We provide capital stock estimates for tertiary education from 1972 to 2022. To do so, we use the above tertiary education investment series available from 1972 onwards. We use the composite infrastructure construction price index presented below to revalue the capital stock from year to year.

As New Zealand already had various tertiary institutions at this point, with total student enrolments equal to around 20% of peak levels, we must incorporate an assumption about the value of New Zealand's university capital stock in 1971. We derive this as follows: we observe that the number of tertiary students rose by roughly 5% between 1971 and 1972. We estimate total capital investment of around $5 million (in nominal dollars) in 1972. If tertiary education assets rose proportionately to enrolments, this implies a value of around $100 million for university assets in 1971. We use this estimate as the starting value for our capital stock series.

Figure A30 summarises annual estimates of depreciation rates for the 1990–2022 period. Over this period, depreciation rates averaged 10.91% for tertiary education assets. This implies an average asset life of around 9 years.

Figure A30: Estimated depreciation rates for tertiary education capital stock, 1990–2022



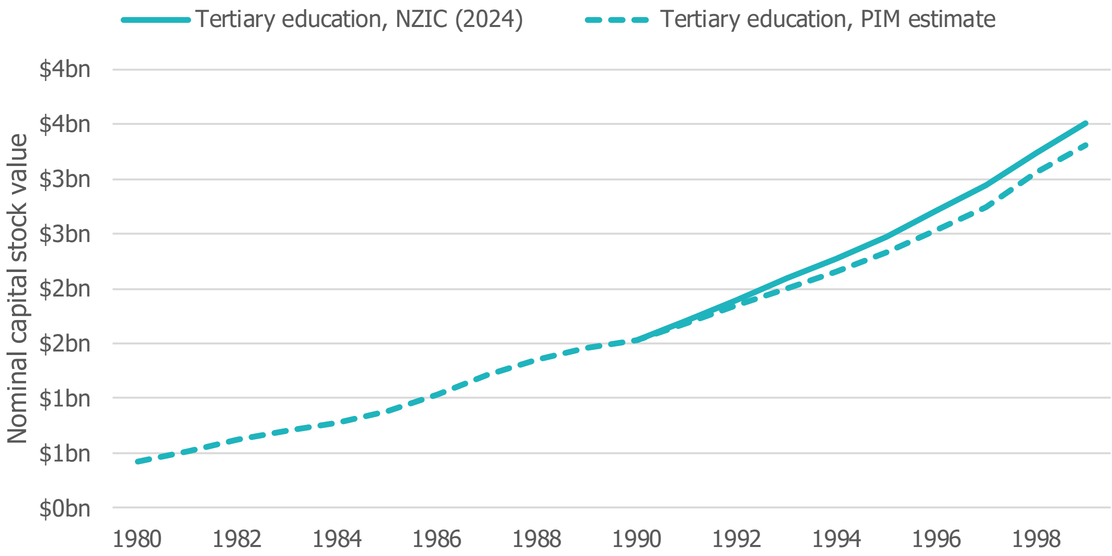
Source: Estimated using data from NZIC.

We find that applying the 1990–2022 average depreciation rate for the pre-1989 period results in a perpetual inventory model estimate of tertiary education capital stock that is slightly too low in 1990 (around 3.2% below observed data). As a result, we instead use the lower-quartile depreciation rate from the 1990-2022 period, which is 10.36%.

Figure A31 shows that the resulting perpetual inventory model estimates are close to post-1990 estimates from NZIC. Dashed lines indicate perpetual inventory model estimates and solid lines indicate post-1990 estimates based on National Accounts data. In 1990, our capital stock estimate for tertiary education is within 0.1% of observed data.

Our final capital stock series splices together the pre-1990 perpetual inventory model capital stock estimates described here with the 1990–2022 data presented by NZIC.

Figure A31: Comparison of perpetual inventory model capital stock estimates with post-1990 data for tertiary education



Source: New Zealand Infrastructure Commission analysis.

Physical network size data

We gather data on tertiary education usage, in terms of number of students enrolled in all tertiary institutes, including universities, polytechnics, and wananga. We did not gather data on the number of universities, polytechnics, and other tertiary institutions as this data is not compiled and presented consistently over time in the OYB. However, it would be possible to survey and compile the dates at which different institutions were established/disestablished.

Table A23: Tertiary education usage metrics

Metric	Years	Unit	Sources
Number of tertiary students	1879–1999	Number	1879–1995: Stats NZ LTDS republishes annual student numbers compiled from the OYB.[64] Note: These figures tend in the same direction as the more recent data series, but there is a level difference between the two series.
Number of tertiary students in public providers	1965–2023	Number	1965–2013: Education Counts publishes data on domestic, international, and total students enrolled in public tertiary providers.[65] 2014–2023: Education Counts publishes data on students enrolled at New Zealand tertiary institutions; we count enrolment in public tertiary providers for consistency with historical series.[66]

Note: All data sourced from OYB required some minor data cleaning, including correcting seeming transcription errors and imputing one or two years of missing data.

[64] Stats NZ, 'Long-term data series: C4.1 Number of students by level'. Accessed at https://statsnz.contentdm.oclc.org/digital/collection/p20045coll35/id/65/rec/58.
[65] Education Counts, 'Participation in tertiary education in New Zealand: Provider-based enrolments'. Accessed via archive.org: https://web.archive.org/web/20180131003102/https://www.educationcounts.govt.nz/statistics/tertiary-education/participation
[66] Education Counts, 'Tertiary participation: Provider-based enrolments'. Accessed at https://www.educationcounts.govt.nz/statistics/tertiary-participation.

Social housing

Context

Social housing infrastructure and services have historically been primarily provided by central government and local government, with a small but increasing role for private social housing providers. Significant central government began in 1938, with some previous small-scale public housing and worker housing schemes.[67]

Capital investment estimates

We provide estimates for social housing capital investment for the 1938–2022 period. Central government investment in social housing began in earnest in 1938, although there had been several minor public housing programmes in prior decades. Local governments have also invested in social housing, but we were not able to find relevant historical estimates for local government social housing expenditure. As a result, we expect this to be a slight under-estimate of historical social housing expenditure.

We construct a capital investment series for social housing by combining historical state housing capital investment data from the OYB with more recent data from NZIC.

[67] https://teara.govt.nz/en/housing-and-government

Table A24: Sources used to construct capital investment estimates for social housing

Years	Source	Notes
1938–1944	OYB	OYB publishes data on cumulative Housing Department expenditure (development costs only) as of 1944, as well as annual data on state housing completions for 1938–1990. We use this to estimate annual state housing development costs during this period. We spread cumulative construction costs as of 1944 based on the annual number of houses completed over the 1938–1944 period. This imputation adjusts for changes in prices over this period using a GDP deflator series published by NZIER.[68]
1945–1979	OYB	OYB publishes annual data on Housing Construction Vote expenditure on development costs (including land costs) for the 1945–1979 period. This expenditure relates directly to state housing construction, and excludes housing built by other government departments (for example, for hydroelectric dam workforce housing). OYB also publishes annual data on the value of building work put in place for government houses and flats (1966–2005). We use the Housing Construction Vote development expenditure series for all years except 1974–1977, when the two series diverge significantly, seemingly due to large land purchases. In these years, we impute growth in capital investment based on the value of building work series.
1980–1985	OYB	OYB's Housing Construction Vote development expenditure series is discontinued in 1979. We use total Housing Construction Vote expenditure to extrapolate growth in development costs. We assume that the ratio of development costs to total expenditure in this Vote stays constant at around 82% (similar to its average in the 1970s, excluding the anomalous years from 1974 to 1977).
1986–1989	OYB	We extrapolate state housing investment over this period based on annual state housing units completed. We multiply the annual number of units completed in each year by the ratio of average capital investment to completed units in 1985, adjusted up to reflect growth in the GDP price deflator over this period.
1990–2022	NZIC	Estimates of gross fixed capital formation for social housing, based on Stats NZ National Accounts – Capital Accounts data. GFCF is negative for periods in the mid-1990s due to the fact that more social housing was being sold than built during these years. Note: Gaps in the data result in under-estimation of investment by Kāinga Ora in recent years.

Figure A32 shows the three OYB series that we used to construct capital investment estimates. These series follow similar trends, but Housing Construction Vote expenditure rises more than the value of building work put in place during the mid-1970s. Failing to adjust for this results in implausibly high estimates of capital investment per completed unit.

[68] To do so, we observe that cumulative capital cost as of time T (K_T) can be written as a function of the flow of investment over time t=0,1,...,T. Investment at time t is equal to the number of units constructed (n_t), the real per-unit cost (c_t), and the price index (p_t). If we assume that real per-unit costs are constant over this period (i.e., c_t=c), and we have estimates for K_T, n_t, and p_t, we can calculate the real per-unit cost as $c = \frac{K_T}{\sum_{t=0}^{T} n_t p_t}$. After calculating c we can then estimate annual investment for each year of the imputation period.

Figure A32: OYB series used to construct estimates of social housing investment (nominal NZD)

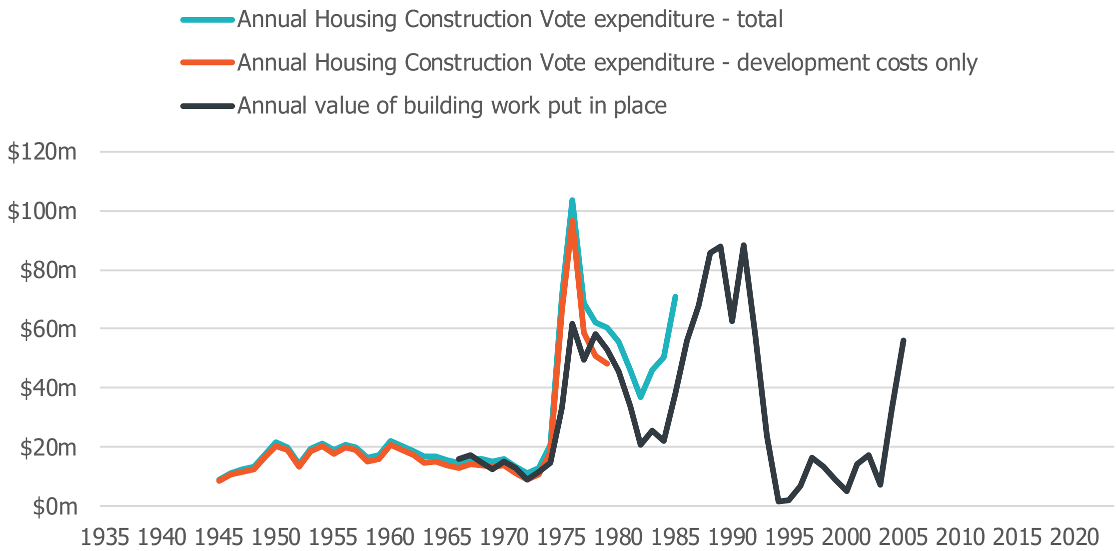
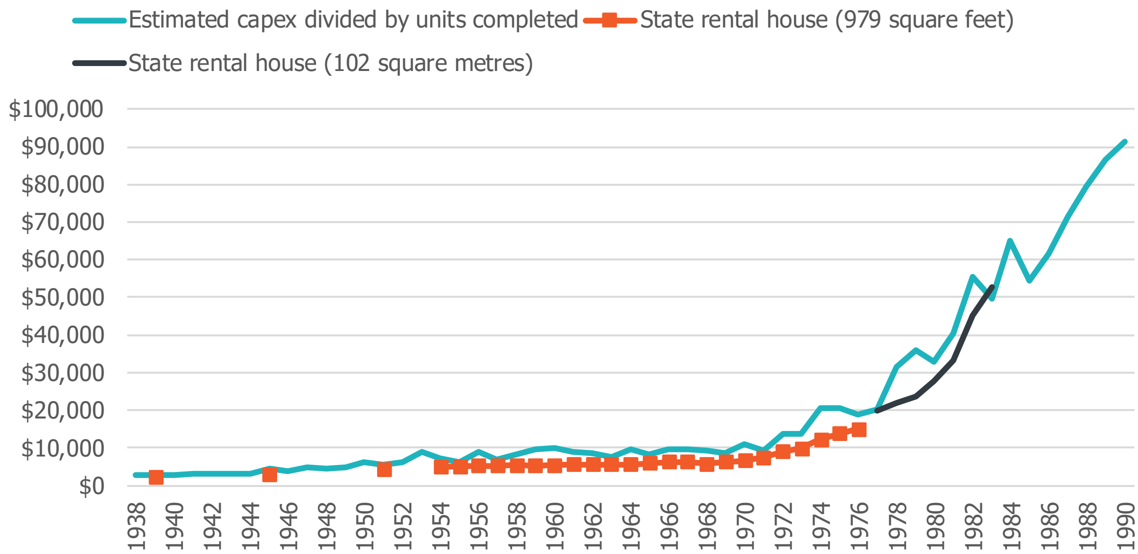


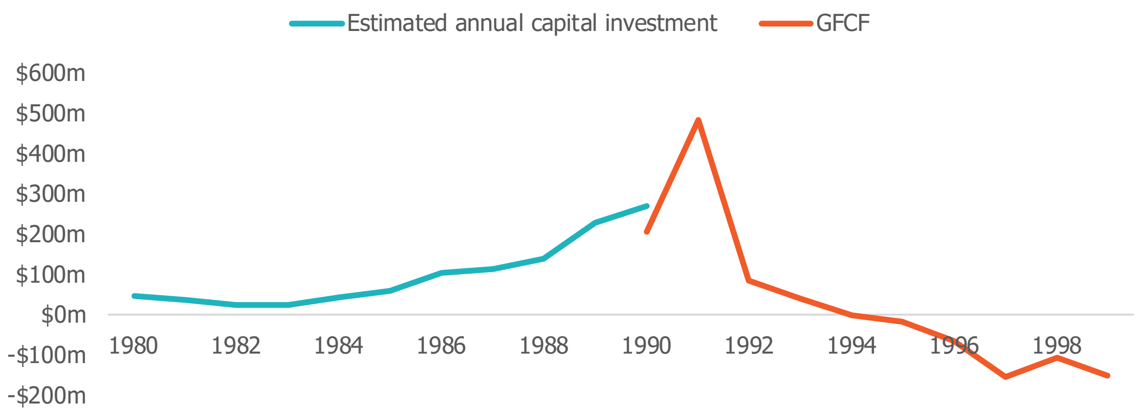
Figure A33 shows how that our capital investment estimates, divided by units comped, are closely aligned with data on state housing construction costs that is reported separately in the OYB. As expected, our estimates are slightly higher, as they will include other development costs and multi-unit development, which tends to be more expensive on a per-square-metre basis. On average over the period, our estimates are 44% higher than state house construction costs. This is well aligned with a 'rule of thumb' that house construction costs should account for around 70% of total development costs, with the balance contributed by land purchase and section servicing costs.

Figure A33: Comparison of capital investment per unit completed with unit cost data (nominal NZD)



There is only one year of overlap between our estimates of state housing investment based on OYB data and the NZIC series we use for recent decades. Figure A34 shows how these two series compare in the ten years before and after the join. These series match up reasonably well (although not perfectly) in levels, but they exhibit very different trends. Notably, social housing investment appears to rise sharply in 1990 and 1991, followed by a sharp contraction. However, this appears to be due to a significant policy change. The total number of state rental units available increased significantly from 1984 to 1991, but started decreasing after 1993 as more units were sold than were completed.

Figure A34: Comparison of input series for social housing (nominal NZD)

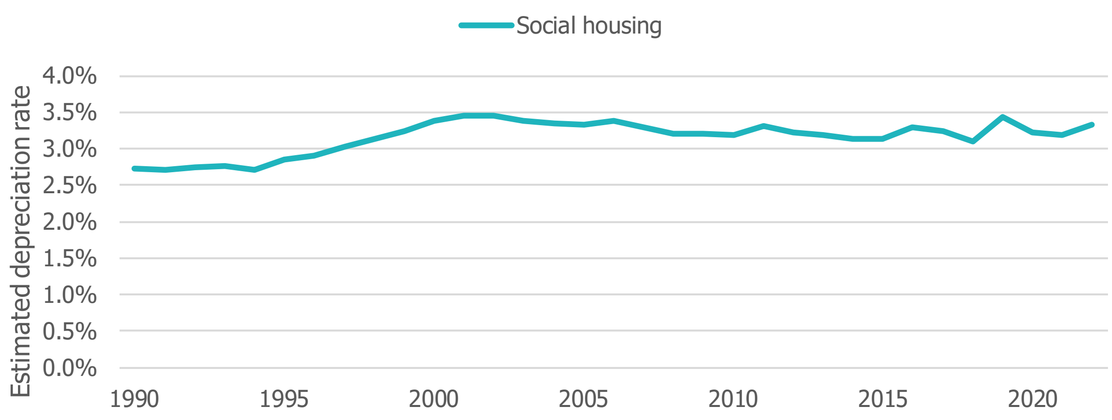


Capital stock estimates

We provide capital stock estimates for social housing from 1938 to 2022. To do so, we use the above social housing investment series available from 1938 onwards. The value of the social housing capital stock was negligible prior to this point. We use the composite infrastructure construction price index presented below to revalue the capital stock from year to year.

Figure A35 summarises annual estimates of depreciation rates for the 1990–2022 period. Over this period, depreciation rates averaged 3.16% for social housing assets. This implies an average asset life of around 31 years.

Figure A35: Estimated depreciation rates for social housing capital stock, 1990–2022



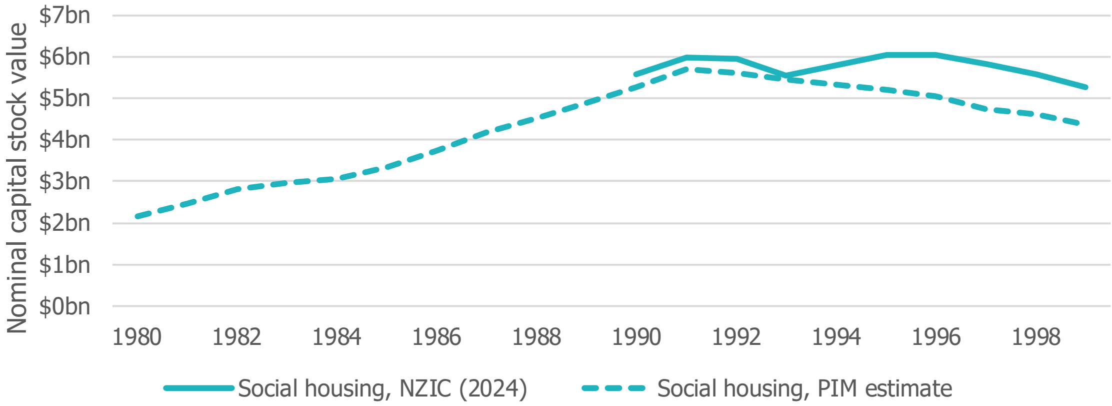
Source: Estimated using data from NZIC.

We find that applying the 1990–2022 average depreciation rate for the pre-1989 period results in a perpetual inventory model estimate of social housing capital stock that is significantly too low in 1990 (around 15% below observed data). As a result, we instead use the average depreciation rate observed from 1990 to 1994, which is around 2.73%.

Figure A36 shows that the resulting perpetual inventory model estimates follow a similar trend and level to post-1990 estimates from NZIC. Dashed lines indicate perpetual inventory model estimates and solid lines indicate post-1990 estimates based on National Accounts data. In 1990, our capital stock estimate for social housing is 5.8% below observed data. Given gaps in the capital investment data series in the 1980s this is a tolerable difference.

Our final capital stock series splices together the pre-1990 perpetual inventory model capital stock estimates described here with the 1990–2022 data presented by NZIC.

Figure A36: Comparison of perpetual inventory model capital stock estimates with post-1990 data for social housing



Source: New Zealand Infrastructure Commission analysis.

Physical network size data

We gather two measures of social housing network size: state rental units available (1938–2023) and number of Community Housing Provider units available (2017–2023). In addition, we gather data on the cumulative number of state rental units that have been completed (1938–1990). As some state houses have been sold to the private sector or demolished for redevelopment, cumulative completions exceed the number of state rental units available.

Table A25: Social housing network size metrics

Metric	Years	Unit	Sources
State rental units available	1938–2023	Number	1938–2009: Te Ara publishes annual data on state rental units available.[69] 2010–2023: Housing New Zealand and Kāinga Ora annual reports publish June quarter data on total managed stock of rental units (including leased dwellings).[70] Note: These two data series align with each other during the 2004–2009 period.
Community Housing Provider units available	2017–2023	Number	2017–2023: MHUD publishes annual data on Community Housing Provider units available.[71]
Cumulative state rental units completed	1938–1990	Number	1938–1990: OYB publishes an annual series on the cumulative number of state rental units that have been completed over time. Note: This differs from state rental units available because some state houses were sold to the private market after development.

Unit costs

The OYB reports data on the cost to construct new state houses of a standard size and quality over time. We compile four series: construction cost for a 'typical four-roomed state dwelling' (1938–1950), construction cost for a state rental house (979 square feet in size) (1939, 1945, 1951, 1954-1976), construction cost for a state rental house (102 square metres in size) (1977–1983), and construction cost for reinforced concrete buildings of 'similar size and type' (1939, 1945, 1951, 1954–1976).

These series appear to reflect the cost to construct constant-quality houses over time and (for the 1972–1983 period) closely track Stats NZ's price deflator for residential buildings.

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[69] Te Ara, 'Story: Housing and government: Total state housing stock'. Accessed at https://teara.govt.nz/en/graph/32421/total-state-housing-stock.

[70] Housing New Zealand, 'Annual Report'. Provides data for 2004-2015. Accessed via archive.org: https://web.archive.org/web/20160417113511/http://www.hnzc.co.nz/our-publications/annual-report/2014-15-annual-report/Annual-Report-2015.pdf.
Kāinga Ora, 'Housing Statistics – Archive'. Provides data for 2016-2023. Accessed at https://kaingaora.govt.nz/en_NZ/publications/oia-and-proactive-releases/housing-statistics/housing-statistics-archive/.

[71] Ministry of Housing and Urban Development, 'The Housing Dashboard: Public Homes'. Accessed at https://www.hud.govt.nz/stats-and-insights/the-government-housing-dashboard/public-homes#tabset.

Public administration and safety

Context

Public administration and safety infrastructure has historically been primarily provided by central government, with a small role for local government. This category is heterogeneous, including central and local government administration, justice, police, and corrections infrastructure, and defence.[72]

Capital investment estimates

We construct a capital investment series for public administration and safety by combining historical capital investment data from Mulcare and Stats NZ National Accounts with more recent data from NZIC.

Table A26: Sources used to construct capital investment estimates for public administration and safety

Years	Source	Notes
1903–1971	Mulcare	Mulcare provides estimates of gross capital formation for central government administration structures (1903–1989) and non-market plant and equipment (1933–1989), and local government administration structures (1903–1989). We sum these three series up, and compare them to the SNZ NA series for public administration and safety for the 1972–1989 period where these series overlap. We then multiply Mulcare's raw series by the average ratio of the SNZ NA series to Mulcare's series over the 1972–1980 period (0.53).
1972–1989	SNZ NA	Gross fixed capital formation for public administration and safety, based on Stats NZ National Accounts – Capital Accounts data. This corresponds to the sectoral definition used in the NZIC series for 1990–2022.
1990–2022	NZIC	Estimates of gross fixed capital formation for public administration and safety, based on Stats NZ National Accounts – Capital Accounts data.

There are 18 years of overlap between the SNZ NA and the unadjusted Mulcare series (1972–1989). Figure A37 shows how these series compare for the overlap period and the ten years prior to it. While both series exhibit the same trends, there is a level differences

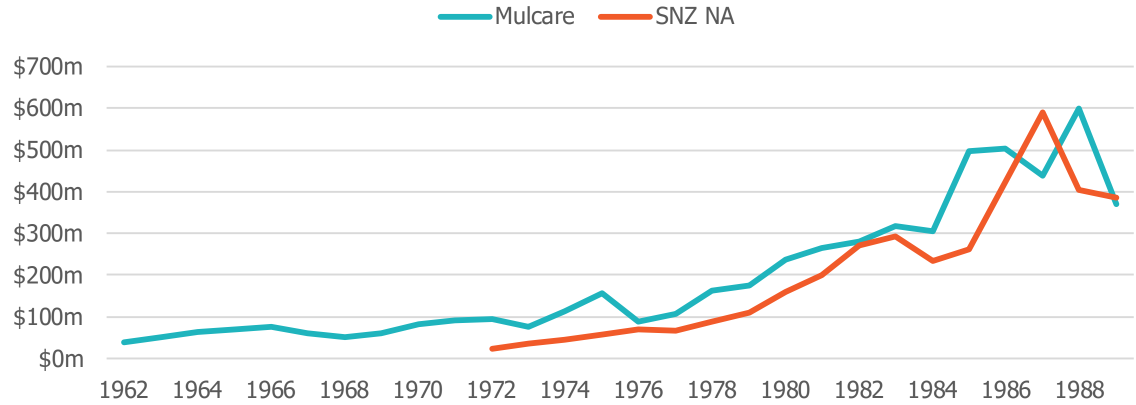
[72] https://teara.govt.nz/en/prisons

between the series. In percentage terms, the level difference is larger in the 1970s than in the 1980s.

It is unclear why there is such a large difference between these two series. It could reflect the fact that gross capital formation (as measured by Mulcare) includes inventory formation, while gross fixed capital formation (as measured by SNZ NA) does not. If public administration and safety organisations were acquiring significant inventories or other non-fixed assets over this period, that may be a reason for the difference.

To better align these two series, we apply a coarse adjustment to the Mulcare series, multiplying it by the average ratio of the SNZ NA series to the Mulcare series over the first half of the overlap period (1972–1980). In doing so, we note that the adjusted series is likely to provide a good indication of upwards and downwards trends in public administration and safety investment over the 1903–1971 period, but that it may mis-estimate the absolute level of investment. This limits our ability to accurately identify investment boom periods.

Figure A37: Comparison of input series for public administration and safety (nominal NZD)

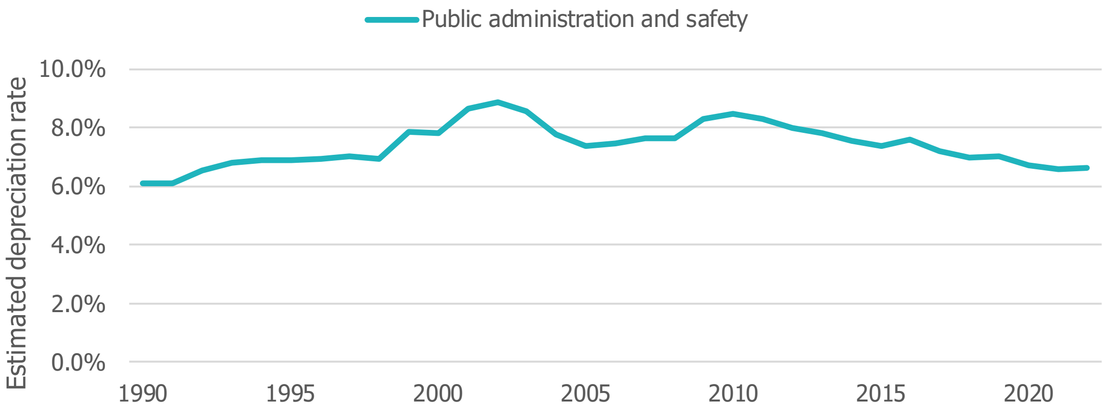


Capital stock estimates

We provide capital stock estimates for public administration and safety from 1903 to 2022. To do so, we use the above public administration and safety investment series available from 1903 onwards. The value of the public administration and safety capital stock is assumed to be negligible prior to this point, at least relative to present day values, although there was some infrastructure used for this purpose. We use the composite infrastructure construction price index presented below to revalue the capital stock from year to year.

Figure A38 summarises annual estimates of depreciation rates for the 1990–2022 period. Over this period, depreciation rates averaged 6.91% for public administration and safety assets. This implies an average asset life of around 14 years.

Figure A38: Estimated depreciation rates for public administration and safety capital stock, 1990–2022



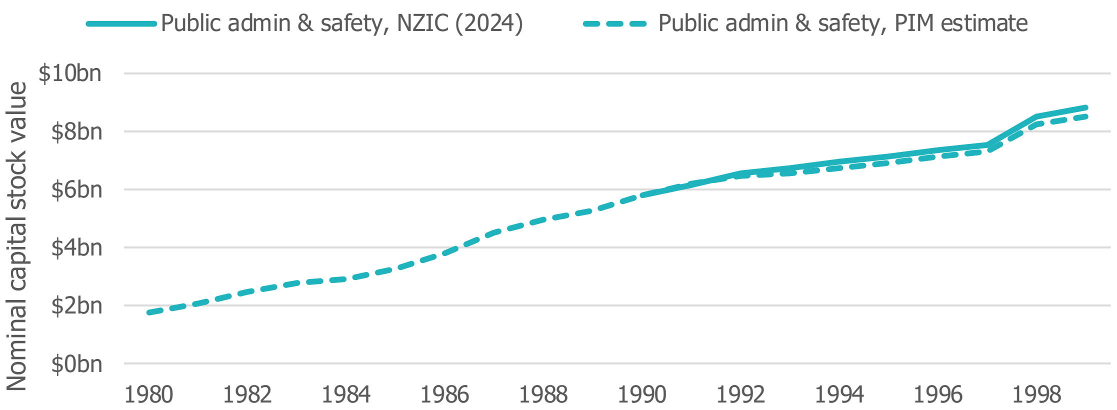
Source: Estimated using data from NZIC.

Applying the 1990–2022 average depreciation rate for the pre-1989 period results in a perpetual inventory model estimate of social housing capital stock that is very close to observed data. As a result, we do not apply any additional writedown assumptions.

Figure A39 shows that the resulting perpetual inventory model estimates follow a similar trend and level to post-1990 estimates from NZIC. Dashed lines indicate perpetual inventory model estimates and solid lines indicate post-1990 estimates based on National Accounts data. In 1990, our capital stock estimate for public administration and safety is within 0.7% of observed data.

Our final capital stock series splices together the pre-1990 perpetual inventory model capital stock estimates described here with the 1990–2022 data presented by NZIC.

Figure A39: Comparison of perpetual inventory model capital stock estimates with post-1990 data for public administration and safety



Source: New Zealand Infrastructure Commission analysis.

Physical network size data

Because the public administration and safety sector is heterogeneous, we do not have any comprehensive measures of network size or quality. However, we were able to gather a measure of usage for part of this sector – total prisoner volumes (1875–2023). This provides a rough indication of how intensively used police, justice, and corrections related infrastructure has been over time. However, present-day data suggests that these areas only account for roughly one-quarter of the total value of fixed capital in the whole sector.

Table A27: Public administration and safety network usage metrics

Metric	Years	Unit	Sources
Total prisoner volumes	1875–2023	Number	1875–1988: Stats NZ LTDS publishes annual data on total prisoner volumes from 1875 to 1975, plus data for 1980, 1985, and 1988.[73] 1991–2023: Department of Corrections publishes data on total prisoner volumes from the biannual Census of Prison Inmates and Home Detainees (1991–2003)[74] and more recent annual reporting (2004–2023).[75] Estimates for missing years are linearly interpolated.
Prisoner volumes – remand	1991–2023	Number	1991–2023: Department of Corrections publishes data on remand and sentenced prisoner volumes from the biannual Census of Prison Inmates and Home Detainees (1991–2003) and more recent annual reporting (2004–2023). Estimates for missing years are linearly interpolated.
Prisoner volumes – sentenced	1991–2023	Number	Same as above.

[73] SNZ, 'Long-term data series: C1.3 Prison population rate and prison population number'. Accessed at https://statsnz.contentdm.oclc.org/digital/collection/p20045coll35/id/86/rec/49

[74] Department of Corrections, 'Census of Prison Inmates and Home Detainees'. Accessed via archive.org: https://web.archive.org/web/20190124040644/https://corrections.govt.nz/__data/assets/pdf_file/0010/667729/census2001.pdf; https://web.archive.org/web/20190124134124/https://corrections.govt.nz/resources/research_and_statistics/corrections-volumes-report/past-census-of-prison-inmates-and-home-detainees/census-of-prison-inmates-and-home-detainees-2003/13-time-series-comparison/13.html.

[75] Department of Corrections, 'Corrections Volumes'. Accessed via archive.org: https://web.archive.org/web/20190124040726/https://corrections.govt.nz/__data/assets/pdf_file/0011/926516/Corrections_Volumes_201617.pdf

Department of Corrections, 'Prison facts and statistics'. Accessed at https://www.corrections.govt.nz/resources/statistics/quarterly_prison_statistics/prison_facts_and_statistics_-_september_2024.

Other public capital

Context

Other public capital is a 'residual' category that consists of other capital investment, not included above, by local and central government. This category includes capital investment in things like telecommunications and library services provided by local and central government, arts and recreation services provided by local and central government, and healthcare and social assistance (excluding hospitals) that is provided by central government.

Capital investment estimates

We construct a capital investment series for other public capital based on data from NZIC. No reliable estimates are available for the pre-1990 period, but we note that this expenditure category is likely to be small as it averaged only 0.2% of GDP over the 1990–2022 period.

Table A28: Sources used to construct capital investment estimates for other public capital

Years	Source	Notes
1990–2022	NZIC	Estimates of gross fixed capital formation for other public capital, based on Stats NZ National Accounts – Capital Accounts data.

Capital investment estimates

As we do not have any pre-1990 capital investment estimates, we simply use capital stock data from the New Zealand Infrastructure Commission (2024).

Infrastructure construction price index estimates

Compiling a long-term infrastructure construction price index

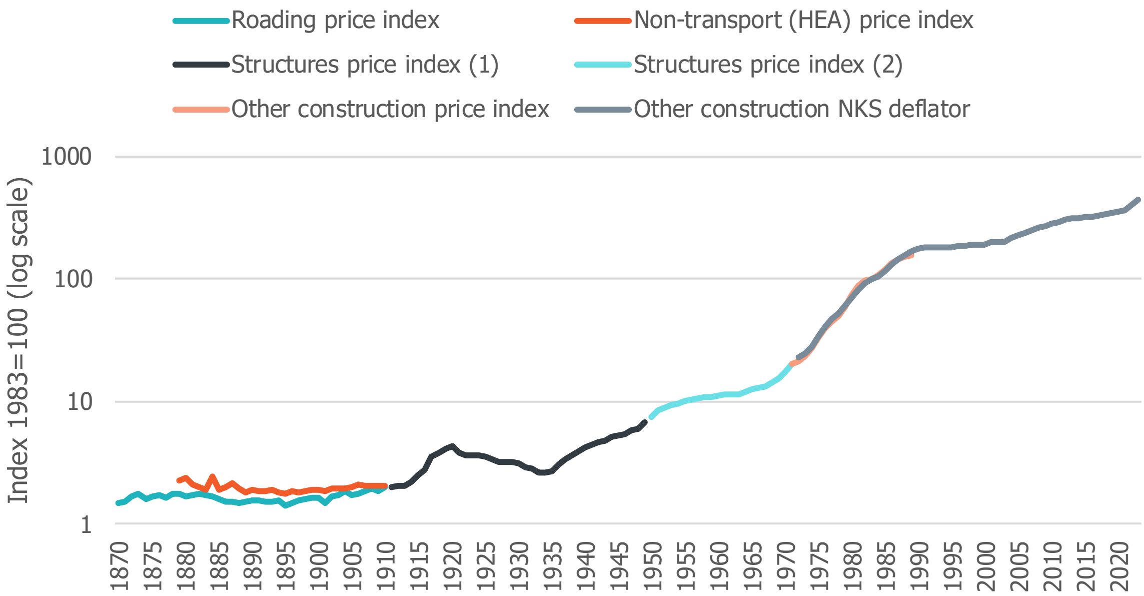
We construct a long-term infrastructure construction price index using data from Mulcare and Stats NZ National Accounts. To do this, we splice together a series of overlapping or partly overlapping indices that, taken together, cover the period from 1870 to 2023. Table A29 summarises the coverage of the underlying indices, and Figure A40 shows how they compare with each other.

As noted above, we require a long-run infrastructure construction price index to construct capital stock estimates.

Table A29: Construction price indices used to develop a long-term series

Index	Source	Years covered	Base year
Roading price index	Mulcare	1870 to 1910	1950
Non-transport (HEA) price index	Mulcare	1879 to 1910	1950
Structures price index (1)	Mulcare	1911 to 1949	1950
Structures price index (2)	Mulcare	1950 to 1971	1983
Other construction price index	Mulcare	1971 to 1989	1983
Other construction net capital stock deflator	Stats NZ	1972 to 2023	2010

Figure A40: Comparison of long-term infrastructure construction price indices.



Source: New Zealand Infrastructure Commission analysis of data from Mulcare and SNZ NA.

We combined these indices into a single index as follows:

- We initially re-based all indices to a common base year (1983) and, after combining underlying indices into a single series, re-based it to a 2023 base year.
- For the 1972–2023 period, we rely only on the Stats NZ NKS deflator series, but cross-check it against Mulcare's price index for this period, and other Stats NZ NKS deflators for construction goods (Figure A41).
- For the 1911 to 1971 period, we rely upon Mulcare's structures price indices, spliced together with the later series.
- For the pre-1911 period, we average Mulcare's roading price index and non-transport price index, when both are available, and splice the results together with the later series.

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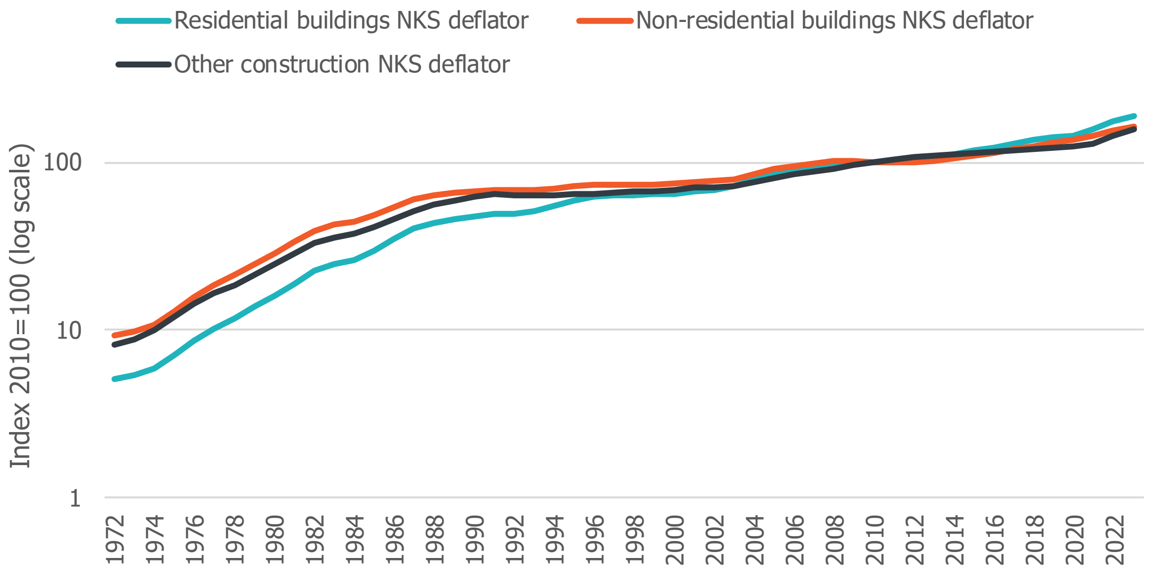
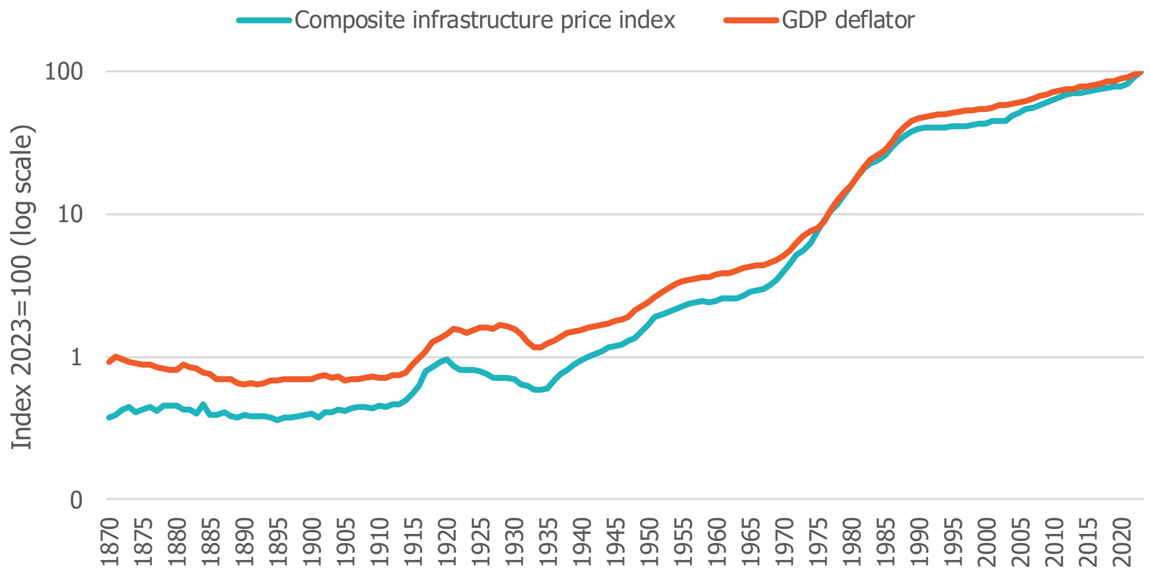
Figure A41: Comparison of Stats NZ NKS deflators for construction goods



Source: New Zealand Infrastructure Commission analysis of SNZ NA data.

Figure A42 summarises our overall long-term infrastructure construction price index, compared with New Zealand's GDP deflator.

Figure A42: Long-term infrastructure construction price index for New Zealand, 1870–2023

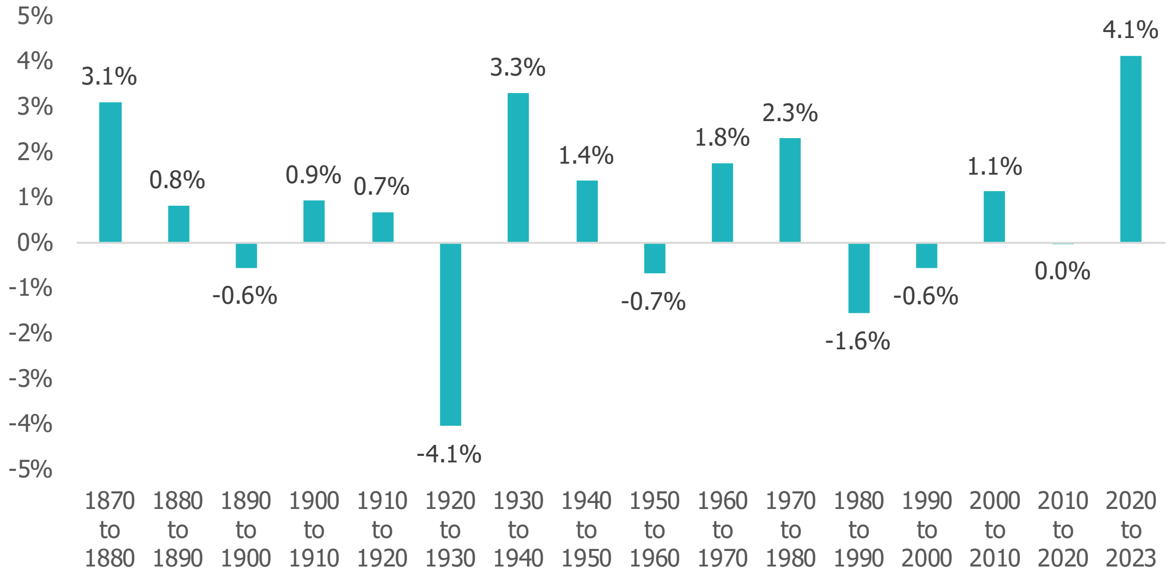


Source: New Zealand Infrastructure Commission analysis of data from Mulcare, SNZ NA, and NZIER Data1850.

Infrastructure construction prices have risen faster than prices elsewhere in the economy over the whole period. This is consistent with broader evidence that productivity tends to grow more slowly in construction than elsewhere in the economy, and that this flows through to higher output prices over time (Hartwig, 2011; New Zealand Infrastructure Commission, 2022a; Nordhaus, 2008).

However, there are also decades where infrastructure construction prices rose at a slower rate than prices elsewhere in the economy. Figure A43 shows average annual growth in real infrastructure construction prices (i.e., the infrastructure construction price index divided by the GDP deflator) by decade. Real infrastructure construction prices declined in the 1890s, 1920s, 1950s, 1980s, and 1990s, but rose in other decades. The 2020–2023 period has seen a rapid surge in infrastructure construction prices.

Figure A43: Average annual growth in real infrastructure construction prices, by decade



Source: New Zealand Infrastructure Commission analysis of data from Mulcare, SNZ NA, and NZIER Data1850.

Impact of alternative price indices on capital stock estimates

Capital stock estimates can be sensitive to the choice of price index used to revalue existing assets from year to year. As described above, our infrastructure construction price index tends to rise more rapidly than economy-wide prices over the long run, but there are also periods where construction seems to be getting cheaper relative to other goods.

As a sensitivity test on our findings, we construct an alternative set of perpetual inventory model capital stock estimates using the same inputs for capital investment, depreciation, and capital writedowns, but an alternative price index – the economy-wide GDP deflator.

Figure A44 shows how the resulting alternative estimate of total infrastructure capital stock (black line) compares with our base estimates (orange line) and the post-1990 NZIC capital stock series, which are based on SNZ National Accounts data (blue line). Figures are shown as a share of GDP.

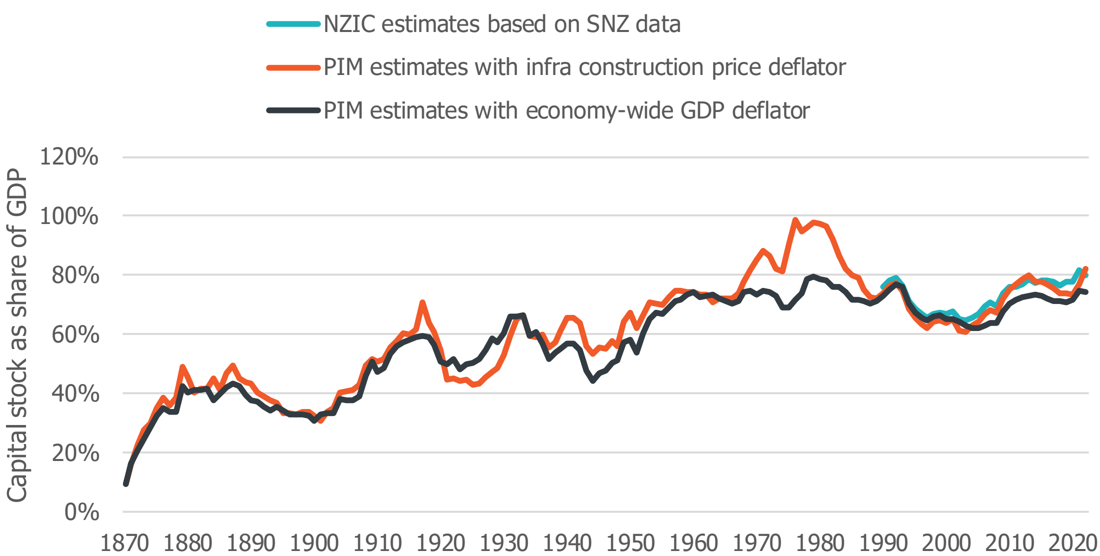
This suggests that choices of price index do not have a large impact on long-run capital stock estimates. Both our main and alternative estimates indicate gradual increases in the infrastructure capital intensity of the New Zealand economy since the late 1800s and early 1900s.

However, price indices can have a significant effect on the short-run path of capital stock estimates. We identify several periods where infrastructure construction prices declined significantly relative to the GDP deflator and subsequently rose significantly (1920s and 1930s), or vice versa (1960s/70s and 1980s/1990s). During these periods, capital stock estimates based on different price indices diverge significantly.

For instance, our base infrastructure capital stock estimates suggest that the value of infrastructure assets rose to nearly 100% of GDP in the late 1970s. Alternative estimates based on an economy-wide GDP deflator suggest a lower ratio during this period. This comparison suggests that the late 1970s peak in the infrastructure capital-to-output ratio was due in significant part to price index and revaluation effects, which were subsequently reversed due to declining real infrastructure construction prices in the 1980s and 1990s.

Since around 2000, infrastructure construction prices have risen faster than prices elsewhere in the economy. This means that capital stock estimates based on an infrastructure construction price index have risen relative to alternative estimates based on a GDP deflator. Our base PIM estimates are closer to what is reported in SNZ's National Accounts.

Figure A44: Perpetual inventory model infrastructure capital stock estimates using alternative price indices, as a share of GDP



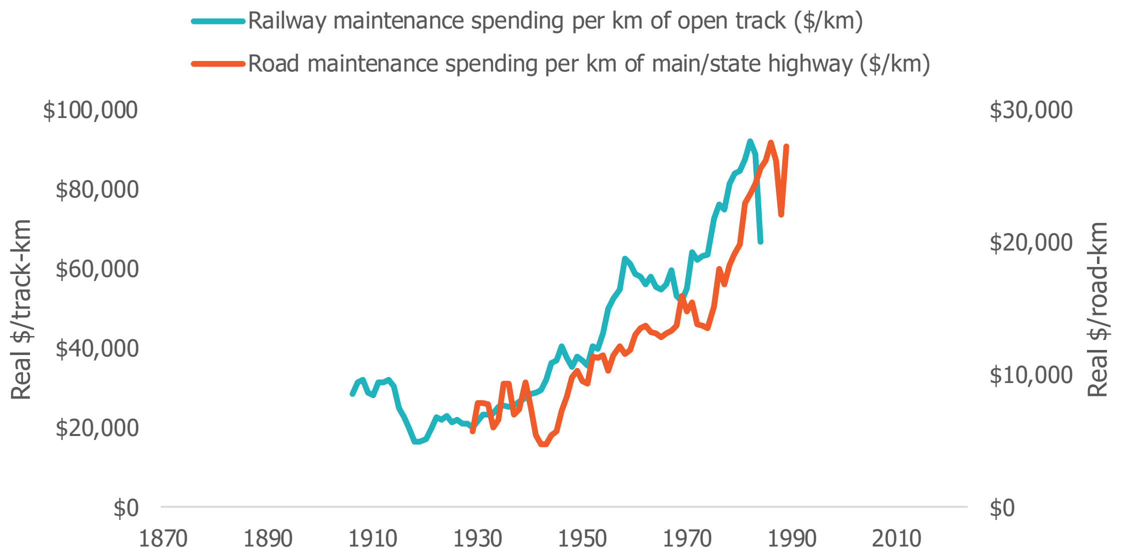
Source: New Zealand Infrastructure Commission analysis.

Real unit price trends for selected infrastructure goods

The following charts show real unit cost trends (adjusted using the GDP deflator) for the six categories of infrastructure goods for which we can provide long-run unit cost trends. We highlight some broad trends in this data:

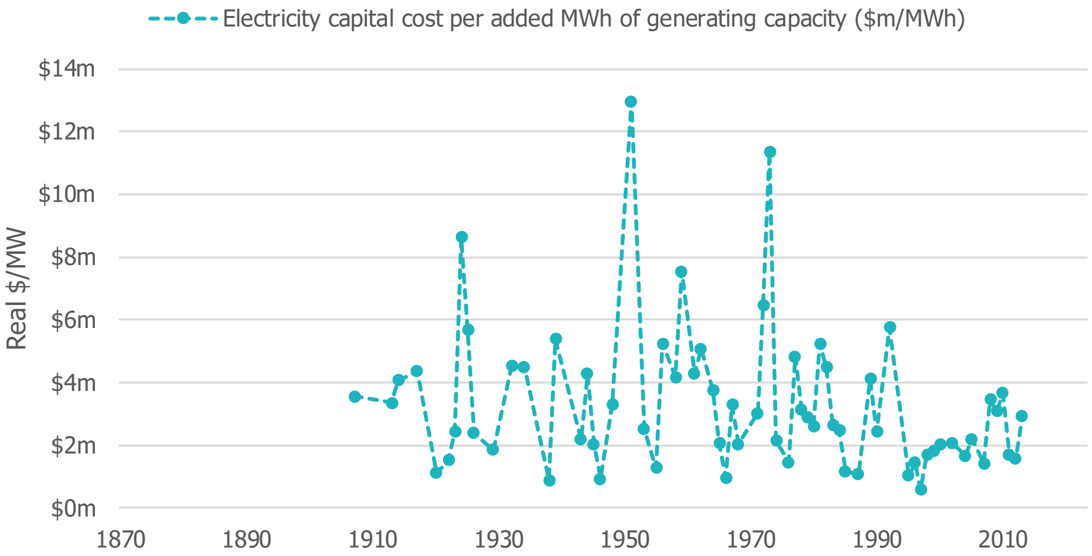
- Real unit costs for road and rail maintenance and state house construction rise more rapidly after around 1970 than in previous decades. This is broadly consistent with trends in the real infrastructure construction price index compiled above.
- Real unit costs for electricity generation and telephone connections fluctuate over time but do not necessarily trend up or down over the whole period. This is consistent with the idea that ongoing technology improvements in these sectors have contained increases in investment costs.

Figure A45: Real (GDP deflator-adjusted) unit costs of road and rail maintenance



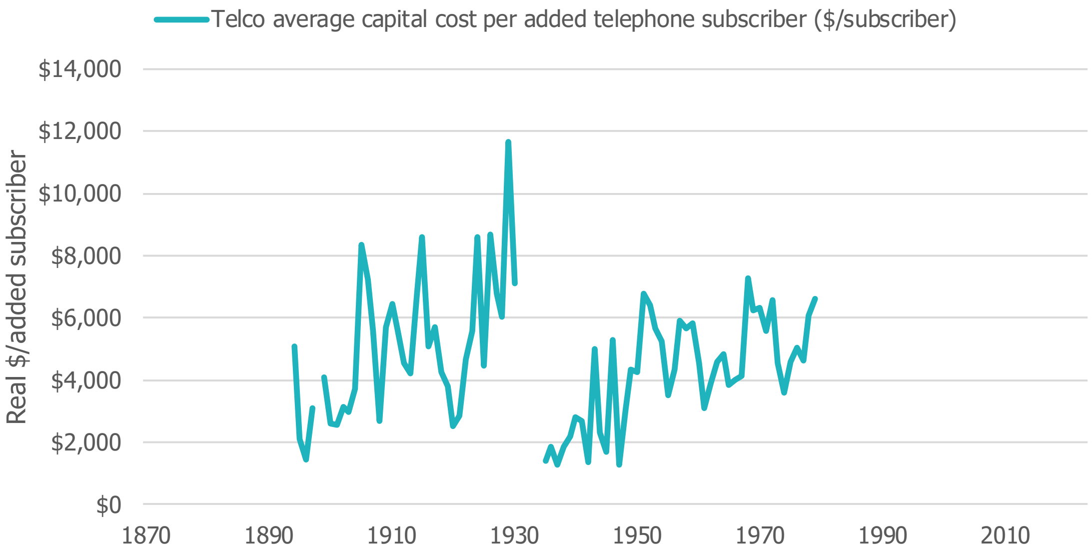
Source: New Zealand Infrastructure Commission analysis of New Zealand Official Yearbook data.

Figure A46: Real (GDP deflator-adjusted) unit costs for electricity generation



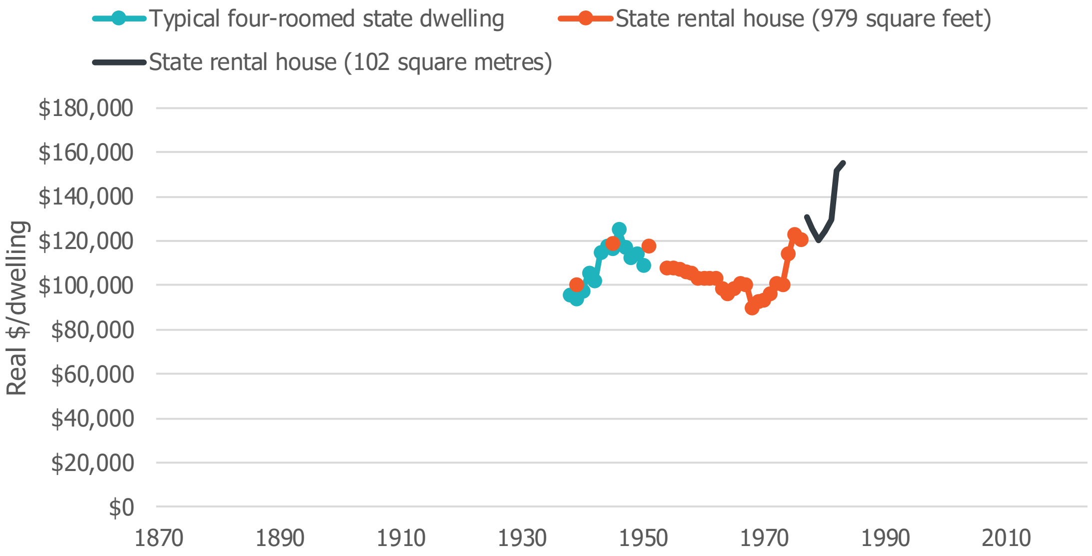
Source: New Zealand Infrastructure Commission analysis of Electricity Authority data.

Figure A47: Real (GDP deflator-adjusted) unit costs for telephone connections



Source: New Zealand Infrastructure Commission analysis of New Zealand Official Yearbook data.

Figure A48: Real (GDP deflator-adjusted) unit costs for state housing construction



Source: New Zealand Infrastructure analysis of New Zealand Official Yearbook data.

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