NEW ZEALAND INFRASTRUCTURE COMMISSION
*Te Waihanga*

# Probabilities, Not Predictions: Practical tools for modelling uncertainty and supporting better decisions

**Te Waihanga Research Insights series**

# New Zealand Infrastructure commission / Te Waihanga

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

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

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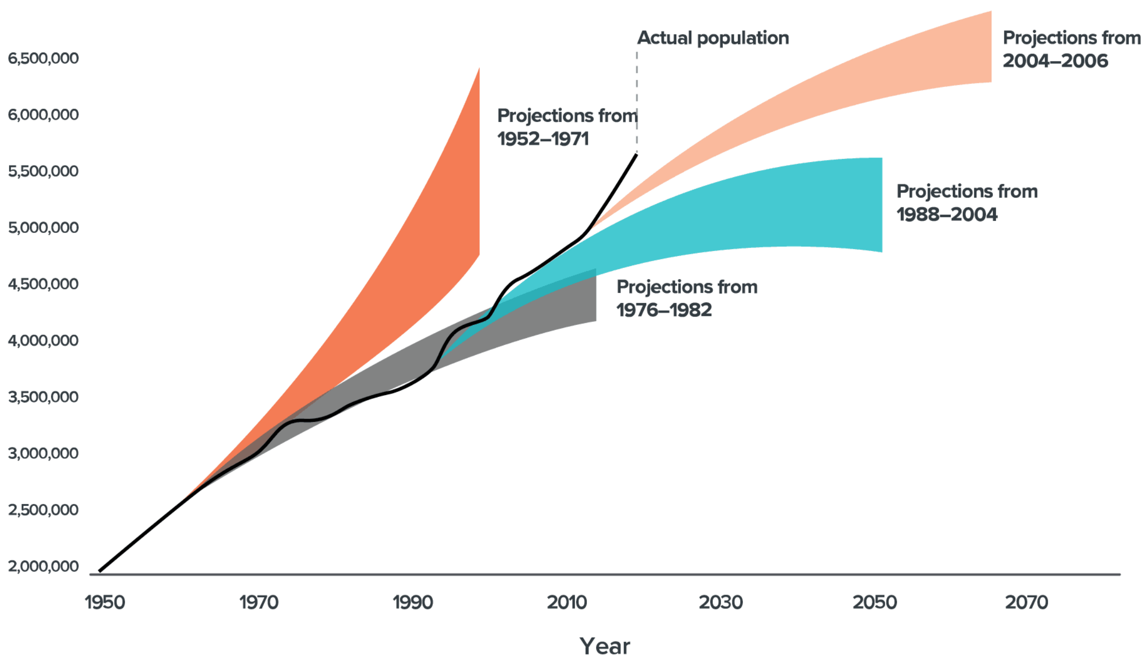
## Predictions are hard, especially about the future

**Infrastructure investment is a bet on the future.** Each project commits resources today for uncertain benefits in the future. Infrastructure assets are long-lived and decisions about what to build are often irreversible. After a project is built, its up-front construction costs and ongoing maintenance and operational costs must be recouped over a long period of time.

**We face significant uncertainty over the infrastructure life-cycle.** Many things can change over the multi-decade life of an infrastructure asset, and some changes can be hard to foresee. Well-established trends can easily turn around on us. For instance, New Zealand has sometimes over-estimated how fast the population will grow and sometimes under-estimated growth (Figure 1). These forecast errors cascade through to project planning.

*Figure 1: Historical population growth compared with historical population projections*




*Source: Adapted from Statistics New Zealand (2016)*

**Infrastructure projects are built based on predicted future demands and service needs**. Assumptions about how fast the population will grow, where people will live, what they will do for work, and how technology, prices, and preferences will change are critical to predicting future demand. These assumptions determine whether a proposed project is expected to 'pay off'.

**The cost of getting it wrong can be high.** Building too little infrastructure relative to demand can lead to congestion and poor service quality, at least until investment catches up. Building too much can result in assets that don't cover their costs, creating ongoing financial burdens. Ongoing operating losses and maintenance make it harder to respond to other emerging needs.

**We can't ignore uncertainty**. It would be nice to think that demand forecasts are usually correct and that large forecast errors are uncommon. Unfortunately, that's not the case. In the Appendix, we show that overall demand for New Zealand infrastructure networks has been both over-estimated and under-estimated at various times. At the project level, statistical reviews show that infrastructure demand and benefit forecasts tend to be over-optimistic. It's common for benefit and demand forecasts to be more than 20% higher or lower than what actually happens (Bezdek

& Wendling, 2002; Dodge, 2019; Flyvbjerg & Bester, 2021; Hartgen, 2013; Hoque et al., 2021; Wignall, 2017). Because forecast errors are so common, the question is how to plan with them in mind.

## Flexible design beats false certainty

**Infrastructure investment always involves risk.** Rather than trying to perfectly predict an uncertain future, we must design infrastructure and investment processes that can perform well even when we are wrong.

**Effective infrastructure planning starts by explicitly recognising uncertainty, quantifying it where possible, and being explicit about how much risk is acceptable.** Risk appetite should be defined in measurable terms — such as acceptable ranges for demand variability, cost escalation, or utilisation shortfalls — and agreed by decision-makers early in the planning process. This enables agencies to balance expected benefits against expected costs and downside risks (New Zealand Infrastructure Commission, 2024b).

**Investment risk can be managed through a staged, flexible approach to building projects, rather than making 'all or nothing' decisions.** It is prohibitively expensive to make every project robust to all potential demand scenarios, or all natural hazard risks. A better approach is to plan ahead and keep options open so that we can respond to what ultimately ends up happening. This approach can be called 'dynamic adaptive planning' (Marchau et al., 2019), 'real options theory' (Dixit & Pindyck, 1994), or 'design flexibility' (Neufville & Scholtes, 2011).

**Little bets are safe. Massive gambles are not.** Investment risks can be managed by expanding networks bit by bit, as demand grows, rather than adding lots of capacity well in advance of demand (New Zealand Infrastructure Commission, 2024c, 2025c). Large projects that are expected to take a long time to pay back are likely to be financially riskier than programmes of small projects. Pursuing them carefully, and selectively, is important when facing uncertainty.

**Designing flexibility into projects improves our ability to manage risk.** Sometimes, there's a need to make a big, lumpy decision to build, or not build. But often, there are ways we can progress with projects while preserving the option to change course in the future if circumstances change (New Zealand Infrastructure Commission, 2023). We can:

- **Wait for more information**: This means drawing up plans, securing resource consents, or buying a site now, and waiting to see whether the project is needed before pouring concrete.
- **Stage delivery**: This means breaking the project into several separate stages, and proceeding with each when demand builds up to a critical level.
- **Build flexibility to expand, contract, or switch uses**: This means designing infrastructure that can easily be expanded if demand is higher than expected, contracted if demand falls below expectations, or converted to another use if nobody uses it at all.
- **Include offramps**: This means starting a project, but maintaining the option to stop or delay it if new information suggests that it won't be needed.

**There are good worldwide examples of how these approaches have played out in practice.** Lisbon's 25 de Abril Bridge shows the value of designing for flexibility. Built in 1966 with deep, reinforced foundations, it was expanded in 1999 with a second deck carrying both road and rail traffic to meet growing demand (Infrastructure and Transport Ministers, 2020). Those early design choices made later adaptation possible at a fraction of the cost of a new bridge.

**Land protection for future infrastructure is often needed to preserve flexibility.** Buying land for a future project, obtaining designations for the use of land, or obtaining resource consents to enable future construction can be valuable even when the need for the project is uncertain. For example, advance purchase of land for a new school in a new suburb is likely to be a better option than waiting, even if there is a large chance that project will never need to be built (New Zealand Infrastructure Commission, 2023). This is because it's likely to be cost-prohibitive to buy land for a school after the suburb has developed to a point where the school is needed.

**Preserving flexibility has costs as well as benefits.** We can't afford to build stronger foundations for every bridge or buy land in advance for every project where the need is uncertain. Buying flexibility to expand capacity is most valuable in places where it is possible, but not certain, that demand will grow rapidly in the future.

## The only certainty is uncertainty

**To design flexibility effectively, we need to understand the full range of possible futures.** That requires modelling tools that can handle multiple sources of uncertainty at once.

**Focusing on a single source of uncertainty can obscure key project risks.** For example, the success of a new highway might depend not only on population growth but also on fuel prices, remote work trends, and future changes to transport technology. These factors interact – demographic, economic, technological, climate, and policy shifts combine to shape demand in ways that single-variable analysis can miss (Goldsmith, 2014; New Zealand Infrastructure Commission, 2024d, 2024a, 2024e, 2025b).

**Analysing multiple uncertainties means going beyond standard sensitivity analysis**. Infrastructure projects are commonly designed and evaluated against a single predicted future scenario. Sensitivity analysis might be used to consider what would happen if specific assumptions about the future were to change – for instance, if population growth was a bit faster or slower than expected. However, it is not well-suited for analysing the combined effect of many uncertainties.

**Monte Carlo modelling analyses uncertainty by simulating a wide range of possible outcomes.** This approach explores how different assumptions about what might happen in the future influence project outcomes, and how different trends might interact with each other.[1] It requires analysts to define probability distributions for key model inputs. For instance, a Monte Carlo model might assume that annual population growth could randomly fall within the range of +0.5% to +3%. After a Monte Carlo model is set up, it is re-run many times to gain an understanding of the potential range of future outcomes for a project. The model produces a probability distribution that shows the expected likelihood of different scenarios, which can then be used to test the value of design options that can adapt to or accommodate different futures.

## Putting Monte Carlo modelling to work

**Infrastructure projects seldom model potential demand uncertainty.** While Monte Carlo methods are well-established and commonly used in some areas, like oil and gas projects, they are rarely used for infrastructure like major transport projects (Machiels et al., 2021).

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[1] Monte Carlo simulation methods were developed in the late 1940s as part of nuclear physics research by Stanislaw Ulam and Nicholas Metropolis. The name 'Monte Carlo' was the code name for the project, derived from the Monte Carlo Casino in Monaco where Ulam's uncle would borrow money from relatives to gamble.

**Model complexity can be a barrier to uptake of Monte Carlo methods.** Demand and benefit forecasting for major transport projects is typically done using strategic transport models that simulate trip generation, distribution, mode choice, and route choice within an entire city or region. It is time-intensive to define project-specific model inputs, run models, and analyse and interpret the outcomes. This means that it's impractical to use these models to produce thousands of randomised model runs, as required for Monte Carlo analysis.

**It's easier to analyse complexity when you have a simple model.** In our previous work, we developed simple, spreadsheet-based Monte Carlo models that could be used to test the value of advance land protection for infrastructure like schools and transport corridors (New Zealand Infrastructure Commission, 2023). These are less sophisticated than the models used for detailed project planning and evaluation but enable a first-cut probabilistic analysis that supports early-stage decisions, like land protection. A useful early-stage model should run in minutes, allow for analysis of multiple types of uncertainty, and provide modelled probability distributions for key outputs like demands and benefits.

**Use big models to calibrate small ones.** For example, strategic transport models capture key drivers of demand for new infrastructure as well as interdependencies and interactions within networks. Neufville and Scholtes (2011) suggest that analysing these model outputs can help to identify which factors affect demand and how much of an impact they have. This can help to make simple models more realistic.

## A case study: Demand uncertainty for a transport megaproject

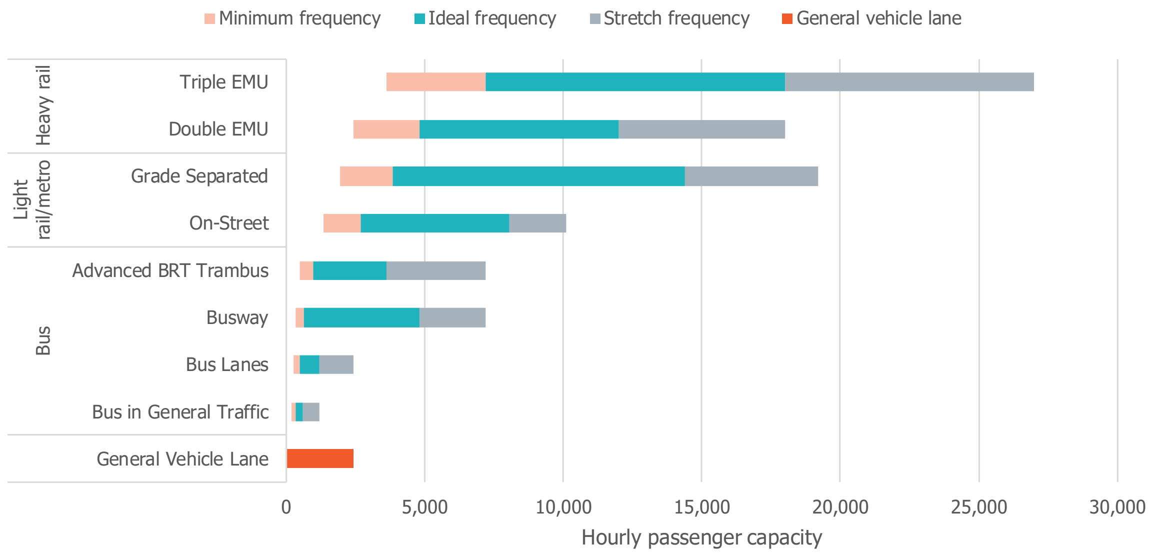
**Transport megaprojects are planned and delivered with uncertainty about future demand.** Once built, their costs are sunk and their capacity is fixed, making it essential to understand the range of possible futures before committing to major investment.

**New research illustrates how to apply Monte Carlo modelling to analyse transport demand uncertainty.** We worked with transport expert Pete Clark (Urban Umber) to develop an approach to Monte Carlo modelling of future demand for major transport projects and implement it on a real-world case study – the former Auckland Light Rail scheme. While the results of the modelling are only illustrative, they demonstrate practical steps that infrastructure providers can take to develop a probability-based view on an uncertain future.

**Rapid transit network planning faces uncertainty.** Passenger demand on Auckland's public transport network is expected to grow over the long term. The New Zealand Transport Agency and Auckland Transport's March 2025 *Auckland Rapid Transit Pathway* report identifies a long-term need for public transport infrastructure upgrades on several transport corridors, including the City Centre to Māngere corridor that was the focus of the former Auckland Light Rail project (Auckland Transport & NZ Transport Agency / Waka Kotahi, 2025). However, the timing and scale of these investments remain uncertain because no one can confidently predict how fast travel demand will grow.

**Demand uncertainty makes capacity choices difficult.** High-cost options such as grade-separated light or heavy rail provide much greater capacity than lower-cost options like buses in general traffic, but they also involve large, irreversible commitments. For example, Figure 2 shows a busway can provide three times as much capacity as a basic bus lane while grade-separated light or heavy rail can provide three times as much capacity as a busway. Transport agencies must decide when they have enough confidence in future demand to justify the step change in cost and capacity.

*Figure 2: Indicative hourly passenger capacity of different public transport modes*




*Source: Adapted from Auckland Transport and NZ Transport Agency / Waka Kotahi (2025)*

**To explore this uncertainty, the research developed a simple model of peak-hour patronage based on strategic transport model outputs.** Statistical analysis of a unique dataset of 147 transport model runs was used to understand how key variables affect transport demand. Table 1 summarises how future population and employment along the route, working from home rates, peak-hour road pricing and parking pricing, and public transport service frequency, capacity, and speed influence forecast demand.

*Table 1: Estimated impact of model inputs on peak-hour patronage at peak load point*

| **Variable** | **Estimated impact on patronage** |
|---|---|
| **Land use along route** | |
| Corridor population | A 10% increase in corridor population **increases patronage by 5.5%** |
| City centre employment | A 10% increase in city centre employment **increases patronage by 9%** |
| Working from home | Doubling working from home from 7% to 14% **decreases patronage by 2.9%** |
| **Pricing of alternatives** | |
| Congestion pricing | Implementing time-of-use charging **increases patronage by 1.5%** (albeit imprecisely estimated) |
| Parking prices | Doubling city centre parking charges **increases patronage by 13%** |
| **Public transport service** | |
| In-vehicle travel time | A 10% reduction in travel time **increases patronage by 8.5%** |
| Vehicle capacity at peak load point | A 10% increase in capacity **increases patronage by 1.4%** |
| Vehicle frequency | A 10% increase in frequency **increases patronage by 1.6%** |

*Source: Adapted from Clark (2026)*

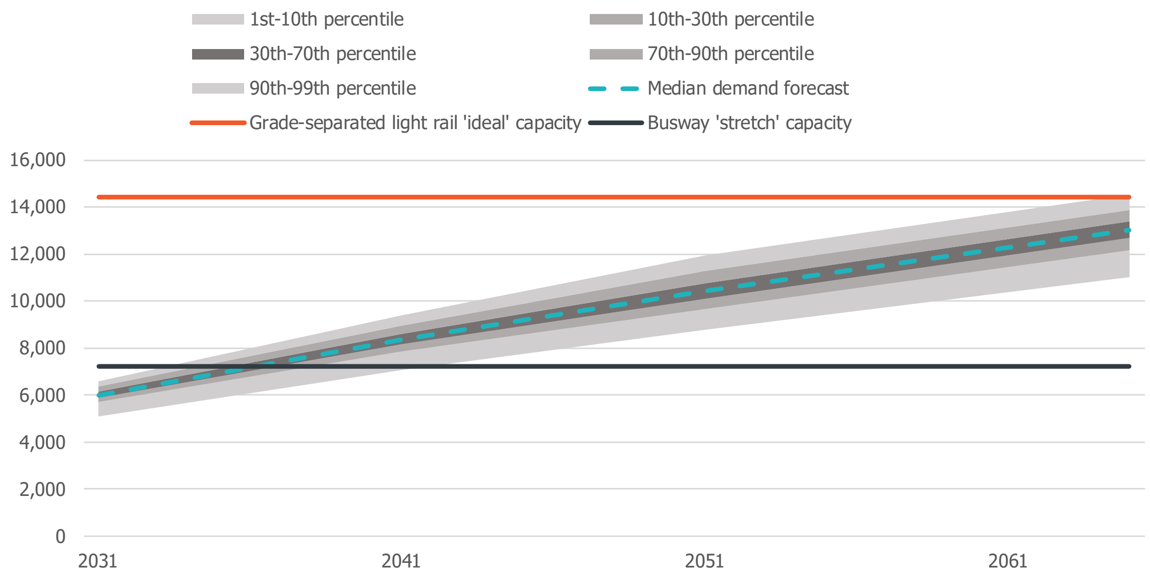
**Monte Carlo simulation explored how land use and policy uncertainties may affect demand.** This enabled analysis of a wider range of scenarios for population and employment growth, and how working from home patterns might evolve in the post-Covid environment. It also assessed the impact of uncertainty about big policy calls like whether to implement time-of-use charging on Auckland's road network or how much to increase parking prices.

**A probabilistic view of demand helps decision-makers understand capacity choices.** Figure 3 shows Monte Carlo model outputs for peak-hour passenger demands, compared against the capacity of different infrastructure options. This modelling reflects what might happen if infrastructure and services were improved to rapid transit standard. Near-term demand growth can be served by increasing bus frequencies and improving bus infrastructure. But at some point, demand may exceed the 'stretch' capacity of even the highest-capacity bus options, shown as a horizontal black line on Figure 3. It's unclear exactly when this might happen because demand could grow faster or slower than the midpoint forecast – hence the decision problem is *timing* the step-change.

**Major new transport infrastructure provides a step-change in capacity, and demand takes time to catch up.** The horizontal orange line on Figure 3 shows the 'ideal' capacity of a fully grade-separated light rail line. Monte Carlo model outputs suggest there is a less than 1% probability that peak-time demand would exceed this capacity, even in the 2060s. This highlights the difficulty of optimising asset utilisation: invest too early, and capacity lies underused for decades; invest too late, and network performance may suffer. A probabilistic approach helps to understand and manage these risks.

**Investment decisions need to weigh costs alongside demand and expected benefits.** Demand is a necessary but not sufficient reason to proceed with a major capacity upgrade. There is seldom a case to invest when existing infrastructure can serve current and expected future demand. But even when capacity constraints are expected, the priority should be to identify the most cost-effective upgrade option. International evidence shows that some countries deliver rapid transit infrastructure at much lower cost through optimised design and delivery, allowing them to build more of it (Aevaz et al., 2021; Goldwyn et al., 2024; New Zealand Infrastructure Commission, 2022).

*Figure 3: Indicative Monte Carlo modelling of peak load demand for a major rapid transit project in Auckland*




*Source: Adapted from Clark (2026) and Auckland Transport and NZ Transport Agency / Waka Kotahi (2025)*

## Planning when the future won't sit still

**Infrastructure planning will always involve uncertainty.** By employing probability-based tools such as Monte Carlo modelling, infrastructure providers can move beyond precision and towards flexibility – planning projects and programmes that perform well across a wider range of possible futures. These tools help to understand the investment challenges we face and the practical steps we can take to address them.

**Transport megaprojects face inherent timing challenges.** Major transport infrastructure often arrives well ahead of peak use, because capacity upgrades come in large, discrete steps while demand grows gradually. This is different to vertical infrastructure like schools or hospitals, where it's easier to expand capacity in small increments in line with demand growth. Network-wide asset utilisation therefore averages around 70% for hospital beds and 83% for schools, and higher at peak times and rapidly growing places (New Zealand Infrastructure Commission, 2025a). While transport projects can be built with some flexibility, a degree of early under-utilisation is unavoidable and should be recognised in investment planning. However, there are several ways to optimise use of new capacity.

**One response is to accept some peak-time congestion as a signal of high capacity utilisation.** When networks operate closer to capacity during peak periods, some demand shifts into off-peak times. This improves all-day asset utilisation and helps ensure that new projects can unlock latent demand from day one. Managed congestion can be a useful signal that demand is maturing toward the next investment threshold – rather than a signal that existing infrastructure is 'failing'.

**A second response is to build major projects in stages.** Delivering the highest-demand sections first allows transport agencies to manage costs, test performance, and expand as utilisation grows. This also reduces the risk of investing too early and keeps options open as conditions evolve.

**Third, land use policies and network pricing can help 'crowd in' demand to new infrastructure.** More people living and working near transport infrastructure means higher asset utilisation. Spatial planning and enabling more development around rapid transit stations can help to achieve this. Similarly, time-of-use road pricing, peak/off-peak public transport fare differentials, and parking management policies can lift utilisation when designed well. Coordinating land use and pricing policies with infrastructure delivery shortens the lag between investment and use.

**Finally, sequencing upgrades across the network can improve benefit realisation.** Spacing out major capacity upgrades avoids the risk that projects 'cannibalise' demand from each other. This makes better use of limited funding and delivery resources. A plan to sequence upgrades in line with demand growth, rather than try to build them all at once, can also help to provide a longer-term pipeline of work for engineering and construction firms.

**Treating uncertainty as something to plan for, not avoid, helps us make investments that stay useful across a range of futures.** That's the essence of planning for uncertainty – not guessing right, but staying ready.

## Appendix: Analysis of past infrastructure demand forecasts

Infrastructure providers and lead policy agencies produce forecasts and projections of future demand to guide investment planning. Sometimes forecasts are accurate and sometimes they are off the mark.

To better understand New Zealand's infrastructure demand forecasting record, we gathered several decades' worth of network-wide demand forecasts made by lead policy agencies or public infrastructure providers and then compared them against actual demand growth. Our focus is on describing our forecasting track record, rather than explaining what's caused forecasts to be 'right' or 'wrong'.

We sourced official forecasts for two 'horizontal' infrastructure sectors (electricity, from the Ministry of Business, Innovation, and Employment and its predecessor agencies, and roads, from the Ministry of Transport) and two 'vertical' infrastructure sectors (schools, from the Ministry of Education, and prisons, from the Ministry of Justice). In some cases, historical forecasts were based on slightly different concepts of demand (eg electricity consumption rather than electricity generation output) or based on demand data that was subsequently revised. We therefore rebased forecasts against the most recent observed data.

### Context: Comparison of forecast and actual demographic change

As context for these infrastructure demand forecasts, we summarise forecast versus actual demographic change over this period. This updates and extends the earlier Statistics New Zealand analysis shown in Figure 1.

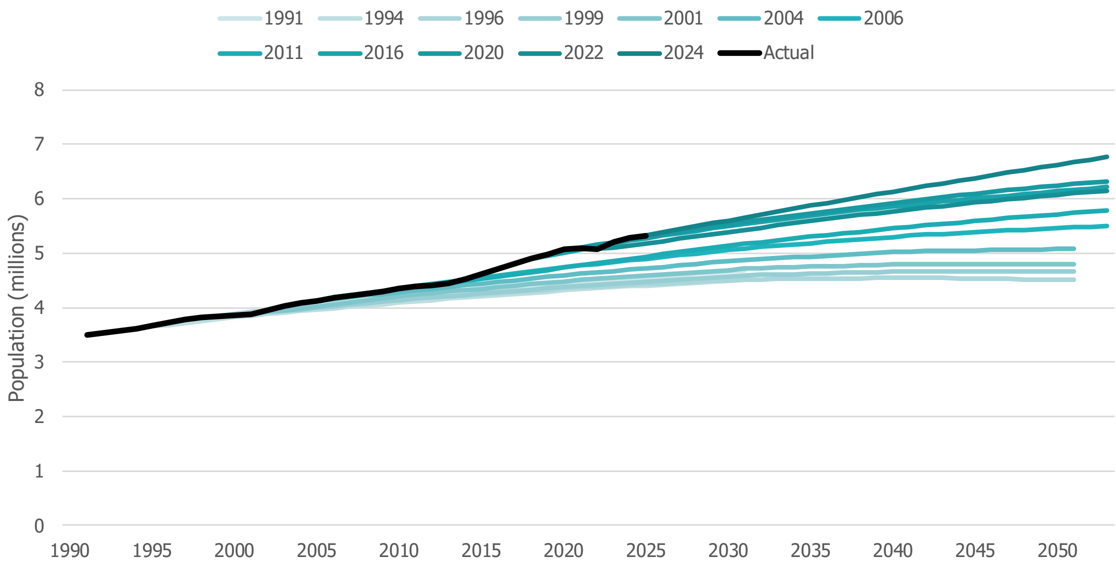
We focus on two key measures that are relevant for infrastructure outcomes: Total population, which affects growth in total demand for infrastructure, and share of the population over the age of 65, which affects how intensively people use different types of infrastructure, like school, hospital, and transport infrastructure (New Zealand Infrastructure Commission, 2024d).

Black lines on the chart show actual outcomes, while blue lines show projections made at different points in time. Blue lines that are higher than the black line represent over-optimistic forecasts, and vice versa.

Figure 4 shows that, since the 1990s, New Zealand's total population has tended to grow faster than projected. This contrasts with New Zealand's experience between the 1960s and 1980s, where population growth was consistently slower than forecast. Forecast errors are mostly, but not always, negative, and often large. For example, forecasts produced between 1991 and 2011 under-estimated New Zealand's 2025 population by an average of around 16%. This is equal to over 800,000 people, or half of Auckland's current population.

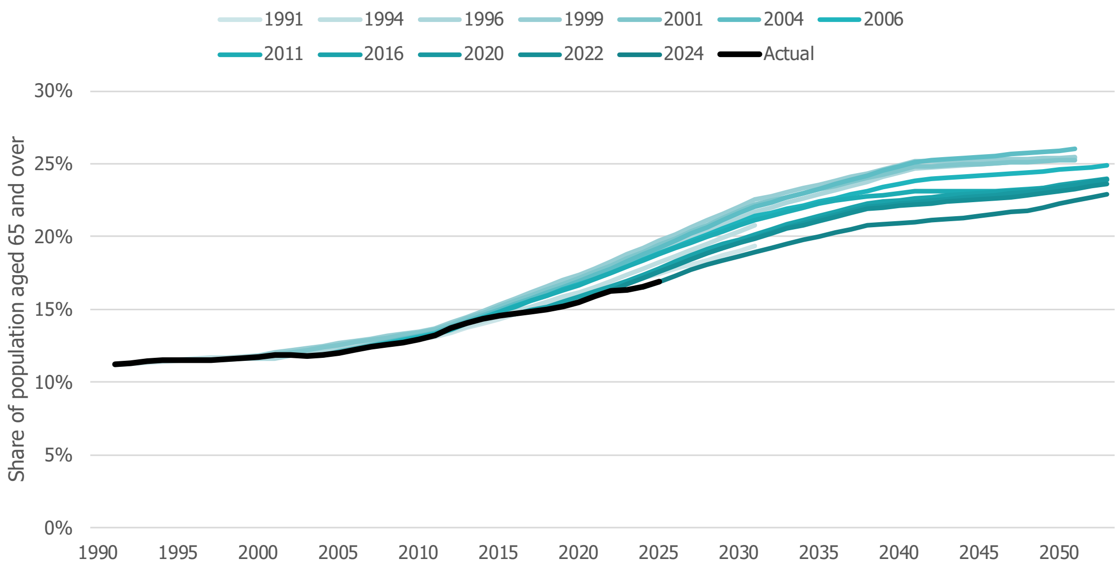
Figure 5 shows that New Zealand's population has aged slightly slower than expected during this period. This is due to faster-than-expected inward net migration, as migrants tend to be younger than the average New Zealander. However, increased migration has been partly offset by a faster-than-expected decline in fertility rates (New Zealand Infrastructure Commission, 2024d). However, while New Zealand's population is, on average, younger than expected, the share of people aged 65 and older has continued to rise. This highlights that faster population growth is not a panacea for the fiscal and economic impacts of population ageing.

*Figure 4: Total population growth: Stats NZ population projections, 1991-2024*




*Source: Annual population estimates (as at June) are from Stats NZ Infoshare series DPE056AA. Projections for 1991-2006 base years are from Stats NZ Official Yearbooks.[2] Projections for 2011-2024 base years are from relevant Stats NZ releases.[3] The chart summarises the median projection for each year.*

*Figure 5: Share of population aged 65 and over: Stats NZ population projections, 1991-2024*




*Source: Annual population estimates by age group (as at June) are from Stats NZ Infoshare series DPE056AA. Projections for 1991-2006 base years are from Stats NZ Official Yearbooks. Projections for 2011-2024 base years are from relevant Stats NZ releases. The chart summarises the median projection for each year.*

[2] https://www.stats.govt.nz/indicators-and-snapshots/digitised-collections/yearbook-collection-18932012/
[3] https://img.scoop.co.nz/media/pdfs/1207/NationalPopulationProjections2011.pdf
https://www.stats.govt.nz/information-releases/national-population-projections-2016base2068
https://www.stats.govt.nz/information-releases/national-population-projections-2020base2073
https://www.stats.govt.nz/information-releases/national-population-projections-2022base2073
https://www.stats.govt.nz/information-releases/national-population-projections-2024base2078

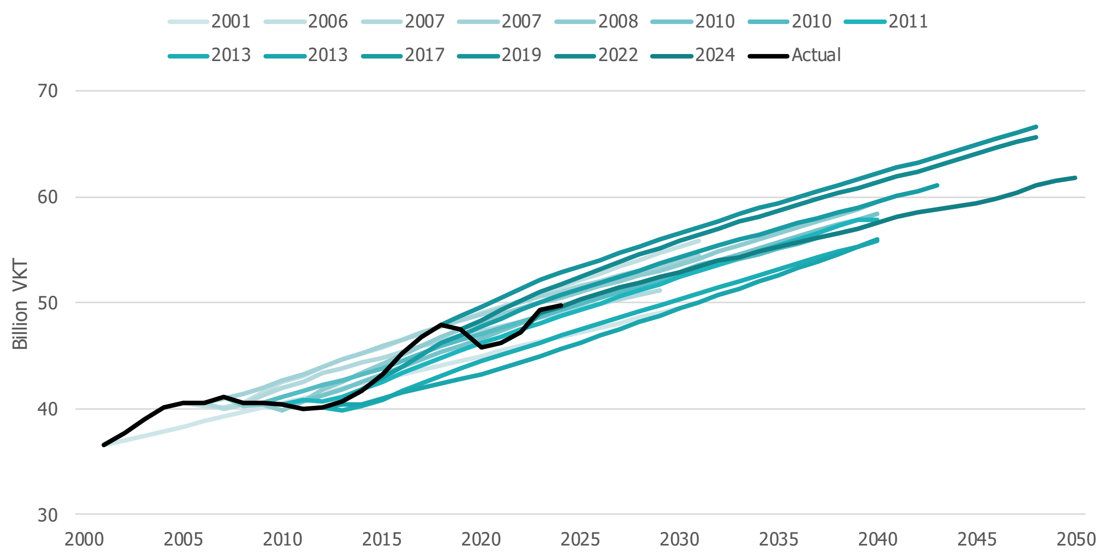
## Comparison of forecast and actual demand growth

The following charts summarise forecast versus actual growth in demand for four types of infrastructure. Each individual blue line on the chart shows a single demand projection, produced at a point in time. The thicker black lines show actual growth in demand over this period. The difference between the blue and black lines indicates the degree of forecast error.

These charts show that forecasts are frequently inaccurate, even over a short period. Actual outcomes (the black lines on the charts) frequently deviate from forecast outcomes (the blue-shaded lines). In some cases, forecasts over-estimate demand growth; in other cases, forecasts under-estimate demand growth.

As shown above, these forecasts were produced at a time when New Zealand's population was growing faster than expected. If population was the only driver of infrastructure demand, we would expect forecasts to consistently under-estimate demand growth. However, this is not what we see in the data. This highlights that even when population is growing faster than expected, other economic, technological, and policy factors can still lead to slower-than-expected infrastructure demand growth.

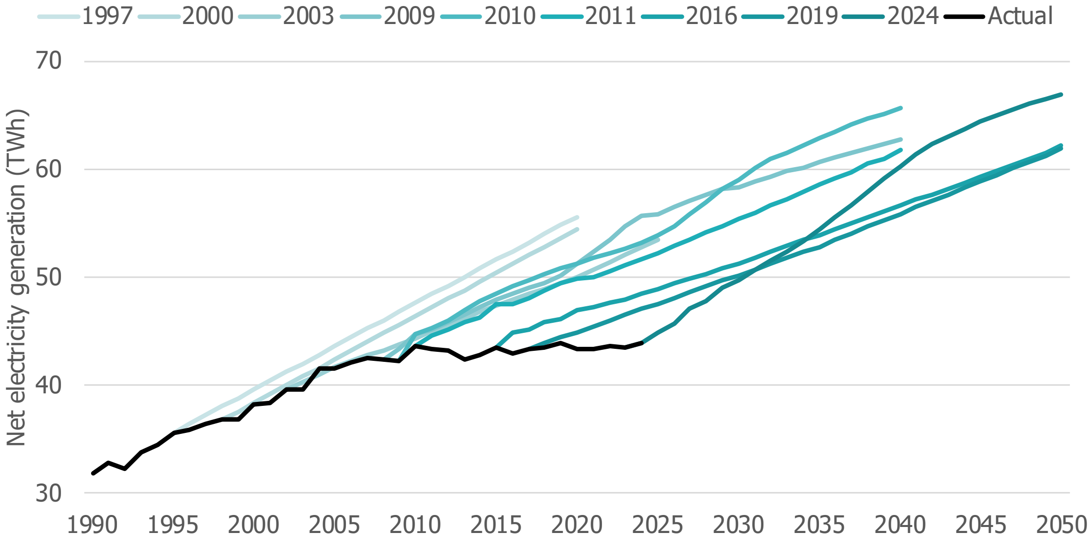
*Figure 6: Road infrastructure demand: Vehicle kilometres travelled projections, 2001-2024*




*Source: Actual traffic volume data is from Ministry of Transport's Annual Fleet Statistics.*[4] *Projections for 2001-2013 were provided by Ministry of Transport, based on various version of the Ministry's former Vehicle Fleet Emissions Model. There are two separate projections for 2007 and 2013, reflecting sensitivity ranges. Projections for 2017-2024 are from the Ministry's updated Vehicle Fleet Model, often sourced from its Transport Outlook publication.*[5]

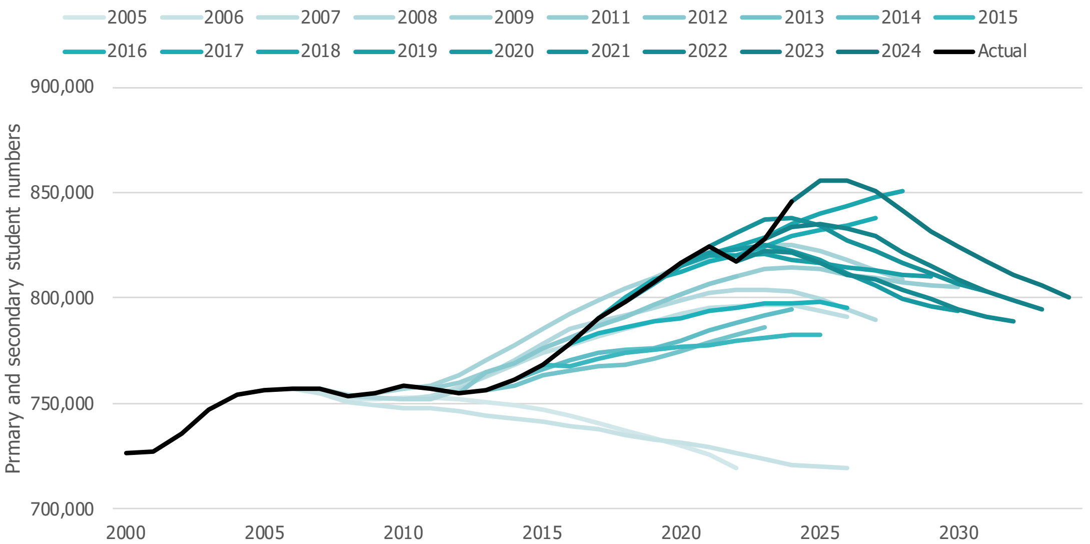
[4] https://www.transport.govt.nz/statistics-and-insights/fleet-statistics/sheet/annual-fleet-statistics
[5] https://www.transport.govt.nz/statistics-and-insights/vehicle-fleet-model/sheet/updated-future-state-model-results; https://www.transport.govt.nz/area-of-interest/infrastructure-and-investment/transport-outlook

Figure 7: Electricity infrastructure demand: Net generation output projections, 1997-2024




*Source: Actual net electricity generation output is from the Ministry of Business, Innovation and Employment's Electricity statistics.[6] Projections for 1997-2000 are from Ministry of Commerce Energy Outlook publications; projections for 2003-2011 are from Ministry of Economic Development Energy Outlook publications; and projections for 2016-2024 are from Ministry of Business, Innovation and Employment Electricity Demand and Generation Scenarios.[7] Starting in 2009 multiple scenarios were reported; we show the 'reference' scenario.*

Figure 8: School infrastructure demand: Primary and secondary student volume forecasts, 2005-2024




*Source: Actual student volumes are sourced from the Ministry of Education school roll data, published alongside student volume projections. Projections for 2005-2024 are from Ministry of Education's National School Roll Projections; projections that are no longer available online were provided by the Ministry.[8]*

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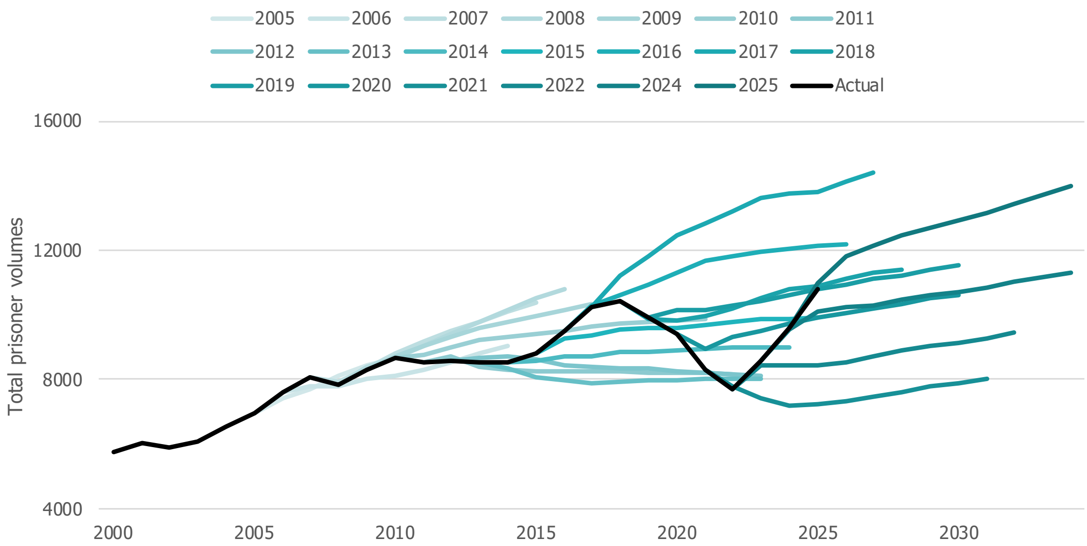
[6] https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/electricity-statistics

[7] https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-modelling/electricity-demand-and-generation-scenarios. Pre-2024 projections were sourced from historical versions of the Ministry of Economic Development and Ministry of Business, Innovation and Employment websites saved on archive.org.

[8] https://www.educationcounts.govt.nz/statistics/national-school-roll-projection

*Figure 9: Prison infrastructure demand: Prisoner volume projections, 2005-2025*




*Source: Actual prisoner volumes, as at June, are from the Department of Corrections' Quarterly Prison Statistics.[9] They include remand and sentenced prisoner volumes. Projections for 2005-2025 are from the Ministry of Justice's annual Justice Sector Projections.[10] Historical projections are available on the Ministry of Justice website.*

## Patterns in demand forecast errors

To understand patterns in demand forecast errors, we calculate and report two simple measures of forecast accuracy for each network, and for total population:[11]

- **Mean percentage error**: This is the average percentage deviation between forecasts and actuals, across all forecasts for which we have data. Positive values indicate that forecasts tend to 'over-estimate' demand, and negative values indicate that forecasts tend to 'under-estimate' demand.
- **Mean absolute percentage error**: This is the average percentage deviation between forecasts and actuals, in absolute values. This measure is always positive – larger numbers indicate larger forecast errors, which could be positive or negative.

For instance, if the last four forecast errors were +2% (forecast demand was 2% higher than actual demand), -1%, -3%, and +4%, then mean percentage error would be +0.5% and mean absolute percentage error would be 2.5%. This would indicate forecasts that were slightly too high on average, with volatility between positive and negative errors.

We calculate these measures for the first through fifth year of each forecast. By and large, forecasts produced in a given year start from historical data up to the previous year, and thus the first forecast year is the year in which the forecast was produced. For example, the Ministry of Business, Innovation and Employment's 2022 electricity generation projection is based on actual generation output up to 2021, meaning that the first forecast year is 2022.

Table 2 summarises mean percentage errors for these four networks over a five-year forecast horizon. This shows that:

[9] https://www.corrections.govt.nz/resources/statistics/quarterly_prison_statistics
[10] https://www.justice.govt.nz/justice-sector-policy/research-data/justice-sector-projections
[11] Added insight could also be gained by calculating a more sophisticated set of metrics, eg along the lines of a recent Reserve Bank of New Zealand review of its forecasting performance (Knowles & Patel, 2025).

- Average forecast errors vary by network – they are larger for electricity and prisons than for roads and schools
- Average forecast errors increase over time – in all networks and for total population, they are larger for year 2 than for year 1, and so on and so forth
- Demand growth for roads, electricity, and prisons has, on average, been over-estimated, while demand growth for schools has been under-estimated. All of the electricity forecasts produced between 1997 and 2022 over-estimated growth.

*Table 2: Mean percentage error for infrastructure demand forecasts*

| Forecast period (years ahead) | Total population | Roads (vehicle kilometres travelled) | Electricity (net electricity generation output) | Schools (primary and secondary student volumes) | Prisons (prisoner volumes) |
|---|---|---|---|---|---|
| 1 | -0.2% | +0.5% | +2.0% | -0.1% | +1.0% |
| 2 | -0.4% | +1.1% | +2.2% | -0.4% | +1.0% |
| 3 | -0.8% | +1.2% | +4.2% | -0.6% | +2.3% |
| 4 | -1.1% | +1.2% | +5.2% | -1.0% | +4.3% |
| 5 | -1.2% | +1.3% | +6.5% | -1.2% | +7.4% |
| *Share of forecasts that are too high after 5 years* | *20%* | *60%* | *100%* | *43%* | *63%* |

*Source: Infrastructure Commission analysis of historical infrastructure demand projections*

Table 3 summarises mean absolute percentage errors for these four networks over a five-year forecast horizon. Larger numbers indicate projects that are more volatile, potentially due to a pattern of both positive and negative errors. This shows that forecast volatility is lowest for schools, higher for roads and electricity, and highest for prisons. Forecast volatility is higher for all types of infrastructure than it is for total population.

Volatility in forecast errors makes it hard to plan network capacity. For example, the mean absolute percentage error for prisoner volumes of 17% after five years means that it would be common to over-estimate prisoner volumes by around 1800 people – or under-estimate them by a comparable amount. This is equal to three times the capacity of the recently-opened Waikeria Prison expansion.

*Table 3: Mean absolute percentage error for infrastructure demand forecasts*

| Forecast period (years ahead) | Total population | Roads (vehicle kilometres travelled) | Electricity (net electricity generation output) | Schools (primary and secondary student volumes) | Prisons (prisoner volumes) |
|---|---|---|---|---|---|
| 1 | 0.4% | 1.7% | 2.0% | 0.5% | 2.5% |
| 2 | 0.8% | 2.9% | 2.6% | 0.9% | 7.7% |
| 3 | 0.8% | 4.2% | 4.2% | 1.1% | 12.7% |
| 4 | 1.0% | 5.2% | 5.2% | 1.6% | 15.8% |
| 5 | 1.2% | 6.0% | 6.5% | 1.9% | 17.0% |

*Source: Infrastructure Commission analysis of historical infrastructure demand projections*

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