NEW ZEALAND
INFRASTRUCTURE
COMMISSION
Te Waihanga

The decline of housing supply in New Zealand: Why it happened and how to reverse it

Te Waihanga Research Insights series

March 2022

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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Contents

Cut to the chase

Te Waihanga's *Infrastructure Strategy* highlights that we cannot have economically productive and inclusive cities without abundant and affordable housing. However, over the last 20 years, New Zealand has experienced faster growth in real house prices than any other OECD country. Housing has gone from being abundant and reasonably affordable to being scarce and prohibitively expensive, especially in our fast-growing cities.

This raises two questions: Why did housing supply and affordability decline, and what can we do to reverse this trend?

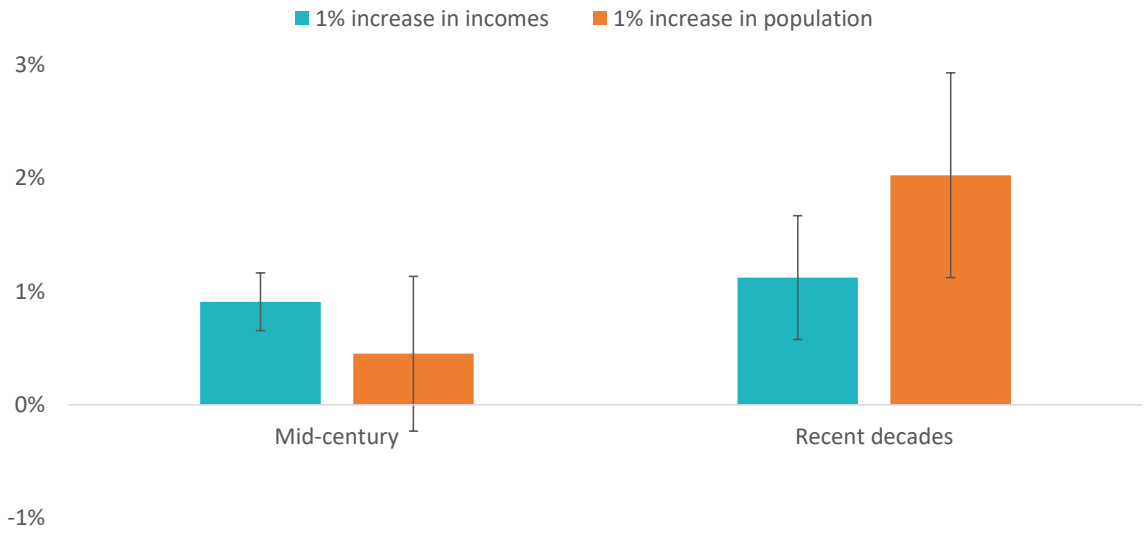
The problem is slowing supply, rather than accelerating demand

We analyse how housing prices and supply have changed between the 1930s and 2010s. Population and incomes, which drive housing demand, grew more rapidly in the middle of the 20th century than in recent decades. However, house prices have risen more rapidly in recent decades and new housing construction has slowed down.

Increased housing demand now has a larger impact on prices than it did in the past (Figure 1). Between the late 1930s and late 1970s, a 1% rise in population caused house prices to increase by roughly 0.5%. Between the late 1970s and late 2010s, a 1% rise in population caused house prices to increase by roughly 2.0%. Income growth also had a larger impact on prices in recent decades.

Prices now rise more rapidly because housing supply is slower to respond to demand. We estimate that when demand for housing increases, we now build one-quarter to one-third fewer homes than our grandparents did.

Figure 1: How much do house prices increase in response to a 1% increase in housing demand?



Source: Te Waihanga analysis. Bars indicate estimated model coefficients, and black lines indicate one standard error ranges around estimated coefficients.

We can explain the decline in housing supply

We use an urban economics model to show that changes to urban planning policies and urban transport speeds can explain most, if not all, of the acceleration in house prices and decline in

housing supply in recent decades.

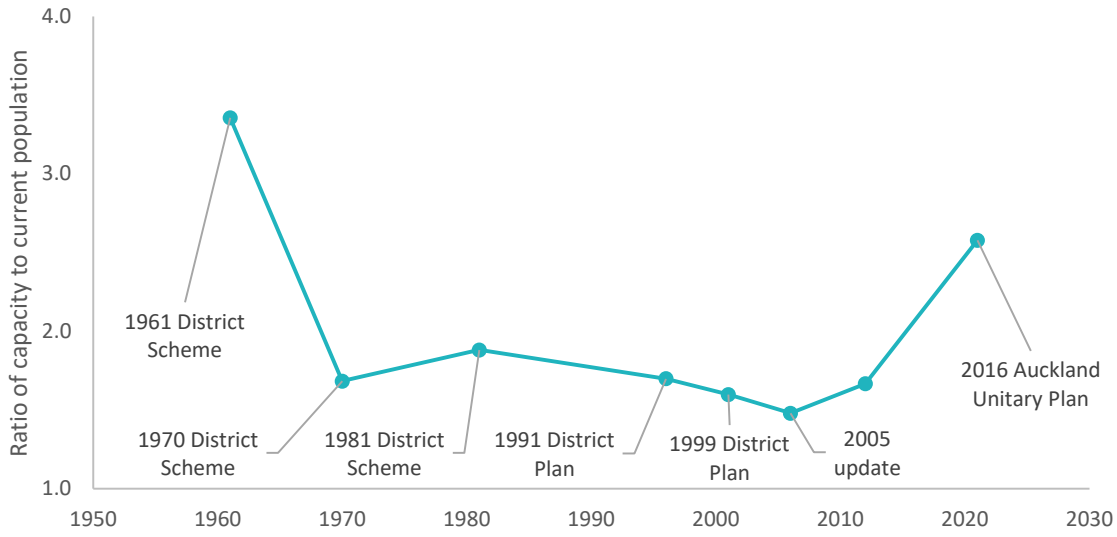
When urban planning policies limit development, either 'up' in the centre of the city or 'out' at the fringes, it leads to higher house prices and reduced supply over time. When travel speeds change, it changes the attractiveness of different locations are desirable for housing development, which can open up more opportunities to build. Urban planning and transport facilitated housing prior to the 1970s, but subsequent changes have erected barriers to housing.

Planning has become more complex and restrictive

Between the 1930s and 1970s, planning rules made it easy to build new houses or apartments in existing suburbs and to build new suburbs. In Auckland, plans provided enough capacity for central suburbs to triple in population (Figure 2). However, planning rules became more restrictive and more complex over time. Central Auckland's capacity for new housing was cut in half in the early 1970s – a change that was partially reversed in the 2016 Auckland Unitary Plan.

Legislative changes also had an impact. The Town and Country Planning Act 1977 made it easier to appeal planning decisions and increased the role of consultation in plan-making. This led to plans that prioritised preservation of amenity for existing residents over provision for new housing and infrastructure. The Resource Management Act 1991 then introduced an effects-based planning regime. Councils responded by carrying over development restrictions from existing plans and writing more complex plans that tried to manage a wider range of effects.

Figure 2: Ratio of estimated zoning capacity to current population in central Auckland



Source: Te Waihanga analysis

Urban travel speeds dictate the pace of urban expansion

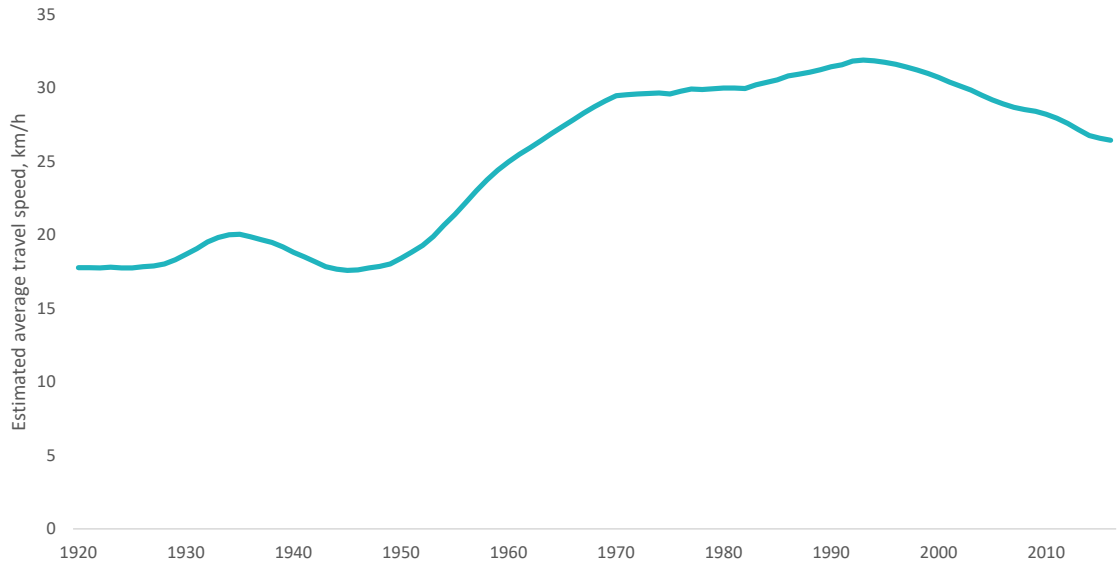
Between the 1930s and 1970s, average urban travel speeds increased rapidly due to the adoption of a new technology (the car) and improvements to urban roads (Figure 3). Improvements to travel speeds slowed in the 1970s and reversed starting in the early 1990s. By the late 2010s, increasing traffic congestion had eroded around one-third of previous gains in travel speeds despite significant motorway expansion. Transport modelling suggests that this trend will continue even with further increases in investment.

Rising travel speeds between the 1930s and 1970s facilitated housing supply by increasing the

area where new homes could be built. Auckland's built-up area expanded rapidly during this period. When growth in travel speeds slowed in the 1970s and then began to reverse in the 1990s, urban expansion also slowed down as it became harder to build at the edge of the city.

It will be difficult to reverse the decline in travel speeds through investment, as new road capacity tends to 'induce' additional driving, resulting in few sustained benefits for travel speed. A potential approach would be to use a combination of congestion pricing, to mitigate severe congestion and widespread, low-cost deployment of new transport options to lift mobility.

Figure 3: Urban travel speeds increased from the 1940s to the early 1990s and then declined



Source: Te Waihanga analysis

The negative impacts of changes to urban planning and changes to urban travel speeds compounded each other. Ironically, councils chose to limit urban intensification at the point at which changing transport speeds were about to make urban expansion harder.

We can make different choices

Our analysis shows that accelerating house prices were not inevitable. If we had not downzoned central Auckland in the 1970s, or if we had chosen to adopt successful congestion-mitigation policies, then housing would now be more abundant and house prices would be lower.

Going forward, we can boost housing supply and improve affordability by reforming our approach to urban infrastructure and urban planning. Our analysis reinforces the value of recommendations in Te Waihanga's *Infrastructure Strategy* to write plans that allow cities to grow and change, restore the link between planning and infrastructure, make different choices to lift urban accessibility, and provide different infrastructure to serve changing cities.

Introduction

We have a housing supply and affordability problem

Over the last 20 years, New Zealand has experienced faster growth in real house prices than any other OECD country (OECD, 2022). In the space of a generation, housing has gone from being abundant and reasonably affordable, to being scarce and prohibitively expensive. Home-building has increased significantly over the last half decade, but it will take time to address a deficit of housing that has accumulated over a long period of time.

The social and economic costs of scarce and unaffordable housing are large. All large and mid-sized New Zealand cities have median house prices well over five times the median household income (Urban Reform Institute and Frontier Centre. 2022). This makes it difficult for young people and people on low incomes to seek economic opportunities in cities, leading many to seek opportunities in Australia (Nunns, 2021). New Zealanders are spending an increasing share of their incomes on rent and mortgage payments, limiting how much we can save for retirement or invest in businesses (Ministry of Social Development, 2019). A lack of quality housing also means that many people live in damp or moldy homes, experience overcrowding and have poor health and wellbeing as a result (SNZ, 2019, 2020a).

However, unaffordable housing is not inevitable or inescapable. Homes are more abundant and hence affordable in many other countries. Some places, like Japan, have succeeded in improving housing affordability and increasing construction over time (Sorensen, 2005; Gleeson, 2019). And housing used to be more affordable in New Zealand, for instance in the decades after World War II.

Infrastructure and urban planning can help

Housing markets are shaped by infrastructure provision and urban planning policies. For instance:

- Providing transport infrastructure can open up new locations for development or make existing areas more attractive for redevelopment (Duranton and Turner, 2012; Garcia-López, 2012; Mohammad et al, 2013)
- Water and wastewater services are needed to enable urban housing development (Coury et al, 2022)
- Planning policies can integrate and coordinate housing, employment, and infrastructure development, or, conversely, constrain development in desirable areas (Cheshire, Nathan, and Overman, 2014; de Groot et al, 2015).

Te Waihanga's *Infrastructure Strategy* outlines some opportunities to improve. Reforming our approach to urban infrastructure and urban planning could boost housing supply and improve affordability.

We can learn from the past

The purpose of this Research Insights piece is to improve our understanding of how infrastructure can contribute to housing supply and affordability. To do so, we analyse how housing prices and supply have changed over the nine-decade period from the 1930s and 2010s.

First, we benchmark against our past, using long-run data series to measure how the New Zealand housing market functioned in the middle of the 20th century relative to how it has functioned in

recent decades. This allows us to understand whether more rapid price increases in recent decades are due to faster growth in housing demand, or slow housing supply responses.

Second, we investigate causes of changing housing supply and price dynamics. We use a standard urban economics model to identify underlying infrastructure and urban planning factors that might have caused housing supply to slow down. We measure how those factors have changed over time and use our model to show that these factors can explain observed changes in housing markets.

We conclude by considering the implications of this research. Our findings provide further evidence for several recommendations in the *Infrastructure Strategy*. However, they also highlight how difficult it may be to restore housing affordability. Some factors that acted as tailwinds for housing supply in the middle of the 20th century have turned into headwinds. It is possible to overcome these challenges, but it will not be possible unless we change our approach to planning and infrastructure provision.

Benchmarking against our past

House prices, population growth, and income growth, 1926-2018

In the long run, demand for housing is driven by fundamentals: how many people need housing, and how much can they pay to get it? Demand for housing has risen through New Zealand's history, as our population grows and as incomes rise.

However, how we respond to increased housing demand has changed over time. In recent years, large increases in house prices – indicating high demand for housing – have coincided with a slower pace of new construction – indicating less responsive housing supply.

In this section, we assess how the New Zealand housing market has responded to increased demand over a nine-decade period. We use data on house prices, incomes, population, and housing stock to examine changes over the 1926 to 2018 period.[1] We find that:

- Housing demand increased more rapidly in the decades after World War II than in recent decades, mainly due to faster population growth
- House prices have increased more rapidly in recent decades than in the middle of the century
- Faster increases in house prices appear to reflect a decline in housing supply responsiveness, rather than stronger demand.

Appendix 1 provides supporting information for this section.

Population, incomes, house prices, and new construction

We compile historical data on the New Zealand housing market from a range of sources, which are described in Appendix 1.[2] This data shows how demand for housing has evolved over time and how the supply and price of housing has responded.

Population growth has slowed, while income growth has continued

Figure 4 shows population growth rates since 1930. All else equal, a larger population will demand more housing – either more homes to accommodate more households, or larger homes to accommodate growing households.

New Zealand's population growth rate peaked in the 1950s and declined in subsequent decades. Population growth rates bottomed out in the 1980s – a decade of significant economic crisis – before increasing in the 1990s. While there is a perception that New Zealand is experiencing unusually high rates of population growth, growth rates remain significantly below what we experienced in the 1940s, 1950s, and 1960s.

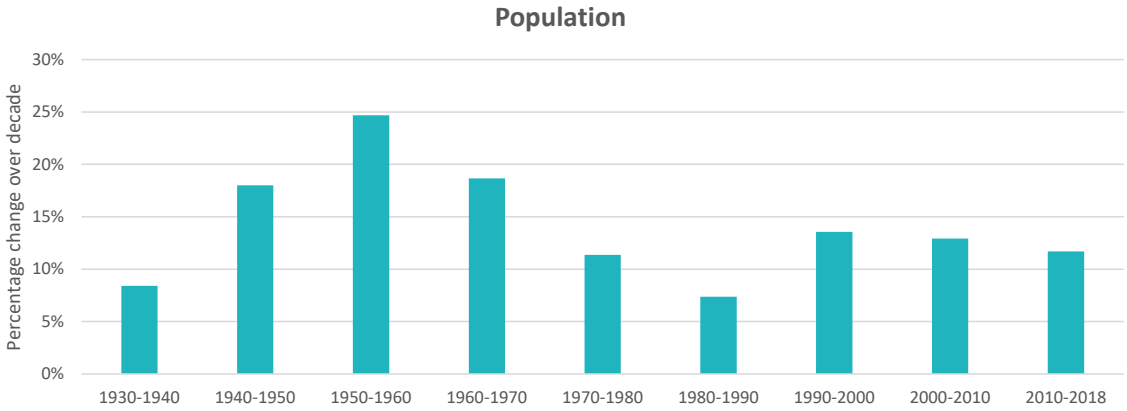
The composition of growth has also changed. Net migrant inflows fluctuate significantly between

[1] Our analysis period ends in 2018 due to data availability. Some datasets are available up to 2018 but not for subsequent years. In particular, our estimates of dwelling stock are based on historical Census data Analysis stops in 2018 because historical data is only available thru this year. The 2018 Census is the last record of number of completed dwellings as opposed to consents. There has been a significant increase in consenting of new homes since 2018, but we do not yet know how many consents have been turned into completed dwellings.

[2] We would particularly like to thank Andrew Coleman for compiling and sharing house price data for the 1926-1986 period. Without this data, this analysis would not have been possible.

years but were similar as a share of population in the post-war decades as in recent decades. But because birth rates have dropped significantly, migration now contributes a larger share of total growth.

Figure 4: Changes in New Zealand population, 1930-2018

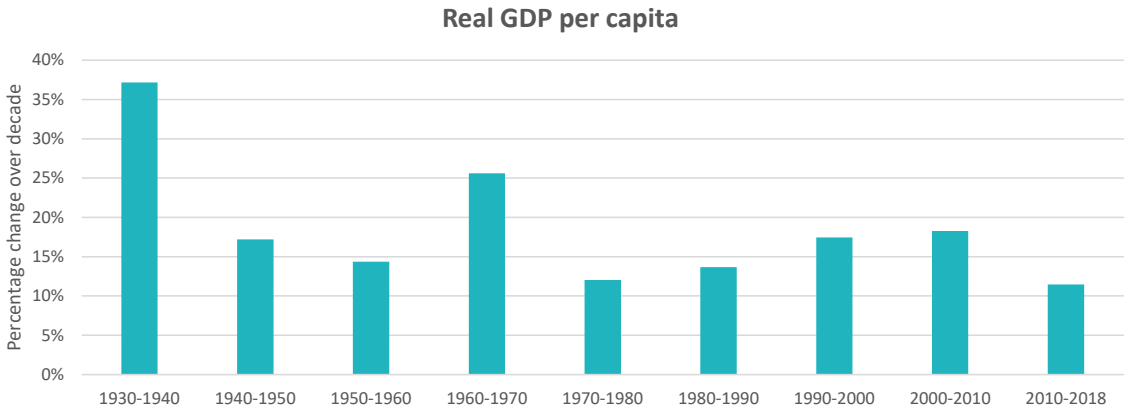


Source: Te Waihanga analysis of data described in Table 4

Figure 5 shows growth in incomes, proxied by real (inflation-adjusted) GDP per capita, since 1930. All else equal, a wealthier population will demand more housing – either larger homes to accommodate increased demand for space, or higher-quality homes located in more desirable places.

Growth in per-capita GDP has been reasonably steady throughout this period. There were periods of faster growth in the 1930s, as New Zealand recovered from the initial shock of the Great Depression, and in the 1960s, as the post-war baby boom began to enter the workforce.

Figure 5: Changes in real GDP per capita, 1930-2018



Source: Te Waihanga analysis of data described in Table 4

Changes to mortgage interest rates are another potential driver of housing demand. When interest rates are lower, people can afford to pay more for housing relative to their income. We could not capture interest rates in our analysis as data is only available from 1964. This is an area where further work would be useful.

Changes in interest rates and lending policies since the 1980s are likely to have contributed to subsequent house price growth (Andrews et al, 2010; Eaqub and Eaqub, 2015). However, credit conditions were also relatively liberal in the immediate post-war decades. Figure 16 in Appendix 1

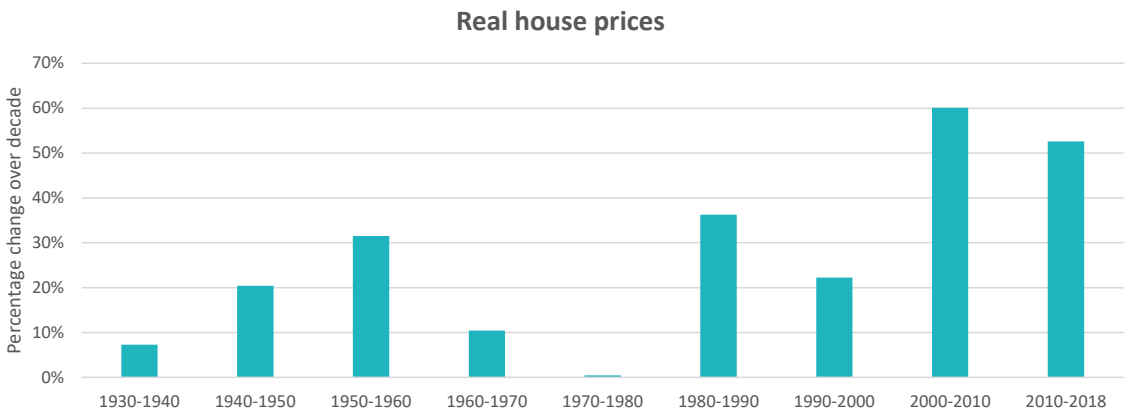
shows that real (inflation-adjusted) mortgage interest rates were significantly lower between 1964 and 1982 than they are today. Post-war governments also adopted various policies to increase credit availability for homebuyers, including government guarantees for low-interest mortgages and the option to capitalise the family benefit into a home deposit.

Housing prices have accelerated, but new construction has declined

Figure 6 shows changes in real (inflation-adjusted) house prices since 1930.[3] House price growth accelerated between the 1930s and 1960s, before slowing in the next two decades. House price growth resumed in the 1980s. Prices grew more rapidly in the 2000s and 2010s than in any previous decade.

The recent acceleration in house prices contrasts with slowing population growth and stable income growth. Real house prices grew twice as rapidly in the 2000s than in the 1950s, even though income growth was similar in both periods and population grew twice as rapidly in the 1950s.

Figure 6: Changes in real house prices, 1930-2018



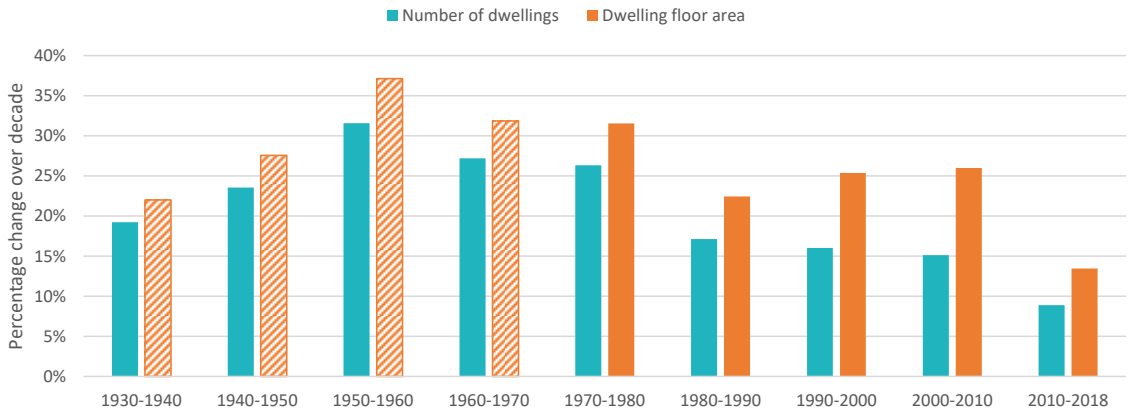
Source: Te Waihanga analysis of data described in Table 4

Figure 7 shows changes in New Zealand's dwelling stock, in terms of number of homes and estimated total residential floor area, since 1930. New Zealand was building at a rapid rate in the post-war decades. The total number of homes increased by one-third in the 1950s and more than one-quarter in the 1960s and 1970s – faster than population growth. The pace of construction has declined since then. Over the 2010-2018 period, the number of homes increased by only 9% - less than growth in population. However, this period does not capture further increases in dwelling consents after 2018.

The average size of new dwellings has increased over this period. Between 1974 and 2018, the average size of new homes increased from 109 square metres to 170 square metres (SNZ, 2020b). Total residential floor area has continued to grow at a faster rate than total number of dwellings. Construction of new residential floor area has not declined as rapidly as construction of new dwellings, but it has still declined relative to the post-war decades.

[3] As set out in Appendix 1, house price growth is estimated using a combination of data sources. House price growth from 1962 to 2018 is adjusted for changes in the quality and size of houses, while house price growth prior to 1962 is not quality-adjusted. Because housing has generally increased in size and quality over this period, this means that we are likely to over-state price growth prior to 1962.

Figure 7: Changes in dwelling stock, 1930-2018



Source: Te Waihanga analysis of data described in Table 4. Changes in dwelling floor area prior to 1974 are estimates rather than actual data.

A simple housing market model

Housing supply seems to have slowed down, but how much has it declined?

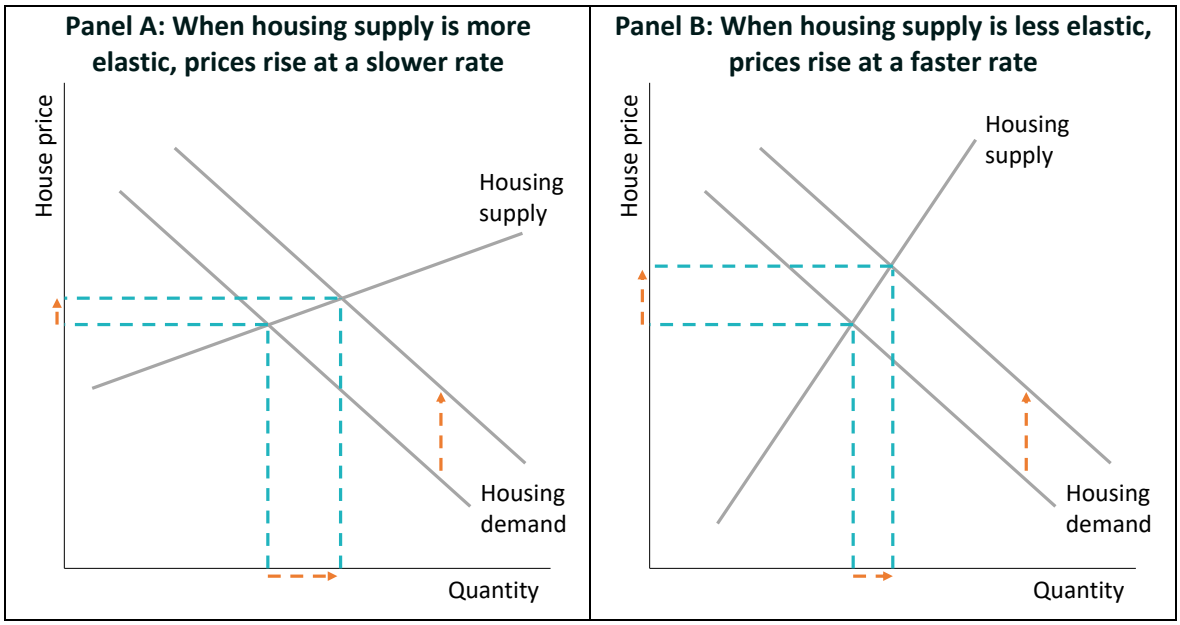
To answer this question, we outline a simple supply and demand model of the New Zealand housing market and estimate this model using historical data. This is an aggregate model of the entire New Zealand housing market, which is useful for identifying long-run changes in housing markets but not necessarily for explaining why changes have occurred.

Figure 8 illustrates the model. At any point in time, housing prices and the total quantity of housing available is set by the interaction of housing demand (the downward-sloping lines) and housing supply (the upward sloping line). Housing demand rises over time due to population growth or rising incomes. When this happens, new housing is supplied, but at an increasing cost because the sites that are easiest to develop tend to get developed first.

Panel A shows that when housing supply is more responsive, or elastic, to price, increases in housing demand result in more new construction and smaller price increases. Panel B shows that when housing demand is less responsive, increases in housing demand result in less new construction and larger price increases.

As a result, measuring how house prices respond to rising housing demand in different time periods allows us to estimate changes to housing supply responsiveness. Appendix 1 lays out our approach for doing so, which is based on Malpezzi and Maclennan's (2001) analysis of long-run changes to housing supply responsiveness in the United States and United Kingdom.

Figure 8: A simple housing supply and demand model



Source: Te Waihanga

Prices now rise more in response to demand

We used historical income, population, and housing data to estimate a simple model of New Zealand housing prices over multi-decade time periods. Our analysis focuses on two four-decade periods:

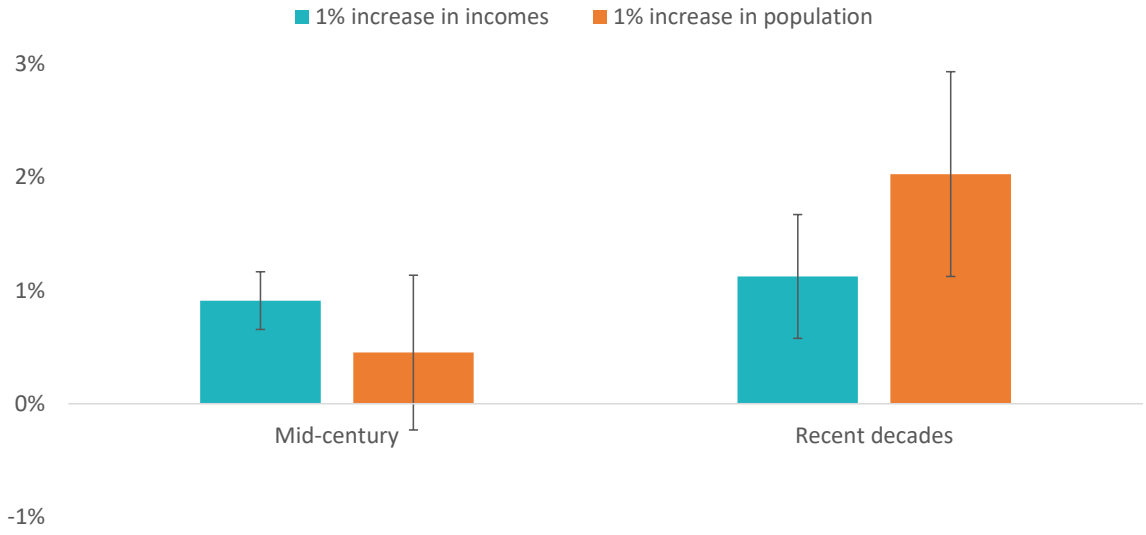
- **Mid-century (1937 to 1977)**: Model results for this period illustrate how the New Zealand housing market functioned in the decades between the Great Depression and the 1970s oil price shocks.
- **Recent decades (1978 to 2018)**: Model results for this period illustrate how the New Zealand housing market has functioned in the decades after the 1970s oil price shocks. This includes the period of economic crisis and reform in the 1980s.

Appendix 1 describes how the model was estimated and how these time periods were chosen and provides full results from model estimation, including results for the full 1926-2018 period. Figure 9 presents our key results. It shows how much house prices increased in response to a 1% increase in either population or incomes in each period. Point estimates imply that:[4]

- Between 1938 and 1977, a 1% rise in incomes led to a roughly 0.9% increase in house prices, while a 1% rise in population lifted prices by roughly 0.5%.
- Between 1979 and 2018, a 1% rise in incomes led to a roughly 1.2% increase in house prices, while a 1% rise in population lifted prices by roughly 2.0%.

[4] These coefficients are not estimated very precisely, as shown by the standard error bars on the chart.

Figure 9: How much do house prices increase in response to a 1% increase in housing demand?



Source: Te Waihanga analysis. Bars indicate estimated model coefficients, and black lines indicate one standard error ranges around estimated coefficients.

We build less than our grandparents

This analysis shows that house prices have grown more rapidly in recent decades not because demand for housing is growing faster, but because housing supply is now less responsive to demand. This causes prices to rise faster in response to a similarly sized increase in demand.

In Appendix 1 (Table 7), we use these results, plus some supplementary assumptions, to estimate housing supply elasticities for each period. Our results suggest that the New Zealand-wide housing supply elasticity has declined by one-quarter to one-third between the mid-century period and recent decades. In other words, when demand for housing increases, we build one-quarter to one-third fewer new homes than our grandparents did. However, the homes we build tend to be larger.

Explaining these patterns

The role of urban planning and the role of urban travel speeds

The previous section shows that house prices now increase more in response to population and income growth than they did during the middle of the 20th century. This suggests that housing supply responsiveness has declined over time. This section analyses the causes of this decline.

A large body of research looks at why housing supply is more responsive in some places and less in others. Lower housing supply has been linked to physical geography that limits development, like hills and harbours, and urban planning systems that make it more difficult to build new housing (Saiz, 2010; Gyourko and Molloy, 2015; Mayo and Sheppard, 1996).

While we have a good understanding of why housing supply differs between locations, there is less evidence on what might cause it to change over time. There is evidence that housing supply responsiveness has changed over time in some places. Some of these changes have been linked to new planning legislation (Malpezzi and Maclennan, 2001), changes to local land use regulation (Ganong and Shoag, 2017; Fischel, 2015), or even changes to transport technology (Knoll, Schularick and Steger, 2017; Brinkman and Lin, 2019).

In this section, we analyse the impact of past changes to urban planning and urban infrastructure performance on New Zealand's urban housing market. To do so, we develop a more sophisticated housing market model, use it to identify factors that are likely to affect how urban housing markets respond to growing demand, and then measure how those things have changed over time. To conclude, we use this model to show that observed changes in urban planning policies and urban travel speeds explain why housing prices have accelerated in recent decades.

Appendices 1 and 2 provide supporting material for this section.

A more sophisticated housing market model

Our analysis in previous section is based on a simple housing market model that treats the entire New Zealand housing market as a single, homogenous entity. To analyse why market dynamics might have changed over time, we need to develop a more sophisticated model that captures the spatial structure of urban housing markets.

We use the Alonso-Muth-Mills (AMM) model to analyse what will happen when cities grow under different conditions. This is a widely used urban economics model that has previously been used for policy analysis in New Zealand and Australia (Kulish, Richards, and Gillitzer, 2012; Lees, 2014, 2015; Parker, 2021). Glaeser (2008) provides a full exploration of this model, including a range of model variants. Our analysis is based on Bertaud and Brueckner's (2005) version of the model.

In the model, people choose where in the city to live to minimise their combined housing and transport costs. In equilibrium, nobody stands to gain from moving to a different location. This means that differences in house prices between locations are proportional to differences in the cost, in time and money, to commute from those locations. Places that are further away from the city centre have higher transport costs and hence lower house prices, lower population density, and lower land prices.[5] Appendix 2 describes this model and its underlying assumptions.

[5] Our version of the model does not account for employment decentralisation or other 'attractors' for housing development, like access to beaches and other natural amenities, that may be dispersed throughout the city. The basic AMM model can be extended to capture these features, but this would require additional work to gather sufficient historical data to allow us to measure their impact over time.

The AMM model does a reasonably good job at explaining urban spatial structure and how cities evolve over time (Glaeser, 2008). It can be used to analyse how different factors, including population and income growth and changes to urban planning and infrastructure, will affect urban house prices and the shape of cities (Brueckner, 2000).

Key factors that drive urban housing markets

We use the AMM model to identify three underlying factors that might cause urban housing markets to be more or less responsive to increased demand.[6] The first factor is physical geography: cities with less land available for housing development, for instance due to hilly terrain, will find it harder to accommodate growth. However, as physical geography does not change over time, it cannot explain why housing supply responsiveness has declined.[7]

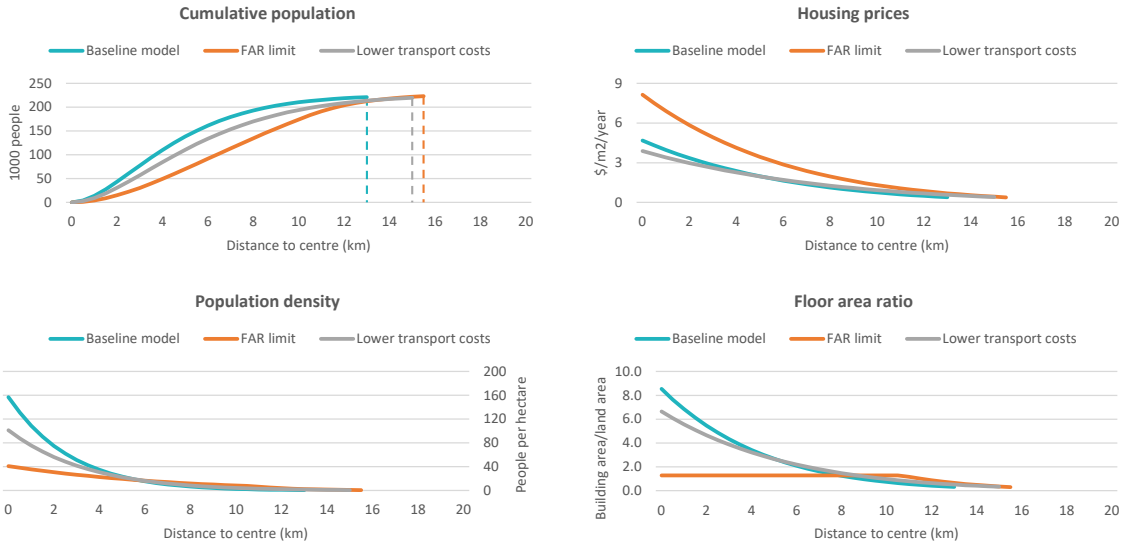
The second factor is changes to urban planning policies that limit development either 'up' in the centre of the city or 'out' at the fringes. The third factor is changes to urban travel speeds that change the number of locations that are available for housing development. These factors can change over time, and as a result may explain why housing supply has changed over time.

Figure 10 uses the AMM model to illustrate how urban planning policies and travel speeds affect urban housing markets. Blue lines indicate outcomes under a baseline model without a floor area ratio (FAR) limit that caps the maximum size and height of buildings, orange lines indicate outcomes with a FAR limit, and grey lines indicate outcomes with lower transport costs.[8]

Imposing a FAR limit and lowering transport costs both result in a more dispersed and lower-density city than the baseline scenario. However, they have opposite impacts on house prices. FAR limits raise house prices throughout the city because they reduce the availability of housing in relatively accessible locations. Lower transport costs make more locations accessible for development, which reduces overall house prices but results in higher prices in outlying areas.

[6] As in the model outlined in the previous section, increased population or increased incomes lead to increased demand for housing within the AMM model.
[7] While the quantity of developable land is fixed, infrastructure can make more of this land available for development by bridging barriers like harbours and hills.
[8] This figure presents the impact of a FAR limit, but other types of housing supply restrictions can also be captured in the AMM model. For instance, Lees (2014) models the impact of an urban growth boundary, while Kulish, Richards and Gillitzer (2012) consider the impact of regulations that raise the cost of development without prohibiting it.

Figure 10: Impact of urban planning restrictions and travel speeds on urban spatial structure



Source: Te Waihanga analysis

The evolution of urban planning in New Zealand

In this section, we briefly review the historical evolution of the legislative framework for planning in New Zealand. We then examine how the legislative framework has been translated into planning rules in cities, using Auckland as a case study. Appendix 3 contains further information on this analysis.

Planning legislation has evolved over the last century

The evolution of urban planning in New Zealand can be broadly grouped into four stages: growth without planning (pre-1926), unsuccessful centrally coordinated planning (1926-1953), local government led planning (1953-1977), and consultation-based planning (1977-today).[9]

During the growth without planning stage (pre-1926), growth occurred with little government control on the spatial form and density of housing, or the separation of residential from other land uses. The unsuccessful centrally coordinated planning stage (1926-1953) attempted to introduce a system where local planning was centrally coordinated, but this system was almost completely unsuccessful. During the local government led planning period (1953-1977), planning was led by local governments under a system with limited consultation and appeal rights.

The consultation-based planning period (1977-today) is characterised by locally led planning processes that are developed in consultation with the community and allow flexibility through discretionary ordinances. The Town and Country Planning Act 1977 introduced a system with more flexibility through discretionary ordinances, greater public participation, and expanded opportunities for appeals.

The Resource Management Act of 1991 (RMA) introduced an effects-based planning regime, where new development must avoid, remedy, or mitigate negative effects. The RMA also mandates extensive public participation and consultation throughout the planning process. This includes a requirement for councils to consult with specific people and groups, the ability of

[9] This typology is based on Productivity Commission (2015a) and Schrader (2016), as well as a review of key features of legislation from 1953 onwards.

people and groups to make submissions on plans and proposed plan changes, be heard at Council meetings, and to appeal planning decisions to the Environment Court (Productivity Commission, 2015b).

Urban planning stopped integrating infrastructure

Table 1 shows how different planning legislation addressed infrastructure planning to support urban development. The Town and Country Planning Act 1953 required local governments to jointly prepare regional plans for coordinating infrastructure improvements and write district schemes that outlined how infrastructure would be upgraded over time. The Town and Country Planning Act 1977 changed the wording a bit but retained the substantive requirements.

The Resource Management Act 1991, by contrast, removed specific requirements for infrastructure planning. Infrastructure was now seen as one of many effects to manage, rather than a foundation for urban development and community wellbeing that must be planned and coordinated in advance.

Table 1: How planning legislation addressed infrastructure planning

Town and Country Planning Act 1953 Regional plans: "co-ordination of all such public improvements, utilities, services, and amenities as are not limited by the boundaries of the district". District schemes: transport networks, sewerage, drainage, and sewage and rubbish disposal, lighting, water
Town and Country Planning Act 1977 Regional plans to outline "regional needs for the provision and protection of" three waters infrastructure, production and distribution of power and fuel, health and educational facilities, transport facilities, and recreational facilities. District schemes: "Provision for the safe, economic, and convenient movement of people and goods"
Resource Management Act 1991 No specific requirements

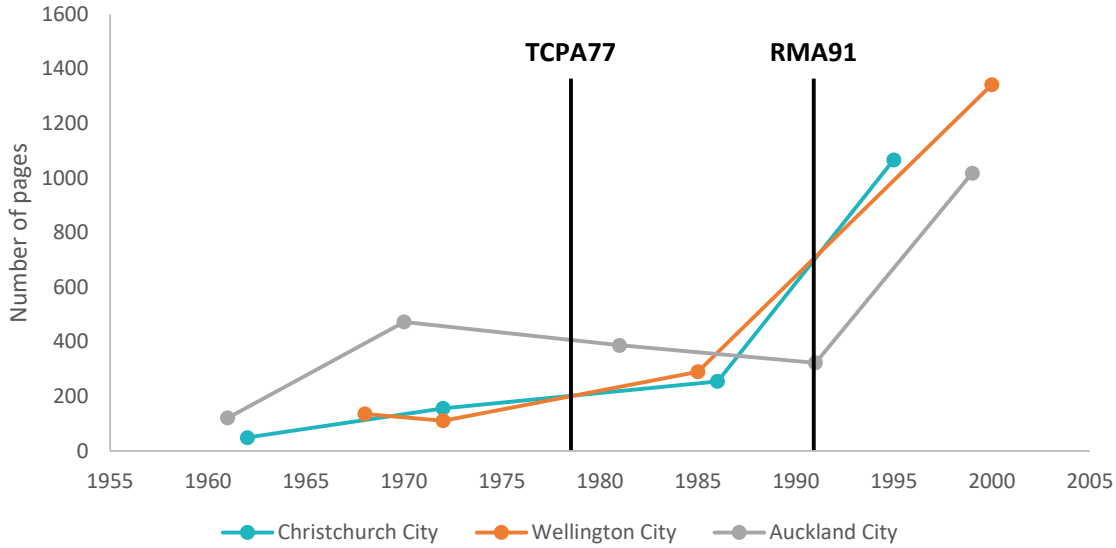
Plans have become more complex over time

We measure the changing complexity of council plans over time based on the length of plans and the number of zones included in the plan.

Length of plan provides an indication of the number of things that are being regulated and the detail in which they are being regulated. Figure 11 shows the length of plans in Auckland, Wellington, and Christchurch between 1960 and 2000. In all three councils, plan length was gradually increasing prior to the introduction of the RMA, followed by a rapid increase in plan length after the RMA. A review of the topics addressed by plans suggests that this is because the RMA enabled councils to regulate for a wider range of outcomes than in the past.[10]

[10] Other policy changes may also have affected plan complexity, such as local government amalgamation in 1989. If new councils chose to carry across predecessor councils' zoning schemes instead of standardising them, this would have increased plan length.

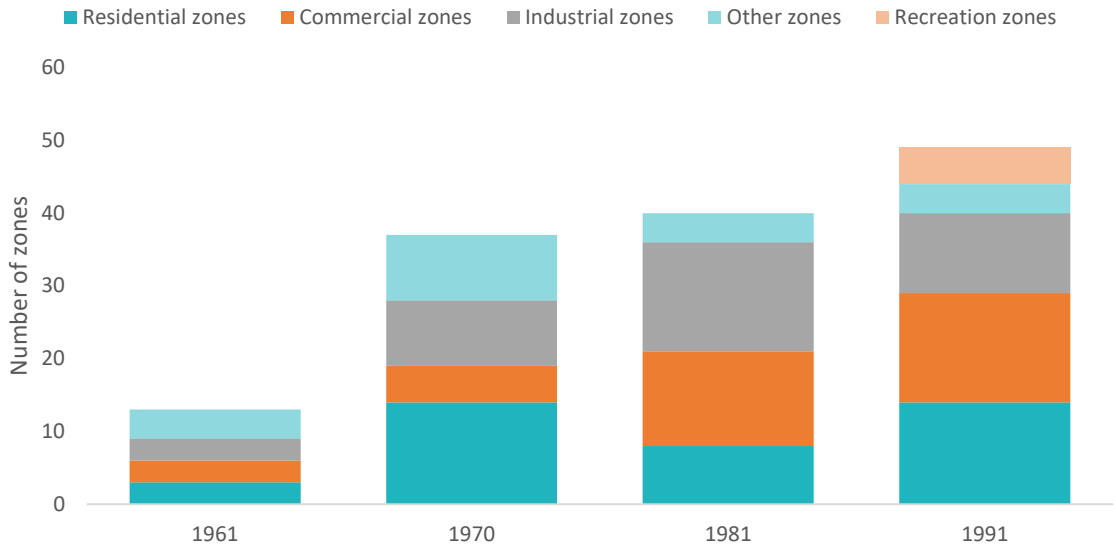
Figure 11: Length of district schemes/plans over time



Source: Te Waihanga analysis of sources described in Appendix 3. Plan length includes annexes but excludes planning maps.

The total number of zones in the plans provides further evidence of increasing plan complexity. While more zones do not necessarily increase the stringency of regulations, it makes plans harder to understand and makes it more difficult for homebuilders to build similar homes in different places. Figure 12 shows the number of zones in four District Schemes in Auckland from 1961 to 1991. The number of zones increased sharply in 1970, with gradual increases in subsequent plans.

Figure 12: Changing complexity of Auckland City Council's zoning schemes over time



Source: Te Waihanga analysis of sources described in Appendix

Plans have become more restrictive over time

Auckland City Council's first District Scheme was operative in 1961. Its stated purpose was "to provide for the future development of the City of Auckland" (Auckland Council, 2018). The 1961 scheme provided capacity for up to 475,000 people, relative to a 1961 population of 141,900.

By 1970, the stated goal of the scheme had shifted to "guiding the efficient, economic and harmonious development" of the city. While accommodating population growth still a goal, this was balanced against preservation of areas at "existing intensity of use because of their pleasant spaciousness, high standard of development, extensive and mature planting, and generally established reputation." The 1970 scheme halved the plan capacity to a maximum population of around 250,000, relative to a 1970 population of 152,200.

Subsequent schemes continued to prioritise preserving existing natural and built environments rather than accommodating growth. The 1981 scheme did not identify accommodation of population growth as a main purpose, and instead identified goals related to "the protection and improvement of the environment", "conservation of features which make a beneficial contribution", and to "maintain the existing housing stock as a resource of considerable value" (Auckland Council, 2018). It stated an intention to provide capacity for 25,000 additional people over the next twenty years, and increased housing capacity by a small amount by increasing opportunities for cross-lease subdivision.

Auckland City Council was amalgamated with eight neighbouring councils in 1989, doubling its total land area.[11] During the 1990s, Auckland changed its district plan to allow apartment development in the city centre and other commercial zones, but did not significantly change capacity in residential zones. In 2010, Auckland City Council was amalgamated with other councils to create a region-wide Auckland Council. Following recommendations from an independent hearing panel, the 2016 Auckland Unitary Plan significantly increased zoning capacity throughout the city, including in residential zones. Planning capacity assessments undertaken between 2006 and 2021 provide data on the additional number of dwellings that can be built in residential and business zones (Auckland Regional Council, 2010; Auckland Council, 2013; Fernandez et al, 2021). We have summarised this data, converted dwelling capacity to population capacity, and compared capacity against current population.

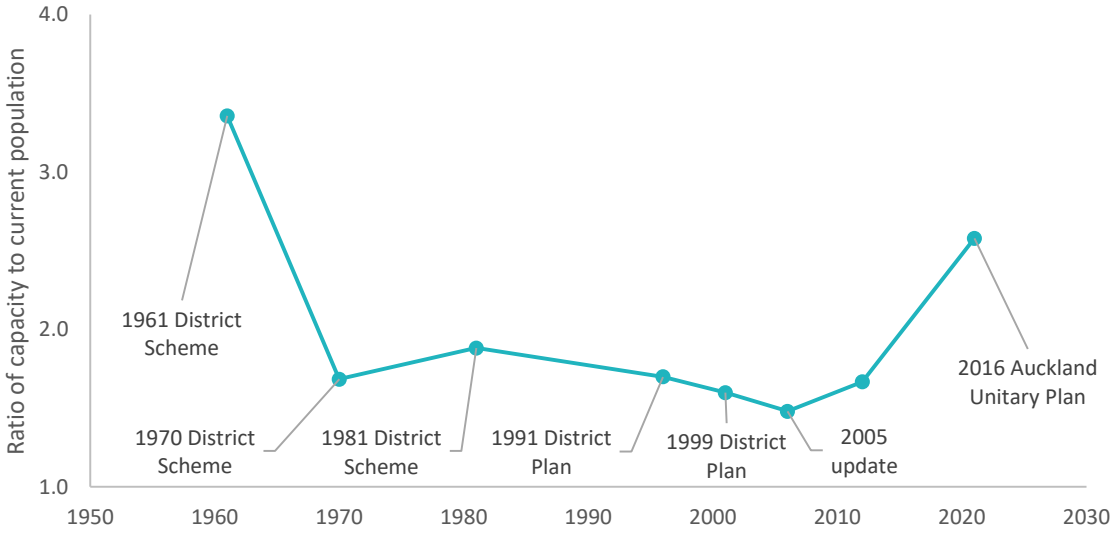
Figure 13 shows the ratio of estimated zoning capacity to current population in the pre-1989 Auckland City Council and its closest successor entities. In 1961, Auckland City had capacity to grow to more than three times its current population.[12] After downzonings in the 1970s and 1980s, it only had capacity to increase its population by 70%.[13] Post-RMA plans increased capacity by permitting apartment development in the city centre but did not reverse downzonings in residential zones. The 2016 Auckland Unitary Plan restored significant housing capacity in residential zones, which would allow central Auckland to grow to up to 2.5 times its current population.

[11] Data from the NZ Official Yearbook suggests that Auckland City Council's pre-amalgamation area was 7472 hectares, while its post-amalgamation area increased to around 14,700 hectares (SNZ, 2021). For a map of pre-1989 councils see McClure (2016).

[12] These calculations of maximum zoning capacity assume that all sites are redeveloped to their full potential. In many cases, density-maximising redevelopment will not be financially viable for developers or desirable for landowners, meaning that the realisable zoning capacity offered by these plans is lower.

[13] Some multi-story apartment buildings were built in suburban areas in the 1960s, 70s, and 80s. The 1970 and 1981 District Schemes set aside a small amount of residential land, mostly along arterial roads, for targeted intensification. We spot-checked several examples, such as the apartment blocks in St Mary's Bay, finding that they were often, but not always, built in these zones.

Figure 13: Room for growth: Ratio of zoning capacity to current population in central Auckland



Source: Te Waihanga analysis of sources described in Appendix. Data for 1961-1981 refers to pre-1989 Auckland City Council (covering roughly half of the Auckland isthmus), data for 1996-2006 refers to the expanded post-1989 council (covering the Auckland isthmus), and data for 2012 and 2021 refers to the Auckland Council local boards most closely corresponding to the pre-2010 Auckland City area. Capacity of pre-1989 plans was estimated based on data in district schemes, while capacity of post-1989 plans was estimated based on data from Auckland Council's 2006 and 2012 Capacity for Growth Studies and its 2021 Housing Assessment.

Tighter limits on housing supply pre-date the RMA

This data shows that council planning practices were largely carried over from pre-RMA plans to post-RMA plans. Starting in the 1970s, council plans were developed locally in consultation with the community. These plans reduced residential development capacity by downzoning residential areas. The 'great downzoning' of the 1970s and 80s was not reversed after the RMA (Hook, 1994). Instead, councils responded to the RMA by writing longer, more complex plans that regulate a wider range of issues while retaining previous restrictions on housing development.

In other countries like the United States and United Kingdom, planning restrictions were becoming more restrictive at around the same time. In the US, land use regulations started to become more restrictive in the 1960s and 1970s, especially in coastal states (Ganong and Shoag, 2017; Hsieh and Moretti, 2019). For instance, New York City reduced its zoning capacity by 79% in 1961 and Los Angeles reduced its capacity by 60% between 1960 and 1980 (Phillips, 2022). Fischel (2015) links increasing restrictions on housing development to legislative changes that made it easier for more parties to object to development. In the UK, strict green belt policies enacted in the 1950s significantly reduced housing supply responsiveness (Malpezzi and Maclennan, 2001; Cheshire and Sheppard, 2002; Barker, 2008). Increasing sensitivity to environmental amenities and rising community opposition to housing development ('NIMBYism') is a common factor behind these changes.

The evolution of urban travel speeds

Urban travel speeds have increased significantly over the last two centuries due to technological changes and infrastructure improvements (Litman, 2022). In 1800, people might travel at a speed of around 5km/h (if walking) or up to 8km/h (if using a horse and carriage). In 1900, they might travel at a speed of around 20km/h (on an electric tram or bicycle) or better than 50km/h (over

longer distances by train). By 1950, people could travel at speeds of up to 100km/h (by car).

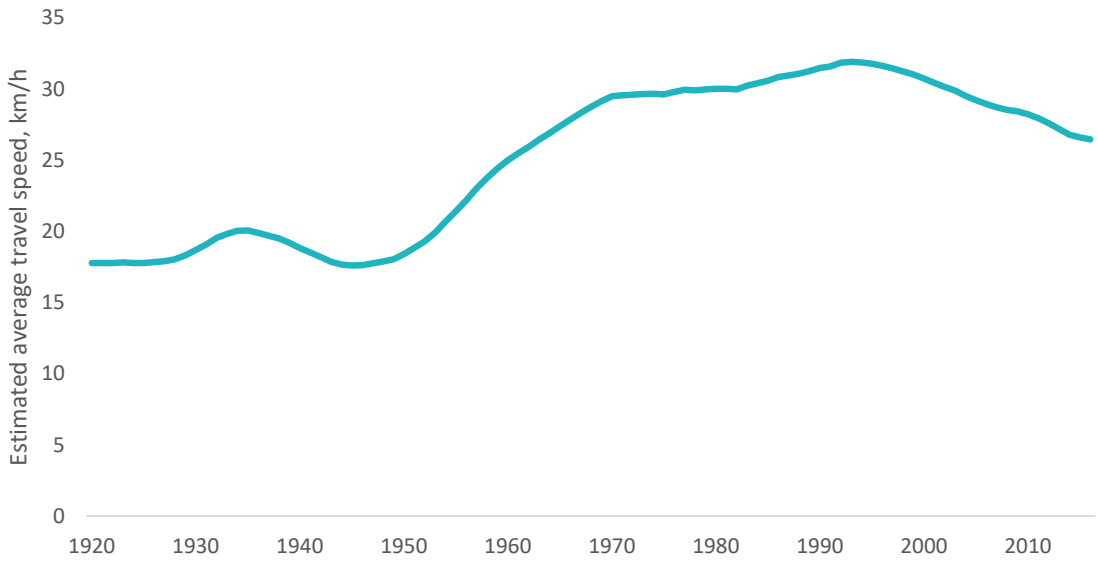
Average urban travel speeds have increased as people adopt new transport technologies. Infrastructure improvements have also bolstered these trends. This has significantly expanded opportunities for housing development (Baum-Snow, 2007; Duranton and Turner, 2012; Garcia-López, 2012; Newman, Kosonen, and Kenworthy, 2016; Gonzalez-Navarro and Turner, 2018). However, in recent decades, rising congestion on urban roads has eroded gains in travel speed, and faster or higher-capacity alternatives have not been delivered.

Figure 14 shows how average travel speeds have changed in Auckland since 1920. The Appendix explains how we compiled these estimates from various historical sources.[14] We find that:

- Average travel speeds increased significantly between 1950 and 1970 as cars became widespread and as roads were improved. The share of urban roads that were sealed, rather than metalled, rose from 20% in 1930 to almost 90% in 1970.
- Improvements in average travel speeds slowed, but did not stop, between 1970 and 1990. This reflects car use reaching saturation levels and more limited opportunities to make fundamental improvements to urban roads.
- Since the early 1990s, average travel speeds have declined due to rising traffic congestion and the lack of high-quality alternatives. Vallyon (2013) finds that travel speeds on nine arterial roads and motorways declined by an average of around 30% between 1986 and 2012 despite significant road widening.

We estimate that rising traffic congestion has eroded around one-third of the gains in average travel speeds experienced since 1950. Current transport modelling suggests that this trend will continue, even with significant investment in transport infrastructure (Minister of Transport, 2021).

Figure 14: Urban travel speeds increased from the 1940s to the early 1990s and then declined



Source: Te Waihanga analysis of sources described in Appendix 3

[14] There is likely to be some error in the estimated level of average speed and short-term fluctuations in speeds, but this analysis captures the timing and direction of key changes. A similar pattern is seen in UK data for the 1970-period (Thunder Said Energy, 2020).

Planning policies and travel speeds explain changes in urban housing markets

We now use the AMM model to analyse how Auckland's urban housing market accommodated growth in different periods. We calibrate the model to Auckland conditions, input observed or estimated changes in city population, incomes, agricultural land prices, planning policies, and travel speeds between the 1930s and 2010s, and simulate impacts on housing prices and urban form.[15] Appendix 2 provides further detail on our modelling assumptions, and also presents charts showing urban spatial structure (Figure 20).

The first column in Table 2 shows model predictions for the 1937-1977 period. During this time, New Zealand's population doubled and Auckland's population more than tripled. Household incomes also increased significantly. Average urban travel speeds rose by 50%, meaning that the cost of commuting fell by roughly one-third.[16] District schemes were comparatively permissive during this period, although they did set limits on housing density and building height. Data from the 1961 District Scheme suggests an average floor area ratio limits of 1.28 in residential zones. On average across all zones, it was possible to build almost 1.3 square metres of floor space per square metre of land.

The AMM model predicts that this will result in house price growth of 96% and an 189% increase in built-up area. This closely replicates the observed (national) house price increase of 113% and observed 230% increase in Auckland's built-up area.

The second column in Table 2 shows model predictions for the 1978-2018 period. During this time, New Zealand's population increased by more than 50% and Auckland's grew by almost 80%. Household incomes continued to increase. Average urban travel speeds declined by 11%, meaning that the cost of commuting rose by around 7%. Downzonings in the early 1970s increased restrictions on housing development. The 1970 District Scheme set an average FAR limit of around 0.8, while the 1981 District Scheme raised the FAR limit to around 0.96 but increased the amount of land required per dwelling. We use an average FAR limit of 0.88 as an estimate of restrictions on development throughout the period. On average across all zones, it was now possible to build only 0.9 square metres of floor space per square metre of land.

The AMM model predicts that this will result in house price growth of 262% and a 22% increase in built-up area. This closely replicates the observed (national) house price increase of 251% and observed 42% increase in Auckland's built-up area.

[15] City population and income levels are treated as fixed, exogenous inputs to the model, and we solve for the housing prices and urban form that this would generate in each period.

[16] This assumes that changes in the overall cost of commuting are (inversely) proportional to changes in travel speeds. Ideally, we would also have accounted for changing financial costs, such as costs of public transport fares, vehicle ownership, and fuel. To a degree, these costs will be proportional to travel speeds – for instance, higher travel speeds mean that the fixed costs of owning a car can be spread over more annual vehicle kilometres. We chose not to adjust financial cost components of travel costs using price index data because price indices adjust for changing quality of transport goods and services over time, and thus may provide a misleading indication of how actual financial costs changed over time (Gordon, 2016).

Table 2: Using the AMM model to analyse historical changes to urban housing markets

Time period	**1937-1977**	**1978-2018**
Scenario	**Baseline model**	**Baseline model**
Scenario assumptions		
Population growth (%)	241%	78%
Household income growth (%)	47%	24%
Floor area ratio limit (#)	1.28	0.88
Change in travel speeds (%)	50%	-11%
Modelled predictions		
House price growth (%)	96%	262%
Change in urban area (%)	189%	22%

Source: Te Waihanga analysis. Scenario assumptions are based on observed or estimated changes over each time period. Auckland population growth was greater than national population growth in both periods. New Zealand's total population grew 98% between 1937 and 1977 and 54% between 1978 and 2018 (NZIER, 2021).

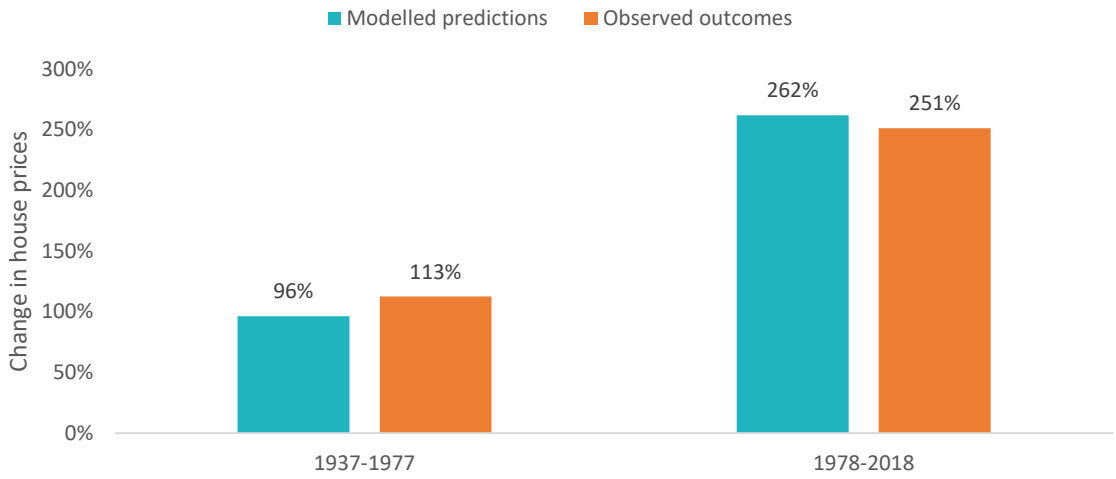
Figure 15 shows how AMM model predictions compare with observed changes in house price growth and urban expansion. As the model omits some important factors, like employment decentralisation, natural amenities like beaches and parks, and the introduction of a binding Metropolitan Urban Limit in the mid-1990s, we would not expect it to perfectly replicate reality. However, even with those omissions, model predictions are close to observed trends.[17]

In short, changes to urban planning policies and urban transport network performance can explain most, if not all, of the acceleration in house prices and decline in housing supply responsiveness in recent decades. While the impacts of changes that started in the 1970s took time to appear, they have added up over time. This highlights the importance of taking a long-term perspective on urban planning and infrastructure policies, rather than judging plans based on immediate impacts.

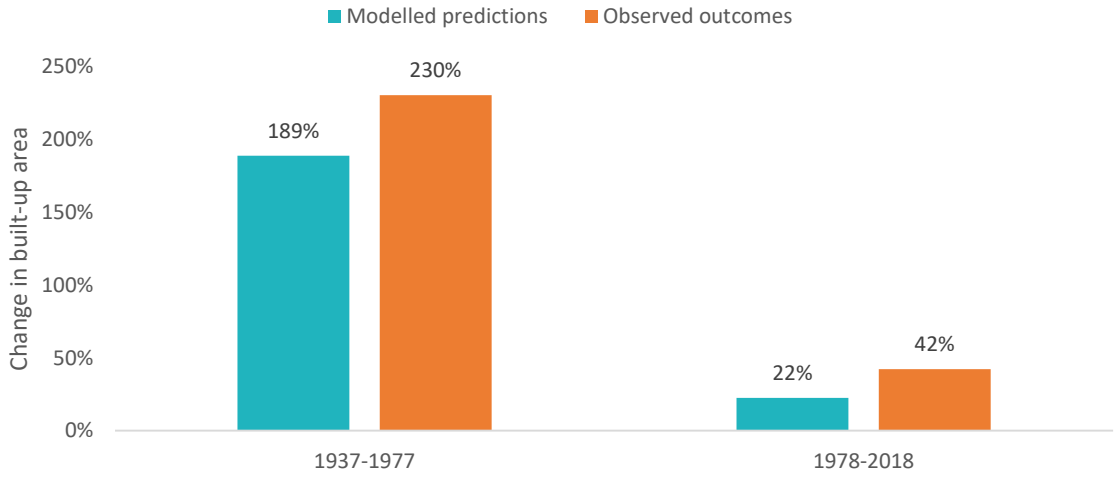
[17] The most significant difference is that the model under-predicts urban expansion somewhat in both time periods. This is likely to be because we have not modelled employment decentralisation, which has increased over the past century, or other attractors for housing development, like access to the coast.

Figure 15: The AMM model predicts changes to house prices and urban expansion

Panel A: Observed vs modelled house price growth



Panel B: Observed vs modelled rates of urban expansion



Source: Te Waihanga analysis. Observed changes to house prices and urban expansion (total built-up area) are estimated using data presented in Figure 6 and Figure 24.

Housing would be more affordable if we made different choices

We use the model to analyse three 'counterfactual' scenarios in which different policies had been adopted. The first counterfactual scenario examines what would have occurred if we had not downzoned central Auckland in the 1970 and 1981 District Schemes. The second examines what would have happened if travel speeds had been maintained at their peak levels, rather than declining in the 1990s and 2000s.[18] The third considers the cumulative effect of avoiding both downzoning and declining travel speeds.

Table 3 compares these counterfactual scenarios against model predictions based on observed data. The first and second scenario both result in predicted house price growth of roughly 150% over the 1979-2018 period. This represents a 40% reduction in price inflation relative to what actually happened. In the first scenario, this is mainly due to increased housing supply in existing suburbs, but in the second, this is mainly due to increased subdivision on the fringe of the city.

[18] This could have been accomplished by a congestion pricing scheme for motorways and arterial roads.

The third scenario results in predicted house price growth of roughly 80% over the 1979-2018 period. This represents a 70% reduction in price inflation relative to what actually happened.[19]

This analysis shows that accelerating house prices were not inevitable – they could have been avoided if we had chosen to adopt different policies. If we had not downzoned central Auckland in the 1970s, or if we had avoided declining urban travel speeds, then urban housing would now be more abundant and house prices would be lower.

Table 3: Using the AMM model to analyse counterfactual scenarios for urban housing markets

Time period	**1978-2018**	**1978-2018**	**1978-2018**	**1978-2018**
Scenario	**Observed data**	**Counterfactual 1: Avoid downzoning**	**Counterfactual 2: Avoid declining travel speeds**	**Counterfactual 3: Avoid both downzoning and declining speeds**
Scenario assumptions				
Population growth (%)	78%	78%	78%	78%
Household income growth (%)	24%	24%	24%	24%
Floor area ratio limit (#)	0.88	1.28	0.88	1.28
Change in travel speeds (%)	-11%	-11%	7%	7%
Modelled predictions				
House price growth (%)	262%	156%	153%	80%
Change in urban area (%)	22%	10%	59%	41%
Modelled reduction in house price growth		**-41%**	**-42%**	**-69%**

Source: Te Waihanga analysis

[19] In this counterfactual world, Auckland housing prices would be roughly half as high as they were in 2018.

Conclusions

In this Research Insights piece, we find that housing supply is less responsive now than in the past. When demand for housing increases, we now build one-quarter to one-third fewer homes than our grandparents did. As a result, house prices have increased more rapidly in recent decades, even though population growth is slower than it was in the decades after World War II.

Observed changes to urban planning policies and urban travel speeds over the last century can explain why house prices have accelerated in recent decades. Between the 1930s and 1970s, planning rules made it easy to build new houses or apartments in existing suburbs and to build new suburbs. Average urban travel speeds were increasing rapidly due to the adoption of a new technology (the car) and improvements to urban roads, which opened up more locations for housing development.

Starting in the 1970s, planning rules became more restrictive. New housing in existing suburbs was curtailed starting in the 1970s, planning rules became more complex, and Auckland enacted a binding Metropolitan Urban Limit in the mid-1990s. Improvements to travel speeds slowed in the 1970s and went into reverse starting in the early 1990s. By the late 2010s, increasing traffic congestion had eroded around one-third of previous gains in travel speeds. Housing development became more difficult within the city and on the edge of the city, leading to accelerating prices.

Our model suggests that reversing the decline in housing supply will require us to take a different approach to urban planning and how we plan and manage urban infrastructure. We conclude by examining some key opportunities to improve.

Write plans that allow cities to grow and change

Te Waihanga's *Infrastructure Strategy* recommends standardising and liberalising urban planning rulebooks. Ideally, plans should make room for a threefold increase in population, as they did in prior to the 'great downzoning' in the 1970s and 1980s.

Recent planning reforms are likely to have a positive impact. Because these fall at or after the end of the 1926-2018 period that we analyse in this Research Insights piece, our analysis does not capture their effect. Key policy changes include:

- The Auckland Unitary Plan (2016), which significantly increased housing development capacity throughout the city. The plan increased the value of redevelopment sites (Greenaway-McGrevy, Pacheco, and Sorensen, 2021) and significantly increased the rate at which new homes were consented (Greenaway-McGrevy and Phillips, 2021).
- Planning responses to the 2011 Canterbury Earthquakes, including enabling additional 'greenfield' housing development and the new Christchurch District Plan (2017).
- The 2020 National Policy Statement on Urban Development (NPS-UD), which directed councils to increase building height limits near rapid transit stations, prohibited minimum parking requirements, and facilitated private plan changes for greenfield development (PwC, 2020).
- The 2021 Medium Density Residential Standards (MDRS), which require councils to allow three-story buildings with up to three dwellings on all urban residential sites (PwC and Sense Partners, 2021).

Modelling suggests that the NPS-UD and MDRS will increase housing supply responsiveness. There is a need to monitor these changes to ensure that they are effective.

Restore the link between planning and infrastructure

Our analysis suggests that changes to urban planning rules will only solve half of the problem with housing supply. To solve the over half of the problem, we also need to improve provision of urban infrastructure to unlock more opportunities for housing development.

Te Waihanga's *Infrastructure Strategy* includes some specific recommendations about how to improve the performance of urban infrastructure. The most important change we can make is to restore the link between urban planning and infrastructure provision. Prior to the Resource Management Act, our planning legislation directed councils to write plans that accommodated expected population growth and signalled how infrastructure would be provided to support growth. Without this statutory link, urban growth has often been uncoordinated with infrastructure provision.

Regional spatial planning could help to fix that problem, but this will only work if funding plans and council zoning rulebooks are brought into line with regional spatial plans.

Make different choices to lift urban accessibility

Travel speeds improved rapidly between the early 1800s and 1970s due to a series of transformative technological improvements that we cannot easily replicate (Gordon, 2016). New infrastructure, such as railways and paved roads, was needed to enable the use of new technologies, but once those technologies were in widespread use, further improvements to infrastructure have smaller impacts.

The challenge we now face is that we cannot re-invent the automobile, and everybody who wants to drive is already driving. In Auckland, a large share of the initial gains in average travel speeds have been consumed by rising congestion even though we have increased road capacity. This is expected to continue: modelling for the 2021-2031 Auckland Transport Alignment Project, which proposes to spend $31 billion on transport infrastructure, suggests that congestion delays will increase by 10% over this time (Minister of Transport, 2021).

Te Waihanga's *Infrastructure Strategy* identifies two opportunities to turn around the decline in urban travel speeds: Congestion pricing and faster deployment of new transport options.

Congestion pricing offers an opportunity to reverse recent declines in average travel speeds and prevent travel speeds from slowing in the future (Ministry of Transport, 2020). Cities like Singapore and Stockholm have successfully used this approach to alleviate excess congestion and then maintain traffic speeds at a stable level. Congestion pricing offers one-off benefits for travel speeds, but if we want to deliver ongoing improvements, we also need to improve infrastructure and enable widespread adoption of new transport options.

Cost-effective and timely infrastructure delivery is therefore essential for lifting urban mobility. In our December 2021 *Research Insights* piece, we found that New Zealand is less efficient at delivering quality infrastructure than most other high-income countries. Our spending measures up, but infrastructure performance does not. If we can address this problem, it will also have benefits for housing supply.

Provide different infrastructure to serve changing cities

Urban housing markets will continue to change, and we may need different infrastructure to

facilitate those changes. Carrying on with a 'business as usual' approach can limit housing supply.

For instance, our analysis shows that changes in urban travel speeds between the 1970s and 2010s increased demand for housing in inner suburbs that were less affected by rising congestion. Recent changes to urban planning facilitate ongoing intensification in these areas. However, water, wastewater, and stormwater infrastructure in these areas is often near its capacity or in need of repair and renewal. Te Waihanga's *Infrastructure Strategy* identifies a need to change how water networks are managed, priced, and expanded to ensure that housing supply is not constrained.

An emerging issue is the impact of adoption of work from home following the Covid-19 pandemic. Working from home, either part-time or full-time, can significantly reduce commuting costs.[20] While remote working is not an option for everybody, we would expect it to increase the attractiveness of locating further away from existing employment centres, especially in areas that offer good natural and urban amenities. Infrastructure Victoria's (2021) analysis suggests that this will affect when and where infrastructure is demanded. For instance, it may increase demand for community facilities in residential areas with high rates of working from home and shift transport demands away from peak commuting times. It is necessary to monitor these trends and ensure that the right infrastructure is provided to serve changing urban housing demand.

[20] For instance, somebody who works from home one day a week will spend 20% less time commuting as a result.

Appendix 1: Estimating long-run housing market models

This appendix provides supporting information for the section entitled 'Benchmarking against our past'. It contains the following information:

- An overview of the data we used for long-run analysis of the New Zealand housing market
- An outline of the simple housing market model we used for this analysis
- Econometric model diagnostics that informed our empirical strategy
- Results from econometric estimation of the simple housing market model
- Some additional robustness checks.

Overview of data

We compiled annual data on housing prices, population size, GDP per capita, and dwelling stock for the 1926-2018 period. Housing prices and GDP per capita were deflated using the consumer price index.

The following table summarises the data sources used in this analysis. All data was available for the period from 1926 to 2018.

Table 4: Sources for analysis of New Zealand housing market trends

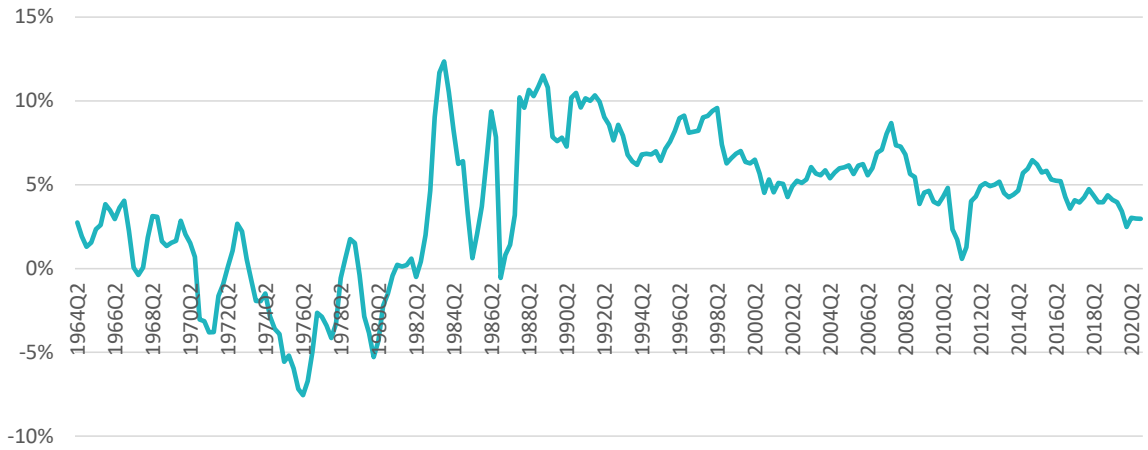
Variable	Sources
House prices	Andrew Coleman kindly provided quarterly data on average house prices for the 1923-1986 period. This data was compiled from multiple sources, including the NZ Official Yearbook (SNZ, 2021). RBNZ's house price index provides quarterly data on quality-adjusted house prices for the 1962-2020 period (RBNZ, 2021a). Data for 1962-1989 is a house price index for detached dwellings, while data for 1990-2020 is a house price index for all dwellings. Data from Coleman is used for the 1926-1962 period, while data from RBNZ is used from 1962 onwards. Quarterly data was averaged to obtain an annual house price index. Coleman's data does not match perfectly with the HPI for the years 1962-1986 where both data series overlap.
Population size	NZIER's (2021) *Data1850* project provides annual data on total population for the 1840-2018 period. This is in turn based on SNZ data for recent decades and NZ Official Yearbook data for earlier years.
Working age (15-64) population	SNZ's (2020c) *Long Term Datasets* provides data on population age structure for Census years between 1926 and 1991, while SNZ's *Infoshare* provides annual estimates of population age structure for the 1991-2018 period. We interpolated data for inter-Census years using changes in total population from NZIER (2021)
GDP per capita	NZIER's (2021) *Data1850* project provides annual estimates of nominal and real per capita GDP for the 1859-2018 period. This data is based on a range of sources.
Dwelling stock	Dwelling stock data is derived from a variety of sources. Data from SNZ's (2021) *Official Yearbooks* and recent Censuses is used to measure dwelling stock for all Census years between 1916 and 2018. The timing of changes in

	dwelling stock between Census years are estimated using dwelling consent data from SNZ's (2021) *Official Yearbooks* (available 1922-2001) and SNZ's (2020b) dwelling consent data (available 1966-2020).
Dwelling size	SNZ's (2020b) dwelling consent data is used to measure the average size of new residential dwellings consented between 1974 and 2020. To obtain rough estimates for earlier years, we assume, based on other historical information, that average dwelling size was around 85m2 in 1926 and that the average size of new dwellings increased smoothly after this point. We then applied these estimates of new dwelling size to changes in dwelling stock to estimate the total quantity of residential floor area added in each period.
Consumer price inflation	SNZ's *Infoshare* provides consumer price index data for the 1914-2020 period. This was used to convert the nominal house price index and nominal real GDP per capita to real prices.

Changes in mortgage interest rates are another factor that might affect house prices. We were not able to include mortgage interest rates in the model as data is not available for the full period. RBNZ (2021b) publishes data on floating first mortgage rates from 1964 onwards. We used this data, along with observed consumer price inflation data from SNZ, to calculate quarterly real mortgage interest rates for the 1964-2020 period.[21] Figure 16 shows that real interest rates gradually declined between 1990 and 2020, which is likely to have added to rising house prices.

However, real interest rates were significantly lower between 1964 and 1982 than they are today, as increases to interest rates lagged behind rising inflation. Combined with the impact of other post-war policies to increase credit availability for homebuyers, like government guarantees for low-interest mortgages and the option to capitalise the family benefit into a home deposit, it is possible that mortgage availability had a larger positive impact on house prices in the mid-century period than in recent decades. This is an area where further research would be desirable.

Figure 16: Real interest rates for first home buyers, 1964-2020



Source: Calculated from RBNZ series B1 and SNZ CPI data

Overview of simple model of housing market

We follow Malpezzi and Maclennan (2001) and describe the aggregate housing market using a simple system of equations (Equation 1). The quantity of housing demanded (Q_D) is assumed to

[21] Ideally, real interest rates should be calculated with reference to inflation expectations. As inflation expectations data was not available for a long time period, we use observed inflation as a proxy.

increase in response to rising real incomes (Y) and growth in population (N) and decrease if real house prices (P) are higher. Conversely, the quantity of housing supplied (Q_S) will increase in response to higher real house prices (P).[22] All variables are stated in natural logarithms, allowing us to interpret coefficients as elasticities. In the housing demand function, the coefficients α_1, α_2, and α_3 are elasticities of housing demand with respect to price, income, and population size, respectively, and α_0 is a constant. In the housing supply function, the coefficient β_1 is the elasticity of housing supply with respect to price and β_0 is a constant.

Equation 1: A simple housing supply and demand model

$$\text{Housing demand function: } Q_D = \alpha_0 + \alpha_1 P + \alpha_2 Y + \alpha_3 N$$
$$\text{Housing supply function: } Q_S = \beta_0 + \beta_1 P$$
$$\text{Market equilibrium: } Q_D = Q_S$$

We set quantity demanded equal to quantity supplied and rearrange these equations to obtain a reduced form model of house prices that can be estimated using the historical data (Equation 2).[23]

Equation 2: Reduced form model for house prices

$$P = \gamma_0 + \gamma_1 Y + \gamma_2 N$$

By estimating this model, we can understand the house price impact of income growth (γ_1) or population growth (γ_2) in different time periods.

We can then convert these estimates into estimates of the overall responsiveness of housing supply in different periods. Equation 3 shows how housing supply elasticity (β_1) can be estimated using the empirical estimate of the elasticity of house prices with respect to incomes (γ_1) and outside estimates of the elasticities of housing demand with respect to price (α_1) and income (α_2).

Equation 3: Estimating housing supply elasticity from reduced-form coefficients

$$\beta_1 = \frac{\alpha_2}{\gamma_1} + \alpha_1$$

Econometric model diagnostics

Econometric models estimated using time series data may be spurious if the time series properties of the data are not considered. If model variables exhibit unit root ('random walk') behaviour and model variables are not cointegrated (ie residuals do not exhibit unit root behaviour), then regressions are likely to be spurious. In this situation, it is advisable to estimate models in first differences.

We therefore implemented the following steps for each regression we estimated:

- First, we tested all model variables (log real house price, log population, and log real GDP per capita) for unit roots using the Augmented Dickey Fuller (ADF) test with a time trend

[22] This model is simple but can be extended to account for other features of housing market. This appendix reports a robustness check that uses working-age population rather than total population, and also presents a variant of this model that allows for new housing construction to lag increases in housing demand, reflecting the fact that homebuilders may not be able to immediately scale up construction.

[23] These coefficients can be expressed as a function of housing demand and supply function coefficients: $\gamma_0 = (\alpha_0 - \beta_0)/(\beta_1 - \alpha_1); \gamma_1 = \alpha_2/(\beta_1 - \alpha_1); \gamma_2 = \alpha_3/(\beta_1 - \alpha_1)$.

and lag selection using Akaike's Information Criterion (AIC).

- Second, if some or all variables exhibited a unit root, we tested for cointegration using the Johansen test.
- Third, if variables did not exhibit unit roots or if variables were cointegrated, we estimated a model with variables in levels using ordinary least squares (OLS) regression. We estimated Newey-West standard errors to allow for heteroskedasticity and autocorrelation in residuals.
- Fourth, if we tested first-differenced model variables for unit roots using the ADF test without a trend and lag selection using AIC.
- Fifth, if some or all first-differenced variables exhibited a unit root, we tested first-differenced model variables for cointegration using the Johansen test.
- Sixth, if first-differenced variables did not exhibit unit roots or if they were cointegrated, we estimated a model in first differences using OLS with Newey-West standard errors.

We implemented these steps for:

- The full dataset (annual observations, 1926 to 2018)
- Rolling 40-year windows (eg 1927-1966, 1928-1967, etc). This results in a total of 51 sets of test stats and (for non-spurious regressions) regression model outputs.[24]

The following table summarises the results of unit root and cointegration testing. Statistical significance of tests is reported at the 5% level. Results of cointegration testing suggest that it is possible to estimate the model in first differences for the whole time period and for 18 out of 51 40-year windows.

Table 5: Results for diagnostic testing of alternative time periods (5% statistical significance level)

Test	Whole period (1927-2018)	40-year windows (n=53)
Variables in levels		
ADF with trend: Log real house price	Reject unit root	Reject unit root in 39 cases (74%)
ADF with trend: Log population	Fail to reject unit root	Reject unit root in 0 cases (0%)
ADF with trend: Log real GDP per capita	Fail to reject unit root	Reject unit root in 2 cases (4%)
Johansen test of cointegration of level variables	Fail to reject no cointegration	Reject no cointegrating relationship in 3 cases (6%)
First-differenced variables		
ADF, no trend: First difference of log real house price	Reject unit root	Reject unit root in 53 cases (100%)
ADF, no trend: First difference of log population	Fail to reject unit root	Reject unit root in 2 cases (4%)
ADF, no trend: First difference of log real GDP per capita	Reject unit root	Reject unit root in 53 cases (100%)
Johansen test of cointegration of first-differenced variables	Reject no cointegration	Reject no cointegrating relationship in 20 cases (38%)

Figure 17 reports ADF test statistics for first-differenced variables. The horizontal black line shows the 5% critical value for this test, and the coloured lines show test statistics for different model variables over different 40-year windows. Values above the horizontal black line indicate rejection of the null hypothesis of a unit root. This shows that house price growth and GDP per capita

[24] We also tested alternative windows (30 years, 50 years, etc) with the same basic results.

growth do not exhibit unit root behaviour, but that population growth does exhibit a unit root.

Figure 17: ADF test statistics for first-differenced variables over varying 40-year windows

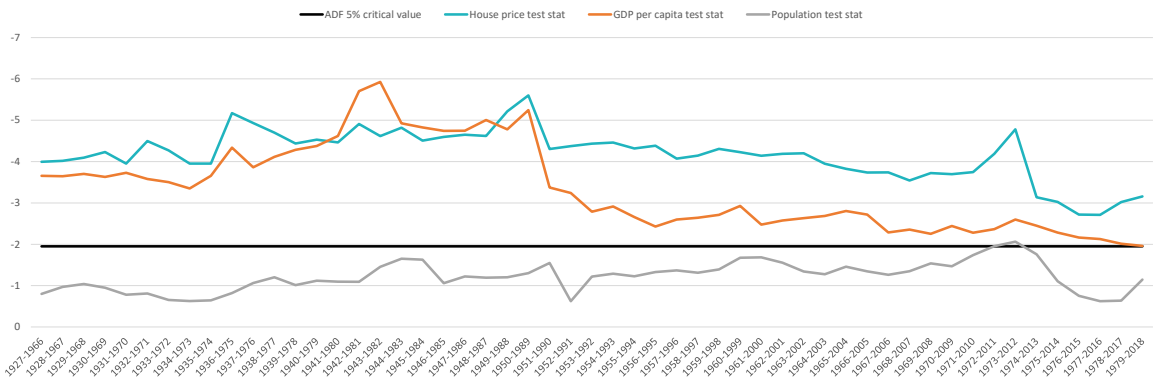
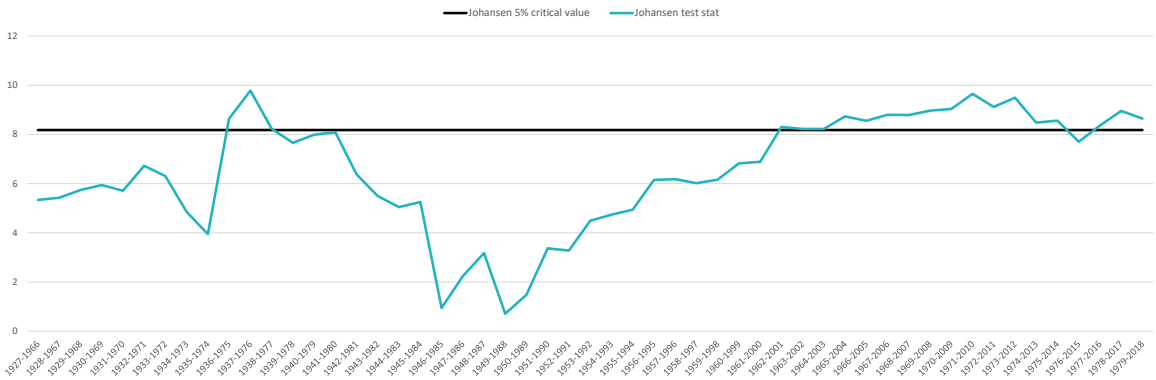


Figure 18 reports Johansen cointegration test statistics for first-differenced variables. The horizontal black line shows the 5% critical value for this test, while the coloured line shows test statistics for different 40-year windows. Values above the horizontal black line indicate rejection of the null hypothesis of no cointegration. Johansen test statistics are close to or above the critical value for 40-year windows between the mid-1930s and mid 1970s and for 40-year windows between the 1960s and 2010s.

The absence of a cointegrating relationship for 40-year windows between the 1940s and 1990s suggests that the 'typical' long-term relationships between house prices, incomes, and population growth broke down at some point during this time. As New Zealand suffered a series of economic crises during the 1970s and 1980s, this is unsurprising. Qualitatively, we would interpret this as evidence for the idea that there was a structural change in how New Zealand's housing market functioned sometime between the mid-century period and the 1990s.

Figure 18: Johansen test statistics for first-differenced variables over varying 40-year windows



Results from analysis

We estimate the reduced form equation for house prices (Equation 2) the full 1926-2018 period and for 40-year windows within this period. Because diagnostic testing suggests that some variables have unit roots but that the model variables are not cointegrated, we estimate the reduced form model in first differences (Equation 4).

Equation 4: Econometric model of house prices (reduced-form model)

$$\Delta P_t = \gamma_1 \Delta Y_t + \gamma_2 \Delta N_t + \varepsilon_t$$

Where ΔP_t is the change in the natural log of real house prices in year t; ΔY_t is the change in log real GDP in year t; ΔD_t is the change in log population in year t; and ε_t is an error term. We use Newey-West standard errors for inference to address the potential for heteroskedasticity and/or autocorrelation in residuals.

The following table summarises outputs from econometric analysis of the reduced-form model. Column (1) shows results for the full sample; (2) shows results for the mid-century period, and (3) shows results for recent decades. Consistent with the descriptive analysis above, we find that house prices rose more in response to increased demand in recent decades. Elasticities of house prices with respect to incomes and population appear to have risen in recent decades (eg from 0.452 to 2.027 for the impact of population), although the large standard errors (reported in parentheses below coefficient estimates) make it difficult to be certain about this.

Table 6: Outputs from econometric analysis of reduced-form model

Period	**Full sample**	**Mid-century**	**Recent decades**
Years	**1927-2018**	**1938-1977**	**1979-2018**
Dependent variable	ΔP_t	ΔP_t	ΔP_t
Explanatory variables			
ΔY_t	0.992*** (0.126)	0.910*** (0.255)	1.125** (0.547)
ΔN_t	0.777 (0.566)	0.452 (0.683)	2.027** (0.904)
Observations	92	40	40
R^2	0.314	0.258	0.425

*Notes: ΔP_t = change in average house price; ΔY_t = change in GDP per capita; ΔN_t = change in population; Statistical significance indicators *p<0.1; **p<0.05; ***p<0.01*

Estimated housing supply elasticities

We use results from Table 6 to estimate housing supply elasticities for all three periods. Following Equation 3, we can estimate the housing supply elasticity using the estimated elasticity of house prices with respect to income and outside estimates of price and income elasticities of housing demand.

Estimates of price and income elasticities of housing demand vary. Malpezzi and Maclennan (2001) suggest that the price elasticity of housing demand (α_1) falls in the range of -0.1 to -0.5, while the income elasticity of housing demand (α_2) falls in the range of 0.5 to 1.0. In New Zealand, NZTC and NZIER (2005) estimate a price elasticity of around -0.4 and an income elasticity of around 1.4, while Hyslop et al (2019) estimate a price elasticity of around -0.3. Internationally, Ermisch, Findlay, and Gibb (1996) estimate a price elasticity of around -0.4 and an income elasticity of around 0.5 for Britain, Zabel (2004) estimates values of around -0.1 and 0.4 for the US, and Fontenla and Gonzales (2009) obtain estimates of around -0.3 and 0.8 for Mexico.[25]

Table 7 summarises estimated housing supply elasticities for each period, based on alternative assumptions about price and income elasticities of housing demand. Under most assumptions, we estimate that housing supply elasticities have declined by roughly one-quarter to one-third between the mid-century period and recent decades.

[25] These papers used various data and methods to estimate demand elasticities. Some methods may result in estimates that are problematic to use for these purposes, eg due to the fact that they are estimating a different reduced form of the same demand system. We have dealt with this by sensitivity testing a range of estimates.

Table 7: Estimated housing supply elasticities

Time period		Full sample (1926-2016)	Mid-century (1938-1977)	Recent decades (1979-2018)	Percentage reduction in supply elasticity
Elasticity of house prices with respect to income (ΔY_t coefficient)		0.990	1.09	1.332	
Price elasticity of housing demand	Income elasticity of housing demand				
-0.35	1.4	1.06	1.19	0.89	-25%
-0.5	1	0.51	0.60	0.39	-35%
-0.1	0.5	0.40	0.45	0.34	-23%
-0.4	0.5	0.10	0.15	0.04	-70%
-0.1	0.4	0.30	0.34	0.26	-25%
-0.3	0.8	0.51	0.58	0.41	-29%

Note: Price and income elasticities of demand are sourced as follows: Top row is NZ values from NZTC and NZIER (2005) and Hyslop et al (2019); second and third rows are the upper and lower end of the range reported in Malpezzi and Maclennan (2001); and fourth, fifth, and sixth rows are values for Britain, US, and Mexico, respectively.

Robustness tests

We conduct two simple robustness checks on our results. First, we estimate a variant of the model using working-age (15-64) population (ΔW_t) rather than total population. This model focuses on population growth in the demographic that is most likely to be forming households and consuming new housing. Due to the post-war baby boom, working-age population was growing more slowly than total population during the 1940s and 1950s but more rapidly over the next three decades. Working age population and total population have grown at similar rates since the 1990s.

Second, we estimate a 'stock adjustment' model of the housing market as a variant of the base model. This model, which is outlined in Malpezzi and Maclennan (2001), includes lagged growth in dwelling stock (ΔD_{t-1}) from the previous year in the model to adjust for the fact that housing supply may respond to growth in demand with a lag. All else equal, faster increases dwelling stock are expected to have a downward impact on house price growth in subsequent years.

Unit root and cointegration test results are similar to the baseline model. Model variables exhibit unit root behaviour in some or all time periods, but we reject the null hypothesis of no cointegration for the full time period and for some, but not all, 40-year windows. Figure 19 shows Johansen cointegration test statistics for the baseline model and the two alternative models.

We also investigated a model variant that broke down population changes by component (migration and natural increase). We failed to reject the null hypothesis of no cointegration for any time periods, meaning that this model variant could not be estimated. This would be a useful area for further work, potentially using a different model specification.

Figure 19: Johansen test statistics for alternative model specifications over 40-year windows

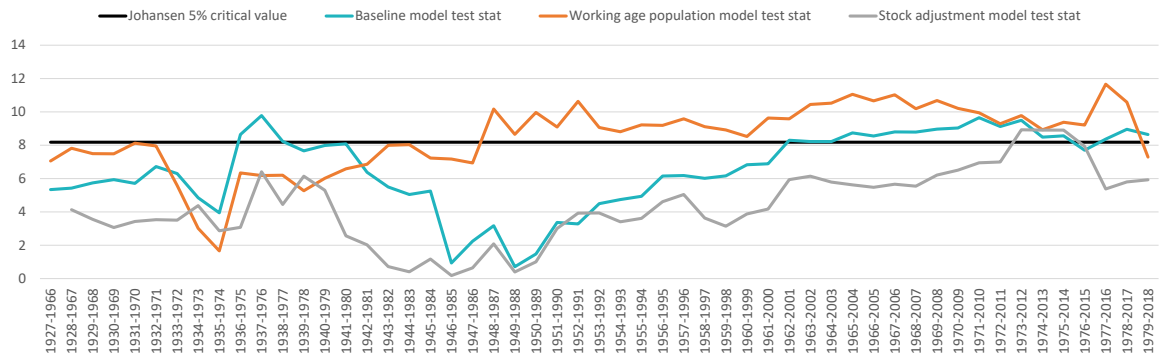


Table 8 reports results from alternative model specifications for the full sample and for selected 40-year windows where we can reject the null hypothesis of no cointegration at the 5% significance level. The first three columns in the table show that the impact of working age population growth on house prices was considerably larger in recent decades than during the mid-century period. This is similar to the pattern we observe for the impact of total population. However, the impact of GDP per capita growth appears to decline slightly in later decades, rather than rise. This is likely to be because working age population is confounded with GDP per capita.

The last two columns show that both population growth and GDP per capita growth have had a larger impact on house prices in recent decades than in the full sample. In addition, changes in dwelling stock have had a larger downward impact on prices in recent decades than in the full sample. Consistent with the baseline model, these results suggest that the New Zealand housing market has grown less responsive to increased demand, especially from population growth, in recent decades.

Table 8: Model robustness checks

Model	**Working age population**			**Stock adjustment**	
Period	**Full sample**	**Mid-century**	**Recent decades**	**Full sample**	**Recent decades**
Years	**1927-2018**	**1948-1987**	**1978-2017**	**1928-2018**	**1975-2014**
Dependent variable	ΔP_t	ΔP_t	ΔP_t	ΔP_t	ΔP_t
Explanatory variables					
ΔY_t	0.992*** (0.135)	1.008*** (0.369)	0.977* (0.495)	1.035*** (0.140)	1.423*** (0.429)
ΔN_t				1.848* (1.039)	3.703*** (1.301)
ΔW_t	0.831 (0.548)	0.875 (0.735)	2.275*** (0.746)		
ΔD_{t-1}				-0.933 (0.612)	-2.504*** (0.676)
Observations	92	40	40	91	40
R2	0.316	0.289	0.475	0.337	0.444

*Notes: ΔP_t = change in average house price; ΔY_t = change in GDP per capita; ΔN_t = change in population; ΔW_t = change in working age population; ΔD_{t-1} = lagged change in dwelling stock; Statistical significance indicators *p<0.1; **p<0.05; ***p<0.01*

Appendix 2: The Alonso-Muth-Mills model of urban spatial structure

This section provides supporting material for the section entitled 'Explaining these patterns'. It outlines the Alonso-Muth-Mills model of urban spatial structure and explains how we used it to analyse the impacts of changing planning restrictions and urban travel speeds on urban house prices and built-up area. Our implementation of this model is based on Bertaud and Brueckner (2005) and Kulish, Richards, and Gillitzer (2012).

We use this model to simulate the impacts of exogenous changes in city population, from a combination of natural increase and migration, income levels, and other changes that may affect urban housing markets.

Model setup

In the model, a city is inhabited by N identical residents, all of whom earn income y from working in the city centre. City residents commute from residential locations, paying a cost of t per round-trip kilometre travelled.[26] t includes both the time and money costs of travelling.[27] A resident who lives x kilometres away from the city centre would therefore have disposable income of y-t*x.

Residents choose where to live and how much housing to consume. They aim to maximise their utility function u(c,q), which increases when they are able to consume a larger quantity of housing (q) and when they are able to consume more non-housing goods (c). Residents' budget constraint is given by c+p*q = y-t*x, where p is the price to rent one unit of housing.[28] As a result, non-housing consumption can be written as c = y-t*x-p*q, and utility can be written as u(y-t*x-p*q,q).

In model equilibrium, residents cannot improve their utility by moving to a different location within the city or changing the quantity of housing they consume. This means that u(y-t*x-p*q,q)=$\bar{u}$ for all consumers. However, when city population is exogenously fixed, as it is in our implementation of the model, the overall level of utility offered by the city ($\bar{u}$) can change in response to factors that make housing more or less abundant.

Housing is built by a profit-maximising developer that combines land and construction inputs under a constant-returns technology.[29] Housing floorspace per unit of land can be written h(S), where h is the intensive form of the production function (ie housing floorspace produced per unit

[26] Employment locations are not 'monocentric' in most real-world cities, but average commuting distances still tend to rise with distance from the city centre as the average job is closer to the middle of the city than the average resident. Glaeser (2008) presents a variant of the AMM model in which a proportion of people commute to central locations while others commute to local jobs. This model variant could be used to assess the impact of employment decentralisation, although we do not pursue that approach to avoid excessive complexity in modelling.

[27] If extra commuting time results in a reduction in work hours, then commuting time can be captured as a reduction in income.

[28] In the model, all housing is assumed to be owned by an absentee landlord who does not live in the city. Relaxing this assumption increases the complexity of the model.

[29] 'Constant returns' means that doubling the quantity of land and construction inputs will double the amount of housing produced. However, doubling construction inputs without increasing land inputs, or vice versa, will lead to a smaller increase in housing floorspace.
This implementation of the AMM model assumes that housing is not 'durable' – ie it can be rebuilt to a higher density without additional costs. Again, this assumption can be relaxed at the cost of model complexity.

of land) and S is the amount of construction input per unit of land. h(S) is also described as the floor area ratio (FAR).

Developers' profit per unit of land equals p*h(S)-S-r, where r is the (rental) price of one unit of land. Economic (excess) profits from housing development are assumed to be zero due to competition between developers. This means that p*h(S)-S-r=0 for housing developers.

Urban planning regulations are modelled as a FAR limit, or a restriction on the maximum amount of housing floorspace that can be built on a single unit of land.[30] This requires that $h(S) \leq \hat{h}$. Because housing density declines as distance to the city centre increases, this limit will bind near the centre but not at the outskirts.

The AMM model is therefore defined by a system of equations, plus several equilibrium conditions. While model equations are stated as functions of utility level, equilibrium conditions imply that utility level is set within the model. These are:

Model equations
q(x,u) = quantity of housing consumed per person, as a function of distance to the centre and utility level achieved by city residents
p(x,u) = (rental) price per unit of housing, as a function of distance and utility level
S(x,u) = construction input per unit of land, as a function of distance and utility level
h(S(x,u)) = quantity of housing per unit of land, as a function of distance and utility level
r(x,u) = (rental) price per unit of land, as a function of distance and utility level
n(x,u) = population density, as a function of distance and utility level.[31]

Equilibrium conditions
$r(\bar{x}, u) = r_a$: Urban land rents at city edge ($\bar{x}$) are equal to agricultural land rents (r_a)[32]
$h\big(S(\hat{x}, u)\big) = \hat{h}$: FAR limits are binding up to a certain distance from the city centre ($\hat{x}$)
$\int_0^{\hat{x}} \theta x \frac{\hat{h}}{q(x,u)} dx + \int_{\hat{x}}^{\bar{x}} \theta x \frac{h(S(x,u))}{q(x,u)} dx = N$: The integral of population density between the city centre and city edge, taking account of the share of this area that is available for development (θ), is equal to total city population.[33]

Model implementation

To implement the AMM model it is necessary to specify functional forms for residents' utility u(c,q) and housing production h(S) and define key model parameters. Following Bertaud and Brueckner (2005) we choose Cobb-Douglas functions for both utility and housing production:

$u(c, q) = c^{\alpha} q^{1-\alpha}$, where α is the expenditure share for non-housing consumption
$h(S) = gS^{\beta}$, where β is the expenditure share of construction input in housing production and g is a scaling factor.

[30] Urban planning regulations can also be captured in several other ways, including as an urban growth boundary that restricts the spatial extent of the city (eg Lees, 2014; Parker, 2021) or a process 'tax' that raises the cost of new construction (eg Kulish, Richards, and Gillitzer, 2012). Our analysis focuses on a FAR limit due to historical evidence that FAR limits were tightened in the second half of the 20th century, prior to the imposition of a binding urban growth boundary in Auckland.
[31] Population density can be calculated as h(S(x,u))/q(x,u).
[32] This assumption assumes that there are no hard limits to housing development on the city fringe that would result in uncompetitive land markets, and also assumes that all land development costs, including infrastructure supply, are counted in construction inputs.
[33] The parameter θ captures the share of the area around the city that is not occupied by water bodies, steep hills, or other geographic features that would prevent housing development.

Based on these assumptions, we solve the above system of equations and equilibrium conditions as follows. The model does not have a straightforward analytical solution, and as a result we implement the model in Microsoft Excel and solve it numerically using Excel's Goal Seek tool.[34]

Equation 5: AMM model equations given Cobb-Douglas utility and housing production

$$q(x,u) = \alpha^{\alpha/(\alpha-1)} u^{1/(1-\alpha)} (y-tx)^{\alpha/(\alpha-1)}$$

$$p(x,u) = \alpha^{\alpha/(1-\alpha)}(1-\alpha)\left(\frac{y-tx}{u}\right)^{1/(1-\alpha)}$$

$$S(x,u) = \begin{cases} \hat{S}, & x \le \hat{x} \\ \gamma\left(\frac{y-tx}{u}\right)^{1/(1-\alpha)(1-\beta)}, & x > \hat{x} \end{cases}, \text{ where } \hat{S} \text{ satisfies } h(\hat{S}) = \hat{h} \text{ and } \gamma = \left[\beta g \alpha^{\alpha/(1-\alpha)}(1-\alpha)\right]^{1/(1-\beta)}$$

$$h(S(x,u)) = \begin{cases} \hat{h}, & x \le \hat{x} \\ g\gamma^{\beta}\left(\frac{y-tx}{u}\right)^{\beta/(1-\alpha)(1-\beta)}, & x > \hat{x} \end{cases}$$

$$r(x,u) = p(x,u)h\big(S(x,u)\big) - S(x,u) = \begin{cases} \alpha^{\alpha/(1-\alpha)}(1-\alpha)\hat{h}\left(\frac{y-tx}{u}\right)^{1/(1-\alpha)} - \hat{S}, & x \le \hat{x} \\ \left[\alpha^{\alpha/(1-\alpha)}(1-\alpha)g\gamma^{\beta} - \gamma\right]\left(\frac{y-tx}{u}\right)^{1/(1-\alpha)(1-\beta)}, & x > \hat{x} \end{cases}$$

$$n(x,u) = \frac{h(S(x,u))}{q(x,u)} = \begin{cases} \alpha^{\alpha/(1-\alpha)}\hat{h}\dfrac{(y-tx)^{\alpha/(1-\alpha)}}{u^{1/(1-\alpha)}}, & x \le \hat{x} \\ g\gamma^{\beta}\alpha^{\alpha/(1-\alpha)}\dfrac{(y-tx)^{(\alpha+\beta-\alpha\beta)/(1-\alpha)(1-\beta)}}{u^{1/(1-\alpha)(1-\beta)}}, & x > \hat{x} \end{cases}$$

Equation 6: AMM model closure conditions

$$\bar{x} = \frac{y - u(r_a/\delta)^{(1-\alpha)(1-\beta)}}{t}, \text{ where } \delta = \alpha^{\alpha/(1-\alpha)}(1-\alpha)g\gamma^{\beta} - \gamma$$

$$\hat{x} = \frac{y - u(\hat{h}/g\gamma^{\beta})^{(1-\alpha)(1-\beta)/\beta}}{t}$$

$$\int_0^{\hat{x}} \theta x \frac{\hat{h}}{q(x,u)}dx + \int_{\hat{x}}^{\bar{x}} \theta x \frac{h(S(x,u))}{q(x,u)}dx = N$$

Parameter assumptions

The following tables summarise the parameter assumptions used in this analysis, along with a brief description of the source of these assumptions. Some parameters are held constant over time, while others vary between time periods.

Table 9: Parameters that are held constant over time

Parameter	Value	Source
α: Non-housing expenditure share in utility function	0.87	Lees (2014)
β : Construction input share in housing production function	0.575	Lees (2014)
g: Scaling factor on housing production function	0.005	Kulish, Richards and Gillitzer (2012)
θ: Radians available for construction	1.8	Lees (2014) uses 2.2. We used 1.8 on the advice of a reviewer.

[34] We use the Goal Seek tool to identify the level of utility that would satisfy the model closure conditions, ie ensuring that the definite integral of population density between the city centre and city edge is equal to exogenously determined city population. The Goal Seek tool can be accessed through the "What-If Analysis" button in the Data tab on the ribbon.

Table 10: Parameters that vary over time

Parameter	1937	1977	1978	2018
N: City population	220,000	750,000	758,000	1,346,000
y: Annual income for city residents ($/year)	$18,606	$27,321	$27,678	$34,400
r_a: Agricultural land rent ($/km^2/year)	$59,496	$87,365	$88,506	$110,000
t: Transport costs ($/km/year)	$417	$409	$414	$580
$\hat{h}$: FAR limit	1.28	1.28	1.28	0.88

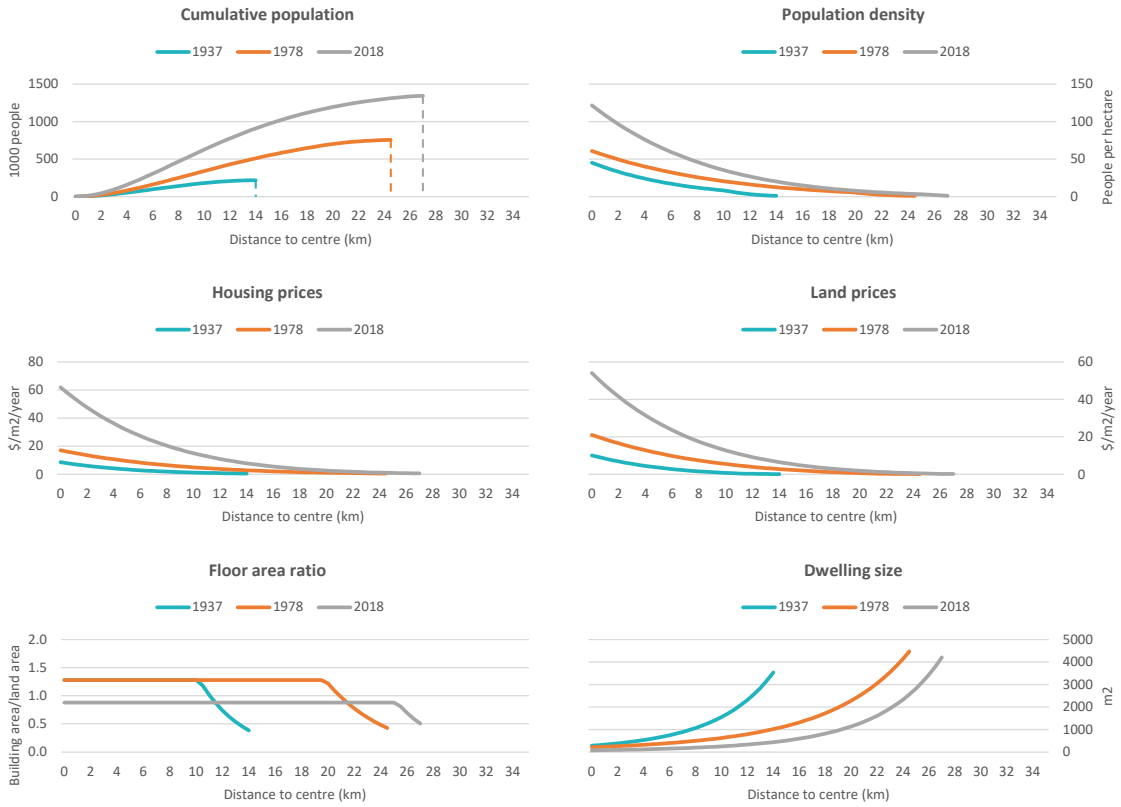
Sources:

- *1937, 1977, 1978 Auckland urban population estimated based on decadal figures from Grimes and Tarrant (2013); 2018 urban population from 2018 Census. Figures exclude outlying towns now included in Auckland Council's area.*
- *2018 annual income per resident is estimated based on 2018 Census data on median personal income for Auckland region ($34,400/year). Values for earlier years are scaled using estimates of real weekly household income from NZIER's* Data1850 *database.*
- *2018 agricultural land rents are estimated based on REINZ data. This data suggests agricultural land prices averaged $27,300/ha in 2018. At a 4% real interest rate this equates to around $110,000/km2/year. Values for earlier years are scaled using estimates of real weekly household income from NZIER's* Data1850 *database, to account for the impact of economic growth on agricultural land prices.*
- *2018 levels of transport costs per km are calculated based on the approach outlined in Lees (2014). This assumes that the opportunity cost of travel time is equal to 60% of average personal income per hour, and that the monetary cost of travel is equal to IRD's mileage rate. Travel costs for earlier years are scaled based on changes in incomes and travel speeds over time. Estimated speed changes between the 1930s and 2010s imply that, relative to incomes, travel costs were roughly 11% lower in 1977/1978 and 33% higher in 1937.*
- *FAR limit for 1936 assumed to be equal to limit observed in 1961 Auckland City Council District Scheme (approximately 1.28 averaged across all residential zones). FAR limits for subsequent years are based on the average for the 1970 and 1981 District Schemes (0.8 and 0.96, respectively). FAR limits were subsequently increased in the Auckland Unitary Plan, which was approved in 2016, ie at the end of this period.*

Model predictions for urban form and housing prices

Figure 20 shows model results for the 1937, 1978, and 2018. These show the predicted spatial expansion of the city, changes in population density, and changes in housing and land prices.

Figure 20: AMM model results for 1937, 1978, and 2018



Source: Te Waihanga analysis

Appendix 3: Historical data for Auckland

This section provides supporting material for the section entitled 'Explaining these patterns'. It explains how we estimated housing capacity from past council plans, how we estimated historical changes in travel speeds, and how we estimated changes in urban expansion over time.

Estimating housing capacity from past council plans

We used the following sources to analyse historical changes to council planning, including estimating housing and population capacity for the pre-1989 amalgamation Auckland City Council and its closest successor entities:

- *Historic District Schemes and Plans of the Auckland Region* (Auckland Council, 2018): This provides digitised versions of Auckland City Council district schemes and plans between 1961 and 2013, and digitised versions of some plans for other predecessors to the current Auckland Council.
- *Christchurch City Historic Plans* (Christchurch City Council, 2018): This provides digitised versions of Christchurch City Council district schemes and plans between 1962 and 2012, as well as plans for other predecessors to the current council.
- *WCC Urban Planning Reference Library of District Plans and Schemes* (Wellington City Council, 2018): This provides digitised versions of Wellington City Council district schemes and plans between 1959 and 2015.
- *Auckland Capacity for Growth Study 2006* (Auckland Regional Council, 2010): This provides estimates of plan capacity for pre-2010 councils in the Auckland region. Estimates are available for 1996, 2001, and 2006.
- *Auckland Capacity for Growth Study 2012* (Auckland Council, 2013): This provides estimates of plan capacity for post-2010 local boards in the Auckland Region. Estimates are based on 2012 zoning, which is carried across from the pre-amalgamation Auckland City Council, and land use data.
- *Housing Assessment for the Auckland Region* (Fernandez et al, 2021): This provides estimates of plan capacity for post-2010 local boards in the Auckland Region. Estimates are based on zoning from the 2016 Auckland Unitary Plan plus 2021 land use data.

We use data from the 1996-2018 Censuses to measure population, dwellings, and average people per household in Auckland City Council and Auckland Council local boards, and data from Statistics New Zealand and the New Zealand Official Yearbook to measure the area of Auckland Council local boards and pre-amalgamation Auckland City Council.

Table 11: Summary of population capacity offered by Auckland City district schemes/plans

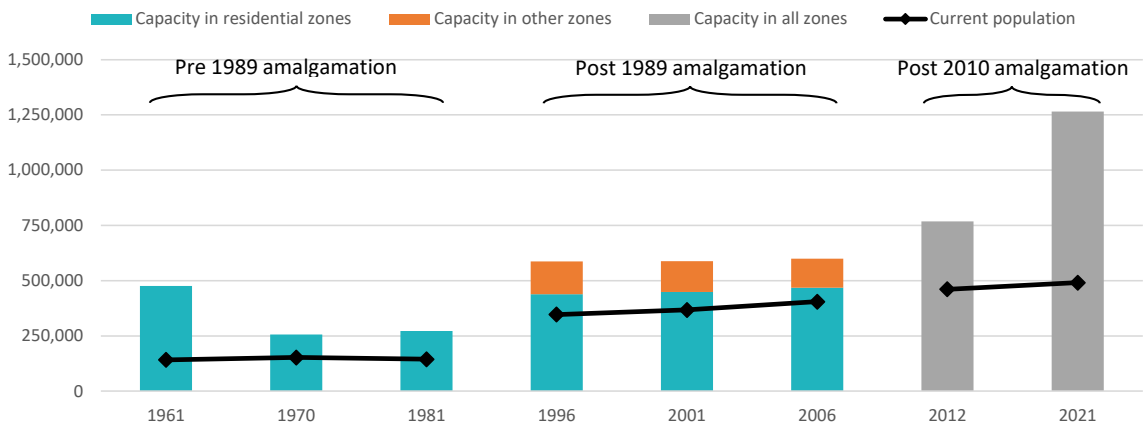
Year	Council	Relevant plan	Land area (ha)	Current population	Population capacity in residential zones	Population capacity in other zones	Total population capacity
1961	Auckland City (pre-1989)	1961 District Scheme	7,472	141,900	476,400		476,400
1970	Auckland City (pre-1989)	1970 District Scheme	7,472	152,200	256,320		256,320
1981	Auckland City (pre-1989)	1981 District Scheme	7,472	144,400	271,745		271,745
1996	Auckland City (pre-2010)	1991 District Plan	14,696	345,870	438,092	149,183	587,275
2001	Auckland City (pre-2010)	1999 District Plan	14,696	367,749	448,578	139,442	588,020
2006	Auckland City (pre-2010)	2005 District Plan update	14,696	404,658	468,131	130,872	599,003
2012	Albert-Eden, Maungakiekie-Tamaki, Orakei, Puketapapa, Waitemata, and Whau local boards	2005 District Plan update	16,203	460,947			768,480
2021	Albert-Eden, Maungakiekie-Tamaki, Orakei, Puketapapa, Waitemata, and Whau local boards	2016 Auckland Unitary Plan	16,203	490,692			1,264,988

Notes:

- *1961, 1970, and 1981 population capacity estimated based on development controls and zoned land areas in District Schemes*
- *1996-2006 population capacity estimated based on 2006 Capacity for Growth Study dwelling capacity estimates plus Census data on average people per dwelling*
- *2012 population capacity estimated based on 2012 Capacity for Growth Study dwelling capacity estimates plus Census data on average people per dwelling*
- *2021 population capacity estimated based on 2021 Housing Assessment dwelling capacity estimates plus Census data on average people per dwelling*

Figure 21 shows this data in chart form.

Figure 21: Estimated zoning capacity and current population in central Auckland



Note: Data from Table 11 above. Land area differs between the three periods on this chart.

The following tables show key information for the 1961 and 1970 District Schemes, including estimates of floor area ratios and population capacity.

Table 12: Key data and estimated population capacity for Auckland City Council's 1961 District Scheme

Residential zone	Land area in zone (ha)	Maximum site coverage	Maximum building height (m)	Minimum site area (m2)	Maximum density (people/ha)	Parking requirement	Townhouses allowed	Apartments allowed	Estimated population capacity	Estimated floor area ratio limit
Residential B	3,251	40%	9.1	607	124	Space for garage must be provided	Yes	Yes	401,700	1.22
Residential C	226	40%	9.1	607	247	Space for garage must be provided	Yes	Yes	55,900	1.22
Residential D	38	60%	33.5	607	494	None	Yes	Yes	18,800	6.71
Total	**3,516**								**476,400**	**1.28**

Notes: Original imperial units converted to metric. Population capacity estimated by multiplying maximum density in each zone by land area, and FAR limits were estimated by multiplying maximum site coverage by the number of 3m floors that can fit within maximum building height. Little to no housing capacity was provided in business zones.

Table 13: Key data and estimated population capacity for Auckland City Council's 1970 District Scheme

Residential zone	Land area in zone (ha)	Maximum site coverage	Maximum building height (m)	Minimum site area (m2)	Maximum density (people/ha)	Parking requirement	Townhouses allowed	Apartments allowed	Estimated population capacity	Estimated floor area ratio limit
R.2	2,934	30%	7.3	607	74	Minimum 1 per unit, rooms x 0.4	No	No	217,500	0.73
R.3	included in above	30%	7.3	405	86	Minimum 1 per unit, rooms x 0.5	Max of 6 per group	Max 40 habitable rooms per acre		0.73
R.4	238	30%	9.1	405	74	Minimum 1 per unit, rooms x 0.4	Max of 6 per group	Max 60 habitable rooms per acre	17,640	0.91
R.5	183	30%	12.2	405	49	Minimum 1 per unit, rooms x 0.4	Max of 6 per group	Max 80 habitable rooms per acre	9,040	1.22
R.6	12	30%	12.2	405	148	Minimum 1 per unit, rooms x 0.5	Max 1 per site	Max 120 habitable rooms per acre	1,740	1.22
R.7	32	30%	33.5	607	247	Minimum 1 per unit, rooms x 0.4	Max 1 per site	Yes	7,900	3.35
R.Special	101	25%	9.1	405	25	Minimum 1 per unit, rooms x 0.4	Max 1 per site	Max 20 habitable rooms per acre	2,500	0.76
Total	**3,500**								**256,320**	**0.80**

Notes: Original imperial units converted to metric. Maximum habitable rooms were converted to maximum population by multiplying by 0.5 (the average ratio of people to rooms from Census). Population capacity estimated by multiplying maximum density in each zone by land area, and FAR limits were estimated by multiplying maximum site coverage by the number of 3m floors that can fit within maximum building height. Little to no housing capacity was provided in business zones.

Table 14: Key data and estimated population capacity for Auckland City Council's 1981 District Scheme

Residential zone	Land area in zone (ha)	Maximum site coverage	Maximum building height (m)	Minimum site area (m2)	Maximum density (people/ha)	Parking requirement	Townhouses allowed	Apartments allowed	Estimated population capacity	Estimated floor area ratio limit
A	50	50%	7.5	405	81	Minimum 1 per unit	No	No	4,037	1.00
B	83	25%	7.5	405	46	Minimum 1 per unit	No	No	3,779	0.50
C	899	35%	7.5	405	60	Minimum 1 per unit	No	No	53,845	0.70
D	1,294	35%	7.5	405	60	Minimum 1 per unit	Max 1 per site	Max of 4 per site	77,532	0.70
E	688	35%	9.2	240	85	Minimum 1 per unit			58,268	1.05
F	416	35%	12.5	200	109	Minimum 1 per unit			45,506	1.40
G	8	35%	100.0	120	450	Minimum 1 per unit			3,460	11.55
H	62	35%	49.0	None	406	Minimum 1 per unit			25,318	5.60
Total	**3,500**								**271,745**	**0.96**

Notes: Plan does not set maximum population or dwelling density in zones, so we estimated maximum density by extrapolating the relationship between FAR and maximum density from the 1970 District Scheme. Population capacity estimated by multiplying maximum density in each zone by land area, and FAR limits were estimated by multiplying maximum site coverage by the number of 3m floors that can fit within maximum building height. Little to no housing capacity was provided in business zones.

Estimating historical average urban travel speeds

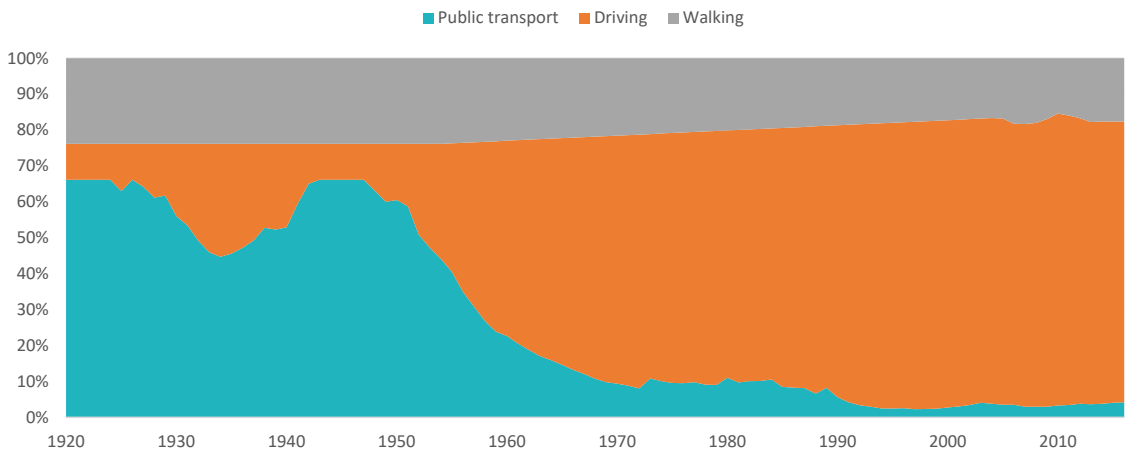
This section explains how we estimated changes in average urban travel speeds in Auckland over a one-century period. Our basic approach was to:

- Estimate mode shares for public transport, driving, and walking using a combination of household travel survey data (available for 1954 and 2003-2014) and extrapolations from historical public transport patronage data (available for 1920-2016)
- Estimate current average speeds and average trip distances for each travel mode using household travel survey data and supplementary information for public transport sub-modes
- Back-cast changes in average car travel times based on data about infrastructure quality (share of urban roads that are sealed versus unsealed, available 1930-2010) and changes to average travel times on key urban routes (1986-2012)
- For each year, average travel speeds across all transport modes, weighting by mode share and length of trip taken by each mode.

This approach captures changes in average travel speeds due to shifts from slower to faster travel modes, infrastructure improvements that allow people to drive faster, and (in recent decades) from rising congestion. Our estimates are robust to changes to key assumptions and are consistent with survey data on changes in travel speeds in the UK between 1970 and 2020 (Thunder Said Energy, 2020).

Figure 22 summarises our estimates of mode share for household trips. Mees (2009) reports that in 1954, 58% of motorised trips in Auckland were taken by public transport, compared with 42% by car. He further estimates that almost one-quarter of total trips were taken by foot.[35] Household Travel Survey data shows that by 2011-2014, roughly 4% of trips were taken by public transport, 78% by car, and 18% by walking (Ministry of Transport, 2015). For intermediate years, we assume that walking mode share declines in a linear fashion, while public transport mode share changes in line with public transport boardings per capita, estimated using Auckland Transport data.[36]

Figure 22: Estimated mode share for household trips in Auckland, 1920-2016



Source: Te Waihanga estimates based on various sources

Table 15 summarises our estimates of average travel speed by mode in the mid-2010s. We further

[35] We therefore estimate 44% of total trips by public transport, 32% by car, and 24% by walking.
[36] We thank Matt Lowrie of Greater Auckland for collating and supplying this data.

break out three public transport sub-modes. Roughly in line with current HTS data, we assume that the average length of motorised trips is around 8 km while the average length of walking trips is around 1 km. Sensitivity testing shows that assumptions around trip length for different modes do not significantly affect our results.

Table 15: Estimated average travel speed by mode, mid-2010s

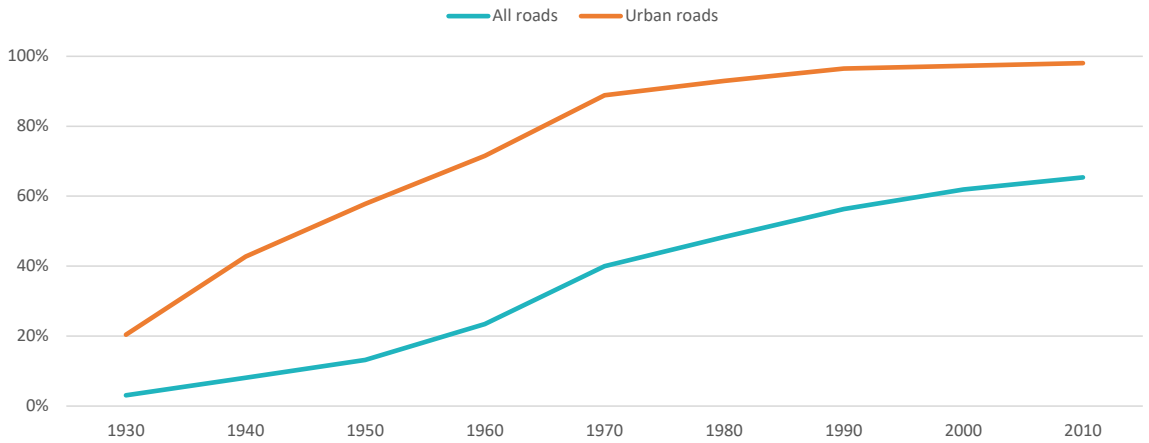
Mode	Average speed (km/h)	Source
Public transport	20 km/h	HTS, 2011-2014
Bus/tram/trolley bus	*18 km/h*	*Estimated to be slightly slower than average PT trip based on data from Wellington and Melbourne*
Ferry	*25 km/h*	*Estimated to be slightly faster than average PT trip due to lack of stops*
Train	*30 km/h*	*Current average speed on Auckland rail network*
Car	32 km/h	HTS, 2011-2014 (car driver)
Walking	4 km/h	HTS, 2011-2014

Source: Various sources

We estimate the historical impact of infrastructure improvements using data from the New Zealand Official Yearbook on the share of urban roads that are sealed versus unsealed (Figure 23). We collect this data at ten-year intervals between 1930 and 2010. We assume that average driving speeds on unsealed roads are around 20% slower than average driving speeds on sealed roads (Turner et al, 2014), and that the proportion of car trips using unsealed roads is similar to the share of roads that are unsealed.

This approach captures the significant benefits accruing from investment in sealing and improving urban road networks between 1930 and 1970, but may underestimate benefits from subsequent improvements, such as motorway expansion. However, data on changes in travel times between the 1980s and 2010s show that the gains from subsequent improvements have generally been outweighed by rising traffic congestion.

Figure 23: Share of urban roads and all roads that are sealed, 1930-2010



Source: Compiled from SNZ (2021)

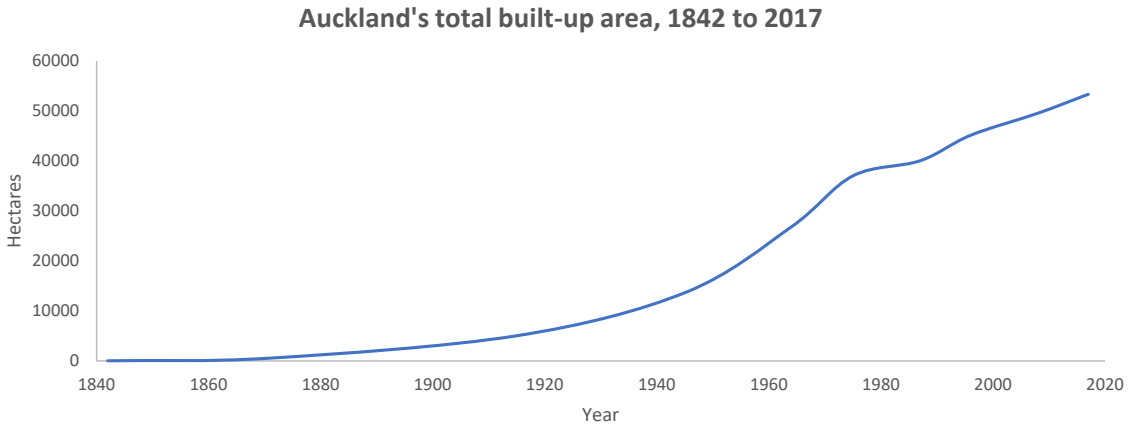
We estimate the impact of congestion on average car travel times using data on average travel speeds on four motorway routes and five arterial roads in 1986 and 2012 from Vallyon (2013). Averaged across all nine routes, travel speeds fall by 32% during peak times and 27% during off-

peak times. We therefore assume that average travel speeds on the Auckland road network declined linearly by approximately 29% (the average of peak and off-peak speed reductions) over this period.

Historical expansion of Auckland's built-up area

Hoffman (2019) maps Auckland's built-up area and provides estimates of Auckland's built-up area and population density between 1842 and 2017. Figure 24 shows this data. Auckland was expanding most rapidly between 1945 and 1976, when it was adding an average of 780 ha of built-up area every year. Since 1976 it has expanded at a slower rate of around 390 ha per year. The shift to slower urban expansion coincides with the slowing and subsequent reversal of improvements in average travel speeds that started in the 1970s.

Figure 24: Auckland's total built-up area, 1842-2017



Source: Compiled from Hoffman (2019)

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