Futureproofing access to aggregate

Economic considerations

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m.e consulting

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Executive Summary

Aggregate is a low-value, high-volume resource and is the most consumed commodity in the world after fresh water[1]. Aggregate is used across society and is a key input into infrastructure. It is used across a variety of applications including concrete, roading, foundations and drainage. Growth requires aggregate as part of the infrastructure investment that supports the built environment catering for residential, commercial, and industrial activities. In turn, the built environment yields value to society from the amenities and services it provides, leading populations to gravitate towards urban centres and areas endowed with high-quality amenities and infrastructure.

The price for delivered aggregate is highly sensitive to transport costs, which are determined by distance. Travel distances also determine the scale of some other, non-market effects such as emissions and social costs. Therefore, the location of quarries relative to where the aggregate is used is critical. The location of quarries is influenced by the policy and regulatory landscape, which means that the efficiency of the aggregate market and the delivered price of aggregate are intrinsically tied to the policies and regulatory conditions governing aggregate quarrying. Clear and forward-thinking policy is required to balance the needs of the economy, land rights, environmental considerations and competing social objectives.

Market Economics (M.E) have been commissioned to provide background information describing the aggregate sector and to provide an analysis of the economic cost associated with interregional aggregate imports. Many of these costs are a product of existing supply pattens and the location of quarries relative to where aggregate is used. A data- and literature-led review of the issues facing the aggregate sector shows the key role it is playing in supporting New Zealand's infrastructure delivery programme. The infrastructure deficit and the country's productivity challenges are well documented, with the aggregate sector holding a pivotal role if they are to be overcome. Having access to high-quality aggregate in sufficient quantities and in appropriate locations is essential. Without a well-functioning aggregate market, efforts to address the infrastructure challenge will be severely hampered. Crucially, quarries are extractive and must expand over time to ensure that there is sufficient resource available to service local markets, and to minimise direct and indirect costs associated with servicing the market.

There is a clear link between population, the economy and growth, and demand for aggregate. As regions and economies grow, so too does demand for aggregate. Research by the New Zealand Infrastructure Commission suggests that to address the infrastructure challenge, New Zealand needs to double public investment in infrastructure and maintain that higher rate for 30 years to address the backlogs, while still catering for maintenance and renewals and allowing for growth[2]. While dollar figures in the hundreds of billions have been cited as the deficit value[3], these estimates allude to the scale of the challenge we face. What those estimates, as well as the estimates contained in this report, emphasise is that there is an immediate requirement for positive action in the infrastructure space.

Notwithstanding the existing pressures, New Zealand's population growth is surging in the post-Covid environment with net migration in the year to November 2023 the highest on record at 127,000[4]. While some of the migration pressures are likely to be pent-up demand, the long-term outlook for population is one of

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[1] Infrastructure resource study – infrastructure commission (2021).
[2] Aggregate supply and demand in New Zealand – Wilson et al. (2022). Report for Waka Kotahi
[3] A widely cited Sense Partners report (2021) put this value at $104bn
[4] StatsNZ November 2023 migration preliminary release (19/01/2024)

continued growth. StatsNZ's population projections suggests that over next two decades, the population will grow by between 15% and 24%. The high growth scenario is on par with the change over the past two decades i.e., an increase of 1.2m people.

Over the short term, real GDP per capita is projected to grow at around 1.5% per year[5]. Both population and economic growth require high quality infrastructure to bring benefits and avoid costs. Achieving value for money in infrastructure spending will be critical, and avoiding unnecessary cost should be an important objective. High interest rates mean that the cost of historic debt is increasing, thereby lowering the actual budget available for spending.

Productivity is a key driver of economic performance and lifting productivity growth is a central challenge facing New Zealand. Construction contributes 6.9% of national GDP, meaning that poor productivity growth in this industry drags the overall economy. Approximately 65% of aggregate is used for roading, contributing to 15 – 27% of construction costs and 8 – 20% of maintenance costs[6]. However, aggregate's role as part of the construction value chain means that this sector must play a role in supporting sectoral productivity. At the same time, aggregate is needed in projects that aim to lift inter-regional trade and support local productivity.

Using a range of data sources, assumptions and proxies, our analysis estimates that:

- Average per capita aggregate production is around 9.3 tonnes. Some sources put the range at between 7 tonnes per capita and up to 10 tonnes per capita[7]. Regionally, the spread varies between:
  - North Island 9.1 tonnes per capita
  - South Island 10.1 tonnes per capita
- Total supply across New Zealand is estimated at 47.9 million tonnes per year, but this can vary based on projects and the economic cycle. Regional variation is also reflected in the assessment and is based on local demand patterns.
- Regions such as Auckland, Bay of Plenty and Wellington have supply deficits, meanwhile other regions have supply surpluses even if the supply-deficit position is marginal (e.g., Waikato, Northland, Canterbury).

Increasing total aggregate demand in line with population growth shows how much supply will need to change to ensure that existing pressures do not constrain the market over the medium to long term. Using current production estimates i.e., assuming no new quarries come online, and production continues at its current level for the entire 25-year period, suggests that by 2048 New Zealand will have a national shortage of 9 – 13 million tonnes of aggregate per year. Due to the finite lifespan and operating capacity of existing quarries, it is reasonable to expect production to fall unless action is taken, and a new consenting pathway is established. Likewise, increased per capita demand from economic growth and work to address historic infrastructure deficits would also add to demand levels.

These high-level estimates suggest that New Zealand will need to lift existing aggregate production by between 8.6 million tonnes and 13.3 million tonnes per year to ensure that there is enough supply to match demand.

[5] NZ Treasury Budget Economic and Fiscal Update 2023
[6] Infrastructure resource study – infrastructure commission (2021).

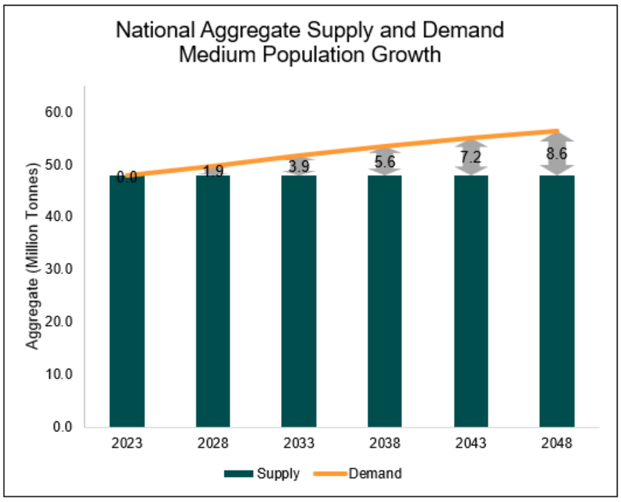
This is the net change, relative to current production (supply) positions. Some quarrying operations will cease over the next 25 years meaning that new quarries will be needed, and existing ones will need to expand to account for lost volumes due to the closures and to respond to growth. It is essential that the consenting pathways reflect and acknowledge these pressures and the importance of aggregate.

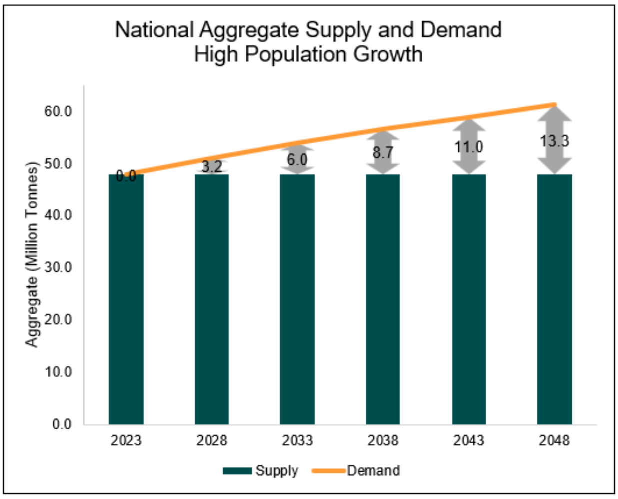
The regional distribution of the growth (2023-2048) is expected to see most of the growth in the main economic centres. The resulting lift in aggregate demand is projected to see an increase (net additional) in aggregate demand, per year, of:

- Auckland +3.9 million tonnes
- Canterbury +1.2 million tonnes
- Waikato + 1.1 million tonnes
- Bay of Plenty + 0.6 million tonnes
- Wellington + 0.5 million tonnes.

These changes are significant, and it is useful to put these into context. Auckland already has a deficit and imports aggregate from Northland and the Waikato. The demand growth will see the local shortfall increase, and interregional imports almost double. If within Auckland aggregate production capacity is not maintained (quarry closure or consent conditions reduce volumes), then the import requirements will be even greater. The associated costs are significant and describe in the report.

Demand outlook relative to current production levels (medium and high growth)





Crucially, these estimates present the anticipated supply-demand gap and does reflect several key factors:

- **Change in demand associated with addressing infrastructure backlogs or incurring extraordinary infrastructure spending associated with extreme weather events will shift demand upwards.** Any upward shift in the demand parameters in response to efforts to address the infrastructure deficits will see the identified differences grow. To put this into context, a 2% increase in demand levels will see the supply gap grow by an additional 26 million tonnes (sum over 25 years).
- **The potential effects associated with an inability to renew existing consents, or obtain new consents to expand the quarry footprint, that would enable production to remain at current levels, are not shown.**

- **The nationwide total values obscure the demand share from major economic centres and the essential role that the aggregate sector and construction must play to efficiently and effectively support growth. These large economic centres are projected to represent significant portions of the total aggregate demand:**
    - **Auckland accounts for an estimated 32% of demand, and is projected to account for 34% of long term demand (by 2048)**
    - **Wellington and Canterbury will both continue to demand substantial shares of overall (New Zealand-wide) demand, with 10% and 14% of total demand respectively.**

System costs

At its core, the cost of accessing aggregate from alternative sources is a transport problem. The further aggregate must travel, the higher these associated costs are.

We estimate New Zealand's transport function for aggregate by employing two experimental approaches which seek to minimise inter-regional transport distances across the North and South Island. Our first approach uses a regional lens to estimate the transport distance between quarries and the regions to which they export, and the associated costs. This approach isolates the cost to get the product to the regional border. The second approach estimates the transport costs to the main urban centres within each region. The first approach provides the absolute minimum distance that regionally imported aggregate travels between regions. The second approach acknowledges the role of aggregate in urban growth and development and uses the main centres as destinations for aggregate[8], ignoring intermediary destinations.

The quantified wider costs of the transport tasks (volume and distance) reflect:

- The direct transport costs,
- Environmental costs, and
- Social costs.

The annual cost across New Zealand is significant. If the new quarries are established at the regional borders, so only the transport to the borders are avoided, the potential saving is estimated as $271m per year. Using the second approach suggests that the potential savings would reach $864m per year[9]. Most of the overall costs are associated with the direct transport costs, which raise the input costs of infrastructure and construction projects. These represent significant numbers in the context of New Zealand's productivity challenges.

Regional focus

By illustrating the potential costs in Auckland and Wellington, the scale of the issue is conceptualised. Auckland is the largest importer of aggregate by a considerable distance. Wellington, meanwhile, has suffered supply shortages during recent infrastructure projects and imports a share of its total.

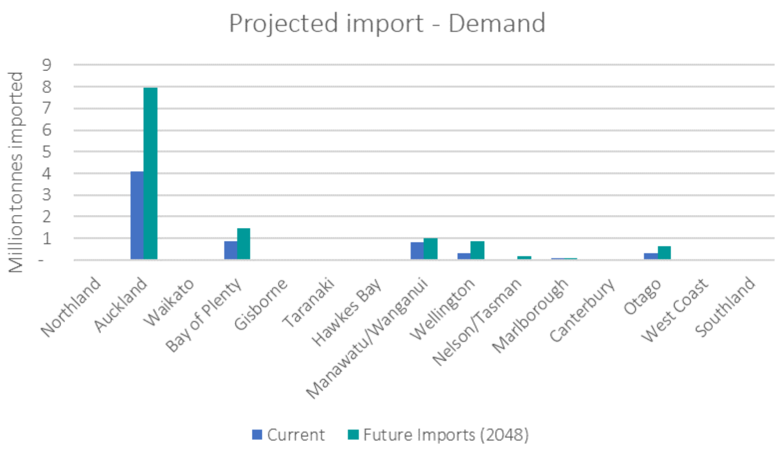
Auckland

[9] These estimates do not include the potential within region transport costs and are seen as the upper thresholds.

We estimate that Auckland imports 4.1 million tonnes (per annum) of aggregate from Northland and Waikato. The cost to transport aggregate to Auckland border is estimated at $166m per year. In addition to these transport costs, there are significant social and environmental costs ($6m per year). This cost can be seen as the 'at least' cost but, crucially, aggregate is transported into Auckland, and looking at the cost to the border understates the true cost position. Extending the analysis to assess the costs to a central **location increases the costs to $381m, with environmental and social costs estimated as $11m and $6m respectively – the total costs is estimated at $398m.**

Enabling Auckland's quarries to expand to address the shortfall and to respond to growth in a way that minimises the need to import aggregate into the region suggests that the over a twenty-year period, the potential cost savings would be (conservatively) $2.3bn[10]. These costs only include monetizable transport, social and environmental costs, which excludes the myriad other social and environmental impacts such as having the extra vehicles on the road. The role of several large quarries in Auckland and Waikato in supporting infrastructure delivery cannot be understated. Changing the imported share of aggregate will have widespread effects.

If Auckland's demand increases in line with the region's medium population projections and in-region production stays at current levels, by 2048 the region will have a shortfall of 8 million tonnes of aggregate per year. Auckland's additional demand will need to be satisfied by enabling new, or expanding existing quarries, or by importing more aggregate from other regions. Based on existing supply patterns (without any increase in local production volumes), **an additional 3.9 million tonnes need to be sourced from the Waikato and Northland – a significant volume**. These levels are a virtual doubling (+95%) of current import levels and a consequent increase in total transport costs, emissions, social costs and the associated externalities.



This is a significant shortfall, requiring large import quantities, potentially affecting local demand in these regions, too.

Wellington

Wellington is a net importer of aggregate, pulling in an estimated 310,000 tonnes per year. Importantly, its proximate areas are not big aggregate producers either. Failure to enable growth and change this trajectory could lead to severe shortages, which has become evident with recent infrastructure projects. The cost to transport aggregate to the Wellington border is estimated at $10.0m per year. The present value of these costs over a twenty-year horizon are $138.0m.

The role of the exporting regions should also be acknowledged. Regions such as Waikato and Northland play a vital role. This analysis does not specifically estimate the potential costs effects on the Auckland or Bay of

[10] Using a 5% discount rate and assuming no demand growth or changes to supply.

Plenty market of constraining the quarries there. However, considering the regional reliance on these quarries, the potential effects and cost would be substantial. Both are projected to be among the four fastest growing by population over the next two decades, meaning locally produced aggregate could be subject to more competition, in addition to demand coming from Auckland.

Concluding remarks

New Zealand faces a severe infrastructure challenge in the coming years, which will require large quantities of aggregate. Without action, this infrastructure requirement, in conjunction with population growth and historic inertia towards the aggregate market, will manifest as chronic shortages and soaring costs. Moreover, action should be taken promptly because of the lead-in time required for any meaningful responses to occur in the sector. The current aggregate supply patterns reflect vast distances that are adding costs to the construction sector. Enabling quarry development and making the process more flexible will assist in reducing the total costs while also contributing to productivity growth.

In addition to the baseline growth, the substantial pressure on New Zealand's infrastructure base will require considerable investment. Such investment will require additional aggregate and resources, lifting overall demand levels for aggregate. Having access to aggregate close to where it is needed reduces the direct costs and avoids several indirect, environmental, and social costs. Regardless, a critical consideration is that aggregate is a core input into many infrastructure elements – ranging from foundations for houses and roads to being a key ingredient for concrete. It is used in large volumes and transporting it adds to the final cost of delivered infrastructure. It is essential that sufficient aggregate can be accessed from appropriate sources, that are near end users. As well as the economic benefits described in this paper, local supplies of aggregate are essential in the event of significant natural disasters that might constrain or completely sever main transport routes. Local supplies are also essential to support rebuilding activities.

1 Introduction

The sufficiency of aggregate supply is essential to New Zealand for achieving a balance between economic growth and development, and environmental sustainability. Effective policy and regulation have a key role in supporting the delivery of anticipated outcomes. Aggregate is used throughout New Zealand as an input into all parts of construction. Growth requires aggregate to create the supportive built infrastructure that populations require and demand. Maintenance of this infrastructure also requires access to the resource. The built environment yields value to society from the amenities and services it provides, leading populations to gravitate towards the larger urban centres and areas endowed with high-quality amenities and infrastructure.

Although aggregate is a low-value resource, as measured by price per tonne, it is produced and used in large volumes. It is the most consumed commodity in the world after fresh water[11]. The high volume and heavy nature of the resource mean that the delivered price and associated costs are directly dependent on the distance it travels. Transport distance is the key determinant of aggregate prices, but it is also the central driver of many other, non-market effects, such as emissions and social costs. Therefore, the location of quarries relative to where the aggregate is used, is critical. Due to transport costs, aggregate is not imported into New Zealand and local demand must be met using domestic production. The availability of substitutes such as recycled aggregates is currently limited.

Quarrying aggregate requires first having access to a suitable resource and obtaining a consent for extraction activities. Production is constrained by not only the availability of land and factors of production but also the regulatory environment and consent conditions governing access to the market. Permits limit production to a specified quantum and can place additional restrictions on extraction. To increase production beyond consented levels, or to obtain a consent to extract aggregate on a new site, involves going through an expensive and lengthy process – the outcome of which is often highly uncertain, thereby undermining the commercial incentive to risk the endeavour. While the sector is working to lift its responsiveness to construction sector demand, the uncertainties mean that it often struggles to meet growing market demands. Very few quarries have spare capacity to increase production above what they currently output. Where they do, this is unlikely to be due to a lack of demand given the ubiquity of demand throughout the country. In some cases, it is possible that issues such as workforce pressures, transport limits and utility constraints inhibit full operating capacity being achieved.

While New Zealand has an abundance of rock available to produce aggregate, supply has failed to keep pace with surging demand or to locate close to the centres where much of the resource is used and where growth is occurring. As a result, some regions and urban centres import large shares of the aggregate needed to satisfy their demand. These imports are expensive, placing significant cost pressures on project budgets, the environment and society. Due to population growth and the impending expiration of existing resource consents, demand is forecast to significantly outstrip supply in the coming years.

The policy and regulatory landscape determine whether the market can respond and adapt to the dynamic needs of New Zealand's economy. The efficiency of the market is intrinsically tied to the policies and regulatory conditions governing aggregate quarrying, management, and use. Clear and forward-thinking strategy is

[11] Infrastructure resource study – infrastructure commission (2021).

required to balance the needs of the economy with land rights, environmental considerations and competing social objectives. Continued inertia around the challenges faced by the industry will lead to suboptimal outcomes, which will undermine economic performance and productivity.

1.1 Project aim and approach

This project aims to provide background information about the aggregate sector and to highlight its fundamental contribution to New Zealand. The existing supply pattens are reviewed and the potential costs associated with an inability to supply market demand locally is illustrated.

The current conditions of the aggregate market are summarised, based on a high-level literature review of domestic and international research into the sector. The literature search includes three focal sources:

- work by Market Economics (M.E);
- research commissioned by the Infrastructure Commission[12]; and
- research commissioned by the New Zealand Transport Agency[13].

This work provides a foundation for understanding many of the issues facing the sector. The literature review is supplemented with quantitative and qualitative data that was collected and analysed to first describe the economic context in which the sector operates. Using official and unofficial statistics published by StatsNZ and government departments, alongside other sources of economic intelligence and market insight, we build a picture of the interdependencies within the aggregate market. This is used to highlight the importance of sufficiency and wider impacts of these issues beyond those which we present as direct costs and benefits through the modelling. Next, we illustrate the aggregate demand and supply market in its current form. A range of assumptions are used to account for data deficiencies and other complex challenges in estimating spatial demand and supply patterns.

The supply side constraints are particularly important and highlighted. We briefly address the suitability of recycled aggregate and both its current and future role for sustainable supply in New Zealand. Previous research has addressed this topic in depth, however, and it is not the focus of this project. Recycled aggregate has limitations, and volume requirements mean that it is unlikely to be a perfect substitute for the majority of demand for aggregate.

The final part of the assessment process studies the costs and benefits associated with the aggregates sector as it currently operates. Using regional demand estimates and quarry-level production data, we develop an understanding of regional sufficiency and the supply flows required to service the regional deficits across the country. A national spatial-simulation model then identifies the flows of aggregate within New Zealand which would minimise the total travel distance needed to overcome regional aggregate shortfalls. The associated environmental, social and transport costs are then estimated based on travel distances and average loads (weights) per vehicle trip. Auckland and Wellington are discussed individually given their significant importance in the national spatial-economy and unique circumstances as pertains to aggregate access, production and demand.

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[12] Aggregate opportunity modelling for New Zealand (2021) & Infrastructure resource study – infrastructure commission (2021).

[13] Aggregate supply and demand in New Zealand – Wilson et al. (2022). A review of aggregates for land transport infrastructure in New Zealand – Wilson et al., (2022).

1.2 Caveats and Limitations

The flaws in data on aggregate supply are well known in the industry and we use assumptions and proxies to mitigate these issues. Although our assumptions are checked against other methodologies and previous efforts to quantify the market, they cannot be verified against a robust official data source. This necessitates caution when interpreting the results. Some of the modelling is experimental in its nature and is aimed at highlighting the sector's challenges.

Estimating aggregate demand is always likely to bring difficulties. Sensitivity analysis is performed by using a second approach to calculate this demand, using regional construction employment data rather than population weights, we re-run the models and report the results in the appendix. We note that there are several data limitations associated with the number and location of quarries, the production values and commodities quarried. Quarries that were identified as inactive, non-commercial or producing materials not included in our aggregate definition were excluded. This assessment then used several different techniques to estimate production volumes where these were not reported. A triangulation process was used to align the assessment with known data points. However, some limitations and caveats remain.

Large infrastructure projects have a disproportionate impact on demand, but the exact amounts they use, where it goes and over what period, are difficult to obtain in real time. As such, our assumptions use more reliable data on population concentrations to account for this deficiency. The sensitivity analysis using construction worker locations may capture some of this demand, though that is difficult to verify.

The costs and benefits of alternatives are derived using a widely employed approach in economic research. They are used to aid an understanding of potential benefits from alleviating market pressures in various locations. Of course, the opposite also holds – if pressure is untreated then additional costs are imposed. The specific market response is unknown, imposing a limitation for the work. A constrained optimisation process is used to minimise a transport function of a market responses, which assumes allocative efficiency, but the true actions of agents will vary from the modelled approach as they are not coordinated in reality. The findings provide a useful benchmark to support discussions and policy design which seek to balance costs with other objectives.

The model uses regions to illustrate the spatial patterns within the sector. A more granular approach is not used because of the complexity it would require, which would detract from how informative the results can be. Furthermore, we focus on inter-regional transport: where aggregate must be imported from outside the region of demand. None of the modelling estimates where the production which remains in the region is delivered. The methodology focusses on the costs of just transporting the load to the border, meaning further analysis would be required for deriving flows within the region. It should be noted, however, that there will be significant costs associated with these intraregional flows, too. In Wellington, for example, much of the aggregate produced in the north of the region will be transported a considerable distance south, to areas such as Lower Hutt and Wellington city. The implications of the within region flows are highlighted in the Auckland case that shows that including within region flows has a significant influence on the overall cost equation.

To understand travel distances and supply trade-offs, the major road network is used to connect locations within each island. We assume that quarries relocate to the network based on the minimum Euclidean distance to a link. This therefore forgoes any costs with the journey to this point. It also assumes that this point would be the most efficient start point on a route. If a quarry begins on a part of the network which is poorly connected, it might increase the presumed distances to regions or urban centres.

This assessment is based on a desktop approach, using available information and a site-by-site analysis was beyond the scope. A small number of potential anomalies were identified in the South Island, around the flows between Southland and Otago. These relate to cross-border flows and is based on several assumptions. The assumptions are based on South Island-wide patterns and local nuances mean that these flows are likely mis-stated. However, in the absence of fine-grained information (especially production volumes around some quarries), and transport patterns, these anomalies remain unaddressed. The anomalies appear confined to a small number of instances.

No specific policy recommendations are made within this report. Its purpose is to illuminate the aggregate landscape while demonstrating the need for targeted action.

1.3 Report structure

The report is divided into 5 sections:

- Section 2 describes the economic context, covering the aggregate market in general, and provides an overview of general trends, such as the infrastructure pipeline.
- Section 3 focusses on the aggregate industry. It uses data and analysis to illustrate the demand and supply picture, as well as the constraints and notable regulatory influences on the market.
- Section 4 contains the modelling of costs and benefits, our data, methodology and results. It provides additional insight for Auckland and Wellington as particular areas of interest.
- Section 5 offers concluding remarks.

2 Economic Context

New Zealand is a small, open economy with key production areas differentiated across urban cities and rural production areas. New Zealand has a highly urbanised population with almost three quarters of the population living in urban areas. Over half of New Zealand's total land area is pasture and arable land and more than a quarter is under forest or plantation cover. Quality infrastructure is critical in linking different parts of the urban and rural economies. At the same time, infrastructure is needed within both urban and rural areas to support everyday life and business activities. Aggregate is an important component of delivering and maintaining infrastructure.

The demographic features and economic situation are fundamental drivers for aggregate demand because aggregate is a key input into infrastructure maintenance and delivery programmes. These programmes operate at varying levels – from central and local government investments to business investments. The programmes relate to the infrastructure investments in roading, applications such as drainage, concrete production, and as base material for foundations and buildings. As regions and economies grow, so too does the demand for aggregate. This section summarises the economic and demographic context for overall aggregate demand. A detailed account of the relationship between aggregate demand, population growth and economic growth is out of scope, but a technical account of these relationships can be found in a recent report for NZ Transport Authority[14]. The section covers:

- The national population context
- The economic landscape
- Productivity, and
- Infrastructure investment.

2.1 National Population

The population of New Zealand is growing and, emerging from the Covid-19 lockdown restrictions, international migration has been setting records. At 127,000, net migration in the year to November 2023 is the highest on record[15]. While some of the migration pressures are likely to be pent-up demand, the long-term outlook for population is one of continued growth.

Table 2-1 shows the historic population data for New Zealand and the medium- and high-growth forecasts from StatsNZ for the coming two decades. Over the past 20 years the population has grown by 30% from 3.9m people in 2002 to 5.1m in 2022 – an increase of 1.2m people over two decades. Over the next two decades, StatsNZ forecasts that population will grow between 15% and 24% to between 5.9m and 6.3m. If this growth is realised, the population will be more than 50% larger in 2042 than it was in 2002. The high-growth scenario is on par with the change over the past two decades i.e., a change of 1.2m people.

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[14] Wilson, D., Sharp, B., Sheng, M. S., Sreenivasan, A., Kieu, M., & Ivory, V. (2022). Aggregate supply and demand in New Zealand (Waka Kotahi NZ Transport Agency research report 693).
[15] StatsNZ November 2023 migration preliminary release (19/01/2024)

Table 2-1. National Population Outlook

Historic Population Data					% Change	
		2002	2012	2022	2012 - 2022	2002 - 2022
New Zealand Population	-	3,948,500	4,408,100	5,124,100	16%	30%
Stats NZ Population Projections					% Change	
	Scenario	2022	3032	2042	2022 - 2032	2022 - 2042
New Zealand Population	Medium	5,124,100	5,522,000	5,889,000	8%	15%
	High	5,124,100	5,788,000	6,344,000	13%	24%

A larger population requires greater levels of built infrastructure, which will use aggregate. Moreover, a larger population puts an increasing strain on existing infrastructure, which must be repaired and maintained to retain its functionality. New Zealand's infrastructure deficit is well documented, and population growth will add to existing backlogs and additional, above trend, investment is needed to address growth pressures.

Table 2-2 shows the fastest growing regions in each of the four decades – two historic and two forward-looking[16]. In each ten-year period, there is a different group of regions exhibiting the fastest growth rates. Although there is some consistency among the top regions – Waikato, for example, features in each of the periods – this variability shows that growth is not spatially inert. As population patterns change, demand for aggregate, will also shift, which makes a responsive sector imperative for growth facilitation. Naturally, faster growth in larger regions will create more demand for materials such as aggregate because of the higher volumes of people. High growth forecasts in Auckland will bring a substantial associated demand increase.

Table 2-2. Regional Growth Leaders. Historic data (2002 - 2022) and StatsNZ Medium Forecasts (2022 - 2042)

	2002 - 2012		2012-2022		2022 - 2032		2032 - 2042	
Rank	Change	Region	Change	Region	Change	Region	Change	Region
1	18%	Auckland	25%	Bay of Plenty	11%	Waikato	10%	Auckland
2	13%	Waikato	23%	Northland	10%	Bay of Plenty	8%	Waikato
3	12%	Nelson/Tasman	22%	Waikato	10%	Northland	7%	Canterbury
4	12%	Northland	19%	Otago	9%	Auckland	6%	Northland

Looking through the regional classification reveals that:

- Auckland was and is expected to remain a key location for growth, this will strengthen the city's relative attractiveness as a destination for business and infrastructure investment – creating a self-supporting growth cycle.
- Tier 1 cities, such as Hamilton, Tauranga/Western Bay of Plenty and Christchurch historically played a strong role in regional New Zealand. This role will remain and become more pronounced.
- Smaller regions including Nelson/Tasman and Northland are also expected to see growth.

Growth is distributed around New Zealand, and even though it is concentrated around the cities, the regions also attract investment. It would be inappropriate to ignore or understate growth and associated pressures in the regions. In fact, the role of New Zealand's "Golden Triangle" in economic performance is well documented – the Auckland-Tauranga-Hamilton area often referred to the 'economic powerhouse'.

[16] The Chatham Islands region has been removed due to the small numbers and incompatibility with the overall modelling approach.

According to NZTA[17], more than half (56%) of New Zealand's total freight movements are within the Golden Triangle. In addition, these three areas generate half of New Zealand's GDP. The economic activity and associated transport infrastructure needs aggregate (through construction activity) to support day-to-day activity, maintenance of assets and infrastructure are essential from a New Zealand perspective.

Sourcing aggregate from close to the growth areas will minimise delivery distance and enhance overall efficiency. The changing spatial growth patterns suggest that as time passes, the distribution of optimal locations could change. So too could the quantities of aggregate demanded. Enabling production to respond accordingly would therefore be critically important to support growth in many different locations, and not just the cities. Because nearly every region is growing, it is unlikely that any sources of aggregate will suffer from diminishing demand. The regions where shortages are most acute, however, could indeed vary and the transport dynamics will place new demands on aggregate sources.

In the urban context, the implications of land use change and tensions between quarrying and other land uses is expected to intensify. Managing access to aggregate resource and urban form changes will be crucial to minimise the overall costs.

2.2 Economic performance

Infometrics estimates the size of the NZ economy at $357.7bn, up from $333.2bn in 2019[18] (before Covid). The economic growth pathway coming out of the Covid-lockdowns has seen New Zealand's economy running into capacity pressures, with inflation building. While not unique in a global sense with many countries facing similar issues, monetary policy has been tightening to slow activity and to lower inflation.

The outlook for the New Zealand economy is uncertain with somewhat opposing force acting on the economy. These forces include[19] a turning housing market that is inhibiting household spending. The exposure to interest rates is a key part of this current slowdown. Other factors influencing the local economy and therefore the likely demand for investment (and aggregate) include high migration patterns, global economic activity, changing central government priorities, geopolitical tensions and global market volatility. The Treasury's pre-election economic and fiscal update points to slow growth in the immediate term but forecasts real GDP per capita to pick up to around 1.5% per year from 2024 – 2027[20].

While the economic volatility is expected to be transitory in nature, there is a possibility that some trends will persist. Annual consumer price inflation peaked at 7.3% in June 2022[21] and interest rates were raised in response to dampen demand and ease inflationary pressure. However, as noted in The Treasury's report, new sources of inflationary pressure have created added complexity to the economic outlook. One element of the complex picture relates to population. Strong migration is adding to economic momentum even if consumption growth on a per capita basis is weak. Strong migration patterns are observed in other countries including Australia, and it is not isolated to New Zealand. The growing population numbers mean that despite difficult economic conditions, demand for infrastructure spending will not diminish.

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[17] https://www.nzta.govt.nz/assets/projects/auckland-northern-corridor/nci-big-picture-map.pdf (undated).
[18] Infometrics.
[19] ANZ research. Quarterly Economic Outlook. November 2023.
[20] NZ Treasury Budget Economic and Fiscal Update 2023
[21] Ibid.

Affordability levels and costs are key issues constraining investment, and increasing interest rates mean that decision-makers must weigh up competing alternatives, consider trade-off and often cancel projects altogether. The Government in New Zealand must pay 5.0% to borrow for a decade, up from less than 1% in 2020 and above the 3% average from 2015 – 2019[22]. This will require diverting tax revenue to pay the interest on accumulated debt, which will squeeze budgets and necessitate prioritisation. Previously funded programmes and projects will become unfeasible, meanwhile the price tag on appealing prospective ones will climb – these changes mean that managing the budgets of investment programmes is vital. Ensuring that unnecessary costs are excluded from the entire system will become even more important.

2.3 Productivity

Productivity is a key driver of economic performance, higher wages, and higher living standards. New Zealand's low productivity growth is a long-term problem and well-documented. Increasing productivity is arguably one of the biggest economic challenges facing New Zealand. The construction industry contributes 6.9% of national GDP, and aggregate's role as part of the construction value chain means that this sector must play a role in supporting sectoral productivity. The role is through:

- Direct
    - By being part of the supply chain
- Indirect
    - By enabling infrastructure investment that facilitates business activity and connections.

There is limited public information about aggregate quarrying or its productivity. Table 2-3 shows the changes in selected businesses price indexes over the past three years. In each case, prices have increased significantly over the period, inducing knock-on effects for associated sectors of the economy. These costs relate to capital costs as well as inputs. For example, capital goods price associated with transport ways (e.g., roads) have increased 24% between September 2020 and September 2023. This is one area of civil construction which uses large quantities of aggregate. Inputs for construction were 22 – 30% costlier depending on which sub-sector is considered.

Table 2-3. Price Indexes

	Change from previous year			Total (compound)
	Sep-2021	Sep-2022	Sep-2023	2020 - 2023
Capital goods index				
Civil Construction: Transport Ways	2%	16%	5%	24%
Producer Inputs Price Index				
Building construction	9%	13%	6%	30%
Heavy and civil engineering construction	5%	17%	3%	26%
Construction services	5%	11%	5%	22%

The cost pressures are felt across the economy, not only in construction. However, aggregate can play a key role for softening these impacts. Generally, lowering average input costs will make construction projects cheaper, improving their viability. A more reliable supply chain, whereby the resource can be accessed

[22] Market Watch. Accessed 01/12/23.

conveniently and in the necessary amounts, will also contribute to economic efficiency. Research by Lane[23] calculates that more than half of all aggregate consumption is by government, meaning the price has considerable implications for public spending. Managing infrastructure project budgets is difficult and budget/cost overruns are common. By securing and protecting access to aggregate in appropriate locations, a portion of the costs associated with infrastructure projects can be managed. Regardless, it makes economic sense to ensure that costs across the entire aggregate supply chain is kept to a minimum.

Not all construction projects will be as reliant on aggregate. For example, residential buildings in New Zealand have a lower dependence compared with heavy construction and roading. Approximately 65% of aggregate is used for roading, contributing to 15 – 27% of construction costs and 8 – 20% of maintenance costs[24]. Appendix 1 provides additional information about the construction sector.

2.4 Infrastructure investment

New Zealand faces a significant infrastructure challenge over the coming years, one which is going to require unprecedented investment. The growing population is adding to infrastructure demand, and the existing infrastructure base is ageing and in need of capital reinvestment. As noted in a recent NZTA report, there has been a deficit in infrastructure re-investment for the medium term[25]. This means that a significant proportion of public infrastructure is nearing the end of its useful and/or economic life. Despite nearly $100bn of infrastructure projects planned and in the pipeline of upcoming work, an Infrastructure New Zealand and Infometrics report concluded that this needs to more than double over the next 30 years to meet the current infrastructure deficit[26].

In addition to renewing infrastructure, several large construction projects are in the pipeline. These projects show important considerations when viewed from an aggregate perspective.

- The Ōpōtiki Harbour Development was developed using funding from the Provincial Growth Fund. It exemplifies the role of aggregate for unlocking the potential of high-value projects – marine aquaculture in this instance. This project required significant volumes of aggregate and access to available aggregate would have been prohibitively expensive. These costs were so elevated because it was expected that aggregate would have to travel more than 100km[27], suggesting that these costs would have made the harbour development unfeasible. But, due in large part to high transport costs, a new quarry was established. **This highlights that aggregate availability can act as either a catalyst or a hinderance for significant infrastructure projects.**
- Significant roading infrastructure is needed to support residential growth, particularly for greenfield development areas, to provide people with transport choices and improve travel capacity. The Penlink Corridor will require a significant amount of aggregate to construct a 7km transport connection between the Whangaparāoa Peninsula and SH1 at Redvale. Additionally, the project will include new local road connections and a bridge crossing at the Wēitī River. These works are estimated to be

[23] Recycled Aggregates on NZ roads - Lane (2017), in reference to a finding by MBIE
[24] Infrastructure resource study – infrastructure commission (2021).
[25] Aggregate supply and demand in New Zealand – Wilson et al. (2022). Report for Waka Kotahi
[26] Estimating the costs of an uncertain infrastructure pipeline – Infrastructure New Zealand and Infometrics (2023)
[27] Infrastructure Resources Study – The Infrastructure Commission (2021)

completed in late 2026 and will cost around $830m. Transport investment supports the growth of cities as they expand outwards and intensify.

- The now cancelled Lets' Get Wellington Moving (LGWM) was a joint initiative to make major investments in high-quality mass rapid transit, State Highway improvements, walking and cycling and public transport over the next 20 years. Several projects for the LGWM programme have been included in the national infrastructure pipeline, while a number remain under review or in planning. Regardless of how the work programme is scheduled or presented, the next two decades are likely to see strong investment activity in the Wellington region in response to existing pressure points as well as growth around the region. These projects are expected to demand substantial amounts of aggregate to deliver.

While roading takes up a large share of aggregate (65%), its uses span an array of sectors such as improving and maintaining water systems or park infrastructure. Residential development (associated with population growth) is another key driver of demand. On a per capita basis, between 9 tonnes and 10 tonnes of aggregate is used by each person, every year– this reflects aggregate that is used in housing developments, as well as well as the supporting infrastructure of roads, water-related infrastructure and parks and amenities – International experience suggests that the average school or hospital requires between 9,000t and 10,000t of aggregate[28]. Kāinga Ora Homes and Communities are currently undertaking significant redevelopment and urban transformation of the public housing estate across the country. Key urban transformation projects in Auckland currently underway include Mt Roskill, Mangere and Tamaki Precincts. These projects require substantial upgrades to stormwater, water supply, public space, and utility – all items that require considerable investment and aggregate.

Recent North Island weather events reinforce the need for resilience and responsiveness. At the start of 2023, floods in Auckland and Cyclone Gabrielle on the North Island's east coast devasted communities and businesses. In July 2023, the Treasury released details of its initial response package, including $275m (total operating) to the National Land Transport fund for immediate repairs to state highways, bridges and local roads[29]. This element was the largest single funding stream, showing that infrastructure is simultaneously vital, expensive and vulnerable.

The 2023 budget announced the National Resilience Plan to support significant medium- and long-term infrastructure investments[30]. With an initial funding of $6bn, it represents a key boost in both ambition and the resources to implement the infrastructure strategy. The draft[31] Government Policy Statement on Land Transport (GPS-LT) proposes a 34% funding (revenue) increase for the National Land Transport Fund, further exemplifying this shift. Having plentiful and local supplies of aggregate will enable funding for infrastructure investment to achieve its purposes at minimum cost. It will also ensure that the construction sector can respond to any rebuild activities after destructive natural disasters (weather or other hazards).

The National Construction Pipeline report from MBIE[32] forecasts that between 2021 and 2027, infrastructure will grow from one-fifth of total building and construction value to over one-quarter. As noted, a large proportion of infrastructure uses aggregate in its construction. With the anticipated growth of infrastructure

[28] Association of Equipment Manufacturers. North America. Published ratios adjusted using NZ information.
[29] Cabinet Paper – North Island Weather Events Initial Package, 11/04/2023
[30] Budget 2023
[31] Because the statement is a draft, it is subject to change. The points are included here indicatively.
[32] National Construction Pipeline report – MBIE, 2022

investment will come demand for inputs, which presents both challenges and opportunities that will shape the economic trajectory of the construction industry in the coming years. Policy makers and industry stakeholders must navigate the dynamics of this changing system to ensure the resilience and long-term viability of the infrastructure sector.

3 The Aggregate Industry

Aggregate is used in construction as part of concrete applications, as well as roading and drainage projects. It is also used across residential, community and business infrastructure development. Aggregate includes many product categories, with different sizes and grades influencing the final application and costs. The different products are used across society and in multiple dimensions of the economy. One of the most obvious uses relates to transport infrastructure through base course, chip seal and in concrete applications (e.g., in bridges, culverts and barriers).

The economic role of quality transport infrastructure in supporting movement and economic connections is well-known. As society grows and changes, development priorities change and shift. However, demand for core roading and water-related infrastructure remain a key part of the overall demand picture. In the absence of enough aggregate in appropriate locations, the cost to deliver new infrastructure escalates, reducing budgets that can be allocated to other projects.

As mentioned, aggregate has a wide range of applications, ranging from the key applications in roading, to also include:

- uses as a means of stabilising and reinforcement,
- in drainage applications,
- as base material under foundations,
- for concrete,
- to protect pipes, fill voids and to provide hard surfaces.

This section summarises historic aggregate production figures and derives a set of ratios that capture the relationship between aggregate use and population and economic growth patterns. The demand-supply ratios are applied in the analysis to illustrate anticipated demand levels and the associated costs/benefits that are reported in Section 4.

This section starts by discussing the distribution and composition of the aggregate sector, and then outlines existing production and demand patterns. Next, the supply constraints are highlighted, and the section concludes with commentary around alternatives, i.e., recycled aggregate, and the outlook.

3.1 Aggregate Production

The public data on aggregate production have limitations and additional work is needed to address data gaps and to mitigate their effects. This is a well-documented issue. In 2022 a report[33] for NZTA recommended to *"develop an aggregate data integration framework to standardise, collate and improve aggregate data information at both the national and regional levels where possible*". The available (official) information covering the aggregate section is the New Zealand Petroleum and Minerals (NZP&M) data. NZP&M is a government regulator that manages New Zealand's Crown minerals estate and administers the Crown Minerals Act. As part of that function, it collects regional-level data on aggregate production and publishes it

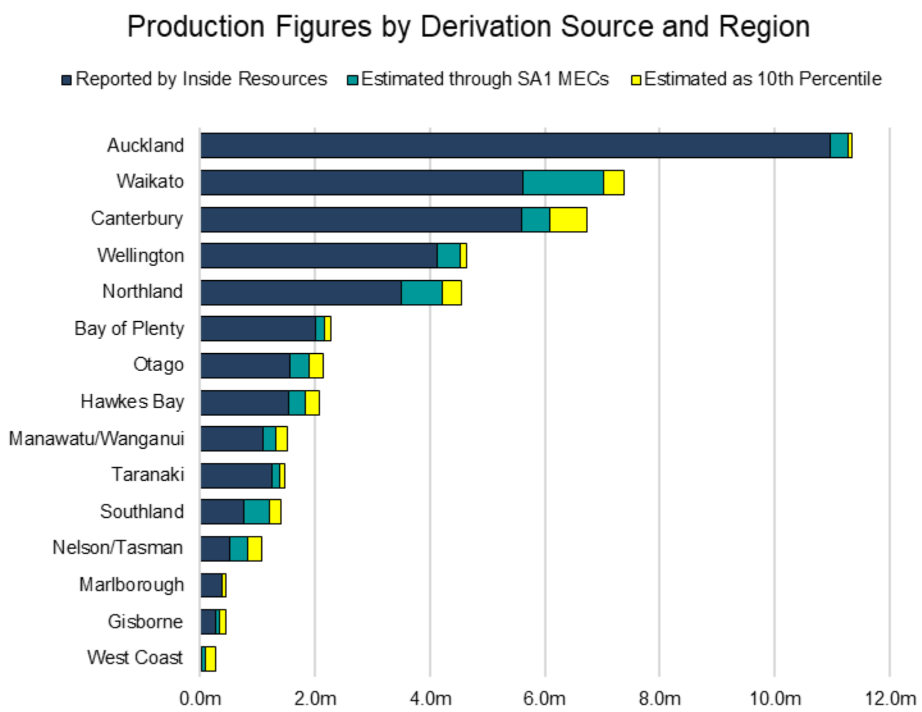
[33] Aggregate supply and demand in New Zealand – Wilson et al. (2022). Report for Waka Kotahi

on an annual basis, going back three decades. The data is collected via a voluntary survey. Historically, the response rate was 76%, but the current (2021) response rate is just 54%. This reduces the ability to use this data without any adjustments. This survey also precludes analysis at an individual quarry level, which is necessary for the modelling approach. Appendix 2 outlines the data gathering process covering:

- The Inside Resources data,
- Adjustments/estimates based on employment data, and
- Filling data gaps using imputed values.

Figure 3-1 shows estimated production values by region and the estimates. The majority of the data in each region comes directly from the Inside Resources database (82%).

Figure 3-1: Production Figures by derivation source



A proportion is estimated using employment data in quarry SA1s (11%). And the remaining data comes from a general assumption about the size of small quarries (7%). It is estimated that 47.9 million tonnes of aggregate are produced in New Zealand. Assessing this output against the literature and comparable studies verifies the data and underlying assumptions. The Infrastructure Commission's 2021 report derived an average per capita production of 8.4 tonnes. Using the 2022 population as reported by StatsNZ (5.1m), our estimates return a marginally higher per capita value of 9.3 tonnes – the different timeframes used is a possible reason for the difference, but the overall quantum is of a similar order of magnitude. This is within a reasonable range of previous work and is therefore considered viable. It is plausible that due to increases in infrastructure spending, current demand and supply exceeds the 2017 levels, on which that estimate was based. The Aggregate and Quarry Association of New Zealand(AQA) estimates demand for aggregate in New Zealand to be between 7 and 10 tonnes per capita[34]. Again, this confirms that the adjusted values appear to be consistent with other sources.

3.2 Aggregate Demand

Because it is not economical to transport aggregate over large distances, we assume that New Zealand does not import any substantial quantities. Therefore, production is approximately equal to demand. An analysis of the UN Comtrade database found that New Zealand imported $1.1m[35] of aggregate in 2022, though this is an insignificant amount given the total volumes traded domestically. This small portion relates to specialist stones, aggregate used in industrial processes[36] and decorative purposes. In addition, these imports are not reflected in official StatsNZ import data, so it could relate to specialist aggregate that is used in industrial processes.

While some produced aggregate might be stored temporarily or stockpiled, the bulk is produced in anticipation of demand. Any demand is subject to the price of aggregate and the equilibrium is dynamic. If aggregate was far cheaper, more construction projects would become cost-effective, increasing the demand for the resource. It is reasonable to assume that quarries only produce to a level that will be demanded given an understanding of their target clients, market conditions and expected level of demand.

The spatial distribution of demand is nuanced and reflects demand induced through urban growth and economic activity. Aggregate is used for the construction of structures and infrastructure, and this is concentrated in urban centres. However, the length of roads per person is greater in rural areas. A more extensive road network is required to connect remote communities, farms and settlements to each other and services.

Regional demand is estimated by analysing weight-adjusted population. Each region's aggregate demand is equal to its population multiplied by the per capita production on that island. This yields the per capita demand (supply) values below:

- North Island 9.1 tonnes per capita,
- South Island 10.1 tonnes per capita.

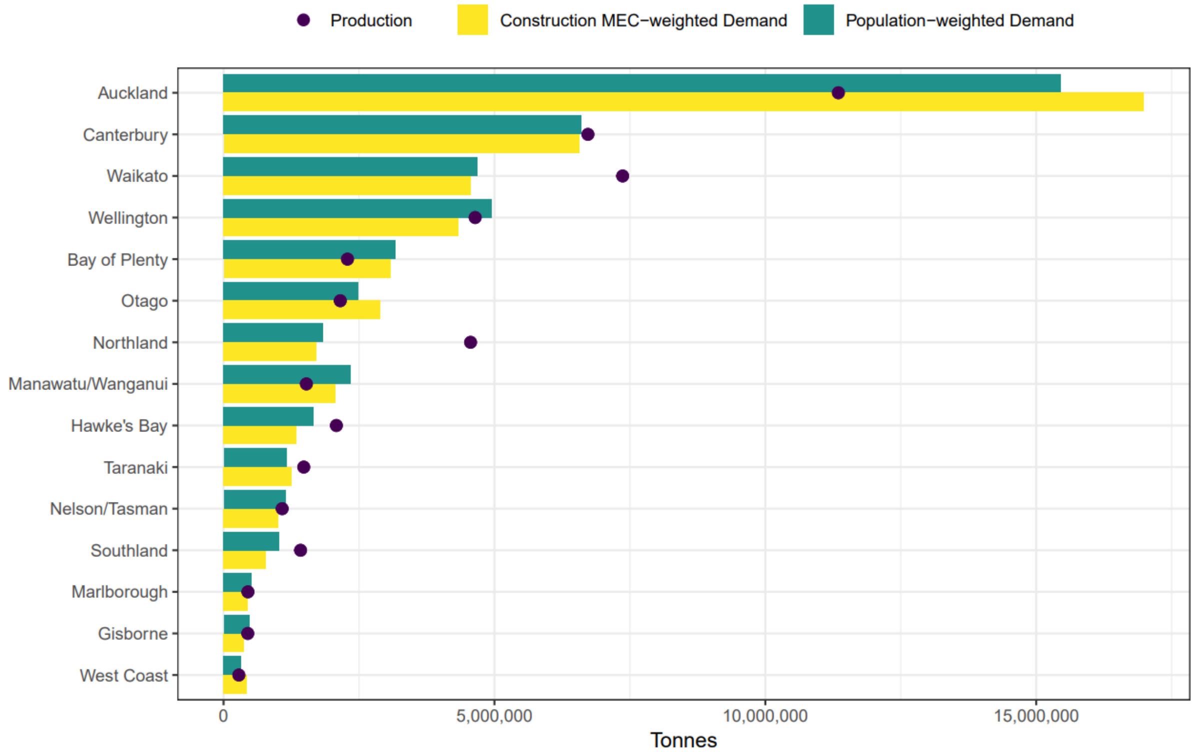
This averages out to equal 9.3 tonnes across the country.

We also conducted some sensitivity analysis by estimating demand using construction employment derivatives. Using this methodology, regional demand is apportioned according to the share of total construction workers recorded in that region[37]. The employment data is based on M.E proprietary regional database that reflects employment counts that have been modified for working proprietors (referred to a Modified Employee Counts). Figure 3-2 shows the estimated regional demand levels as well as the production estimates. Both methods of estimating population demand are included in the graph the demonstrate the

[34] AQA – The Tyranny of Distance
[35] Why do construction input costs change – infrastructure commission (2023)
[36] This includes powers and granules, and chippings. Specialist stone, such as marble is included in this dataset. The average cost was $657 per tonne, so clearly not comparable with construction aggregate.
[37] As with the population approach, each region is treated as its own entity and no aggregate is transported between the islands.

subtle differences. Hereafter, the report's analysis only refers to the population-driven demand. Results from the construction method are contained in the appendix.

Figure 3-2. Regional Production and Demand Estimates



The relative size of the Auckland market against the rest of New Zealand is evident – demand levels are more than double that estimated for second largest region in terms of aggrage demand – Canterbury. The imbalance between Auckland's demand and local supply is evident, and the level of imports from Waikato and Northland is implied in the difference between demand and supply (supply being greater than demand) in these locations.

In Wellington, the population-weighted demand exceeds production, whereas using construction employment, production exceeds demand, returning a deficit position. Under both approaches, most regions with large cities – Auckland, Bay of Plenty and Manawatu-Whanganui – tend to have deficits, meaning significant amounts of aggregate need to be imported from the neighbouring regions. However, the situation in Canterbury differs, with the main urban area (Christchurch, Selwyn and Waimakariri) hosting a large share of activity, but the wider region contributing to aggregate availability. Some regions have large surpluses, notably Waikato and Northland, because the quarries in these regions have historically serviced the deficit in Auckland and the Bay of Plenty.

Regions with a supply surplus i.e., where production levels exceed local demand, export aggregate to other regions. These supply patterns are used in Section 4 to estimate the wider costs and benefits associated with distribution pattern and transport distances.

3.3 Supply constraints

At any given moment, production is limited by the industry's productive capacity and consented maximums. Increasing production in response to demand shifts can only happen if a quarry is operating below its consented thresholds. If demand for aggregate exceeds this quantum, unless other quarries can meet it, shortages will ensue. It is unlikely that quarries will be built or expanded in response to short-term demand pressures, especially given the uncertainty and financial risk associated with the application process. No exceptions to consent conditions exist to help meet short-term pressures. Forward planning of major projects will help to ensure sufficiency, but this will require a conducive consenting process.

Expansion of a quarry's production is reliant on the means to extract more product, such as labour, electricity and machinery. These factors of production cannot always be obtained instantly for reasons including that:

- labour requires training,
- electricity requires costly grid infrastructure, and
- machinery is highly specialised and takes time to manufacture.

It is therefore not always possible to respond to volatile spikes in demand, even when a quarry has capacity within its consent conditions. In addition, consent conditions can also limit the quantum of aggregate that can be delivered to where it is needed (e.g., limits on operational hours and truck movement can put a cap on useable capacity).

Geography or other physical constraints, such as proximity to roads or site boundaries, might render expansion unsuitable at some sites. Rock is a finite resource and once the suitable material is extracted from a site, production must cease. New Zealand has abundant rock reserves, as identified in the Infrastructure Commission's aggregate opportunities report, though these are not all located on the sites of existing quarries.

In a survey conducted as part of NZTA research into the key issues in the supply of aggregates, respondents cited that:

- the consenting of aggregate extraction is becoming more difficult (+70%),
- there is little forward planning for the use of aggregates in the region (+60%),
- there is high competition for aggregates (+40%)[38].

Consents are an integral feature of aggregate production. However, the consenting process is expensive, lengthy, and uncertain. NZTA research[39] shows that what was already a protracted process is becoming increasingly difficult. The process is undermined by inconsistent information requirements and a large variation in process requirements/complexity.

Quarries operate in a heavily regulated environment. Prospective quarries must acquire consents to begin extraction and some existing consents expire and must be renewed if production is to continue. Complementary activities required for quarrying also require permissions, such as water permits or discharge consents. Efficient markets are characterised by low barriers to entry and no costs of information. The aggregate market, by contrast, consistently faces significant barriers and information costs. Some of these features are a necessity given the characteristics of production: because land has a cost and appropriate land is required to produce aggregate, there will always be some barriers to entry. However, the consenting

[38] Aggregate supply and demand in New Zealand – Wilson et al. (2022). Report for NZTA
[39] Aggregate supply and demand in New Zealand – Wilson et al. (2022). Report for NZTA

process in its current form introduces significant costs, which impinge on the market's efficiency and therefore ability to act in the interest of all New Zealanders.

Obtaining a consent takes a long time: five or more years in some cases[40]. Accordingly, any enterprise must absorb the costs of foregone production or use of its factors of production for alternative uses. There is also a risk that the consent will not be issued, meaning costs cannot be offset. This feature of the process also describes the information costs for prospective producers. Uncertainty around whether a consent would be issued for land will deter its purchase if the proposed use would be as a quarry. The current consenting process is seen as inhibiting the ability of supply to expand and respond to new demand pressures, which will reduce overall supply at critical times and result in a higher delivered price.

The existing consent structure can also hinder quarries' ability to increase output. Production levels tend to be increased in two main ways, operating for longer or employing more capital. However, due to social considerations and potential adverse effects, such as noise, consents often restrict hours of operation, or the number of trucks permitted to enter/exit a premises per day. These types of limitations reduce the working capacity of quarry operators, and simply relocate the supply to other locations, and often ignores the overall costs of such moves.

Expanding existing quarry sites are not the only options for increasing supply. New sites can obtain consents and begin operation. Compared with brownfield sites, the time taken for a greenfield site to become fully operational tends to be longer. Full-scale production might take between 5 and 15 years to realise. It takes time to obtain consents, develop a site, train staff, acquire machinery and integrate systems of production. This also overlooks the decision-making process whereby quarry operators either acquire a site or initiate a process to change the use of the land. The financial investment of establishing a new quarry is usually significantly greater than extending an existing one. New sites might require upgrades to the surrounding road network or other infrastructure to facilitate its activities. Residents in the locality of a new quarry are often resistant to their introduction due to dust, noise pollution, operation visibility and the increase in heavy goods vehicles.

3.3.1 National Policy Statements

The recent National Policy Statement for Indigenous Biodiversity (NPS-IB) seeks to maintain biodiversity across New Zealand and limit associated issues[41]. Clause 3.10(1) iii. stipulates that aggregate extraction may be exempted from restrictions where it:

"provides significant national or regional public benefit that could not otherwise be achieved using resources within New Zealand".

Depending on the interpretation of this phrasing, new quarries might always or never comply with its principles. Given New Zealand's ample natural resources, the rock from any given site could nearly always be acquired elsewhere, if the only goal was to obtain a specific quantity and one could acquire the land and consent to do so. Equally, any site is likely to have benefits by putting downward pressure on aggregate prices, leading to a host of downstream benefits, as will be explored in the next section. Because of difficulties

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[40] Infrastructure resource study – infrastructure commission (2021).
[41] Ministry for Environment – National Policy Statement for Indigenous Biodiversity (2023), accessed 05/12/2023.

estimating these benefits with accuracy, it is unclear whether new quarry operations would be able to demonstrate compliance with the NPS-IB.

The National Policy Statement for Highly Productive Land is another policy position that adds complexity that are leading to challenges. The NPS-HPL has similar wording around some exemptions (e.g., clause 3.9(2)(j)(iv)). This clause has already been referred to by Independent Commissioners as a reason to decline resource consent for a new quarry in the Tasman District[42].

Resource extraction in New Zealand must balance environmental impacts with the other needs of its population. The extraction process can disrupt local ecosystems, leading to habitat loss and potential threats to native flora and fauna. It also produces emissions. Developing a framework which promotes sustainable practices is therefore imperative.

There are other policy frameworks that impact quarrying's ability to expand and gain consent. There is now some fluidity in the national policy statement framework due to the change in government. But the potential impacts of the policy framework can be considerable. Work for the Ministry for the Environment (MfE)[43] reviewed the costs and benefits of consenting pathways associated with the NPS-Freshwater Management. That work identifies the critical nature of aggregate to growth and acknowledges the potentially constraining effect of policy on the sector. The role of high-quality aggregate in supporting growth is emphasised and the need to provide flexibility (for wetland regulation) to support quarries' ability to expand or establish in key locations are highlighted. This is because aggregate is linked to, and facilitates the development of, critical infrastructure – but also to facilitate the development of urban growth (dwellings, commercial buildings, roads and footpaths). The need to provide a specific consenting pathway for quarrying in the NPS-FW context was motivated by the following benefits:

- the size of the sector (in terms of employment);
- the potential and ability to expand to support increasing demand; and
- the avoided transport costs associated with accessing alternative sources across great distances, and the additional emissions and social costs.

While the assessment for MfE did not quantify the size of the potential benefits (of providing the consenting pathway), the risks of sterilising some rock resources by preventing future activity, or constraining expansion are highlighted.

3.4 Recycled aggregate – an alternative?

One option for alleviating the costs of supply constraints would be increased use of recycled aggregate as a substitute for virgin products. Consistent recommendations have been made to pivot towards recycled aggregate where commercially viable. A 2021 study by the Infrastructure Commission made specific recycled aggregate standards its first recommendation[44]. In some cases, recycled materials can outperform virgin aggregate[45]. It can also have the advantage of being located close to demand sites, minimising transport

[42] Resource consent applications RM200488, RM2000489, RM220578 – CJ Industries Limited. Decision of Hearing Commissioner dated 28 June 2023, issued 29 June 2023.
[43] Report by M.E, 2022.
[44] Infrastructure resource study – infrastructure commission (2021). The status of the report is unknown.
[45] Aggregate supply and demand in New Zealand – Wilson et al. (2022). Report for Waka Kotahi

distances. However, recycled aggregate is not a clear-cut solution and cannot always substitute for natural aggregate. According to NZTA[46] the challenges associated with using recycled products relate to the assuring quality and can be achieved through investing in technology to:

- sort input material,
- production processing,
- provide quality assurance and auditing.

The reasons for New Zealand's low take-up of recycled aggregate are broad and not confined to one easily actionable policy matter. Barriers exist on both the demand and supply sides. A NZTA report in 2018[47] explored the barriers to uptake of recycled aggregate use on New Zealand roads, finding that despite receptiveness to use recycled materials, many respondents (53%) felt constrained in how they could use such materials, or didn't know enough to make good decisions around use (27%). Policy was the most identified barrier to using alternative materials, with 40% of respondents identifying policy as an extreme barrier, notably via the issued guidance on acceptability of use. Uncertain and inconsistent demand, in parallel with low investment in supply chains was, cited as a notable barrier.

Costs are a factor on both the demand and supply sides. If recycled aggregate was comparably cheaper, uptake would increase. However, the cost is determined by:

- the availability of (quantum) and location of input material;
- the transport cost of carting it to a processing facility – most of which are quarries; and
- the processing costs, i.e., the activity cost of crushing the recycled aggregate[48].

Given these costs, recycling aggregate is likely to be suitable in urban centres where alternative supply is limited, such as Auckland or Wellington, but not commercially feasible in many other locations. A 2020 AQA paper recommended work to establish the incentives or penalties needed to make recycling viable, stating that the technology is not adequate yet, costs are too high, and consumers are still reluctant to adopt recycled materials[49]. Research has recommended identifying and targeting areas where there are opportunities for increased use of recycled materials and natural aggregate supply constraints, as well as encouraging decision-makers and Road Controlling Authorities to initialise shifts[50]. These changes will require policy to initiate any meaningful change.

3.5 Outlook

Having a responsive sector is vital to support the wider construction and infrastructure sectors in addressing the challenges posed by population growth as well as those presenting through infrastructure responses to natural hazards and the rebuilding after weather events.

It is also crucial for any country with development ambitions. The output data above presents one snapshot in time. New Zealand's population is projected to grow significantly over the coming years. In the decade from 2023 to 2033, under StatsNZ's medium population growth scenario, the population is forecast to grow from 5.1m to 5.6m (8%). Extending out to 2048, this growth is forecast to be 18%. Under the high scenario, this is

[46] A review of aggregates for land transport infrastructure in New Zealand – Wilson et al., (2022).
[47] Recycled aggregates on New Zealand roads: Barriers to uptake and drivers for change. NZTA (2018)
[48] Infrastructure resource study – infrastructure commission (2021).
[49] Briefing on the quarry section and aggregate supply – AQA (2020)
[50] Aggregate supply and demand in New Zealand – Wilson et al. (2022). Report for Waka Kotahi

28%. Table 3-1 shows growth projections for selected regions under three StatsNZ scenarios. These regions, which contain large urban centres, are all expected to grow at least as fast as the country under the medium- and high-growth scenarios. Such growth will be accompanied by a significant increase in demand for aggregate.

Table 3-1. Population Growth Under StatsNZ Scenarios, 2023 - 2048

Region	Low	Medium	High
Auckland	10%	25%	40%
Waikato	10%	23%	36%
Bay of Plenty	5%	18%	32%
Canterbury	4%	18%	33%
Total New Zealand	9%	18%	28%

Natural disasters also pose a significant threat to the country. The country experiences around 20,000 earthquakes a year, most of which are small[51]. However, given its situation on high-risk faults, including the Alpine Fault and numerous others across both islands, the potential damage to infrastructure is significant. Rebuilding Christchurch after the earthquakes in 2010/2011 was affected by rising construction costs because of material shortages, which compounded labour shortfalls. The annual price increase in construction costs in Canterbury was 10% in 2012 and 2013, greatly exceeding the national average[52]. Ideally, there would be greater capability to recycle materials in such an event. However, in the absence of suitable and operational recycling plants, reliable access to aggregate is a necessity. In addition, when recovering from a largescale event like an earthquake, timely delivery without unnecessary delays is critical.

Wilson et al. recommended that planning should be done with a long-term horizon of at least 50 years[53]. At present, no such strategic thinking is in place and the sector is therefore suffering. Even immediate policy levers are likely to only alleviate industry pressures down the line.

Under existing policy frameworks, it is very difficult for aggregate production to scale up through expansion or through new quarrying. As existing consents are consumed, replacing these volumes with new quarries or expanding existing quarries will need to seek new regulatory approvals, but these are complex, time-consuming, expensive and uncertain processes. Increasing production requires a suitable pathway for consenting new quarries and expansion of existing ones. This must operate under a framework that balances a forward-looking outlook of opportunities and risks associated with the aggregate market with broader considerations of biodiversity and the implications of quarrying.

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[51] Virtual New Zealand – New Zealand Fault Lines Map
[52] StatsNZ – Canterbury: the rebuild by the numbers
[53] Aggregate supply and demand in New Zealand – Wilson et al. (2022). Report for Waka Kotahi

4 Costs and benefits

Everyone uses aggregate every day even if that use is invisible through infrastructure, roads, and housing. The use is indirect through infrastructure and the built environment people interact with or use. Without aggregate, the benefits of these structures and the activities they support cannot be obtained. Connecting the conditions under which the aggregate market operates to such end uses is uncertain. While it is worth being cognisant of the links between infrastructure investment and the benefits (and costs) society derives from its use, this section takes a much narrower focus. Instead of attempting to link the value of aggregate to infrastructure's benefits, we estimate the direct costs and benefits from moving aggregate to where it is used. While this results in a lower $-benefit, it provides a better indication of the direct costs of aggregate access existing in its current form. A scenario approach with examples is used to show the extra costs that would be loaded onto society if aggregate cannot be accessed close to where it is required.

At its core, the cost associated with accessing aggregate from alternative sources is a transport problem. Transporting aggregate is costly from direct transport costs as well as the associated environmental and social perspectives. The further aggregate must travel, the higher these associated costs are. Generalised estimates of costs can therefore be distilled into a function of distance. How far the aggregate from any given quarry travels is highly individualised, based on local demand and competition, as well as whether the rock is suitable for uses on projects nearby. Quarries can deliver in bulk to distribution centres with stockpiles. Smaller quarries might not have a significant standing fleet of trucks to deliver aggregate, instead using ad hoc demand as a determinant of operational decisions.

Using estimates of regional demand and production, we present a picture of New Zealand which aids an understanding of transport flows and movements. It is these patterns that drive the costs. Changing the transport patterns in a way that increases total transport distances relative to demand levels, increases the costs. Avoided costs are seen as benefits.

This section reports the results of the analysis and describes the costs associated with importing and exporting aggregate between regions in New Zealand.

4.1 Estimating the current patterns

As already established, the transport function is the core determinant of total costs associated with delivering aggregate to the market. Two discrete modelling approaches were used to estimate the transport function.

- Approach 1 uses a regional lens and estimates the transport function.
- Approach 2 applies a major urban economy lens.

Quarry locations, spatial patterns and anticipated transport routes were modelled using geo-spatial and constrained optimisation techniques. Appendix 3 provides additional information about this modelling.

4.1.1 Approach 1: Regional lens

Under the regional-lens approach, we estimate the minimum (total) distance that aggregate must be transported around New Zealand for each region's demand to be satisfied. The spatial allocation process seeks to minimize transport distances and allocates supply from quarries to the nearest location with demand. We assume that total supply equals total demand, and consider the North and South Islands in isolation, that is, there is no aggregate imports or exports between the two islands. We use demand based on population weights. Appendix 5 contains a sensitivity analysis that is based on an alternative approach that uses the regional share of construction workers. Each region has either a surplus or deficit of aggregate (Figure 3-2).

An origin-destination matrix mapping each quarry to every region (per island) underpins the spatial/transport analysis and is based on the major road network between regions. A constrained optimisation algorithm then minimises the loss function. Essentially, this solves a series of equations to identify the quarries that would need to export a share of their aggregate to other regions[54] so that supply equals demand across the islands, but with the lowest possible transport distance. **This calculates the minimum total distance that aggregate would have to travel in each island if current production was allocated between regions with maximum efficiency**. The results suggest that in some regions, the most economical outcome involves exporting a share of aggregate and some regions importing a share to address any surplus/deficit issues.

This represents a theoretical estimate of minimum travel distance with inter-regional import/exports patterns actively working and individual quarries or aggregate users working to minimise transport costs. The costs can therefore be considered as the 'at least' costs and any effort to reduce costs further would need to see an expansion of existing quarries and initialising of new quarries with a view to improve local (within region) delivery or establishing new operations. All the import costs are incurred due to quarries being located outside of the regions where aggregate is demanded. All the presented costs would therefore be alleviated if the quarries were instead located on the region borders, or if new quarries were to be built inside the region. The true level of costs is higher because this aggregate will have to travel further than the crossing point. Additionally, allocative efficiency is unlikely in a disaggregated market.

The models produce an output with one row per quarry per region it exports to. It is possible for a quarry to export to more than one region. In actuality, the models never require a quarry to do this because the algorithm is optimised by the quarry exporting to one region and, if needed, sending the rest of its production to its origin region.

4.1.2 Approach 2: Major urban economy lens

With the second approach, instead of measuring the distance to regional borders, it is assumed that aggregate is delivered to the major urban centre within each region. This means that the travel distance will significantly increase. However, as with the regional approach, the idiosyncrasies of supply within each region are not reflected. Information limitations mean that this resolution cannot be robustly integrated into the modelling structure.

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[54] Where region borders have numerous crossing points, the closest one to each individual quarry is used. This means that a conservative position is maintained, and the actual costs are liable to be higher because the true transport route could be longer than that used in this estimate.

4.1.3 Supply-demand balances

The results are summarised below, and Approach 1 is presented first (see Table 4-1). The table reports regional production, demand, the associated output gap, and the export/input estimates. The output gap shows the different between regional supply and demand. If supply is greater than demand, then that region has a surplus and can export aggregate. If a region has a deficit, then it must import from other regions.

The logic applying in the table is:

$$D_i = P_i + (M_j - X_i)$$

Where:

D_i = Demand in the region

P_i = Production in the region

M_j = Imports from other regions if a local deficit exists

X_i = Exports to other regions

Table 4-1. Region Outputs Results (Million Tonnes)

		Population weighted demand			
Region	Production (P)	Demand (D)	Output gap (P - D)	Exports (X)	Imports (M)
North Island					
Northland	4.6	1.8	2.7	2.7	0.0
Auckland	11.3	15.5	-4.1	0.0	4.1
Waikato	7.4	4.7	2.7	2.7	0.0
Bay of Plenty	2.3	3.2	-0.9	0.3	1.2
Gisborne	0.4	0.5	0.0	0.3	0.3
Taranaki	1.5	1.2	0.3	0.3	0.0
Hawke's Bay	2.1	1.7	0.4	0.8	0.4
Manawatu/Wanganui	1.5	2.4	-0.8	0.3	1.1
Wellington	4.6	5.0	-0.3	0.0	0.3
South Island					
Nelson/Tasman	1.1	1.1	-0.1	0.0	0.1
Marlborough	0.5	0.5	-0.1	0.0	0.1
Canterbury	6.7	6.6	0.1	0.2	0.0
Otago	2.2	2.5	-0.3	0.1	0.4
West Coast	0.3	0.3	0.0	0.0	0.0
Southland	1.4	1.0	0.4	0.4	0.0
Total	47.9	47.9	0.0	8.0	8.0

Auckland has the largest output deficit, 4.1m tonnes. Northland and Waikato are both net exporters, exporting around 2.7m tonnes each. This is mostly Auckland and the Bay of Plenty. Total exports (imports) exceed the total deficit (surplus) due to the optimisation conditions. The absolute sum of deficits (you get the same value if you add the surpluses) is equal to 6.7m. The total imports and exports are 8.0m tonnes, however. This arises because the distance travelled is minimised by some regions exporting extra and this being made up for by imports. Crucially, the analysis suggests that Southland-region has a surplus, the optimisation conditions determine that it exports this to Otago – the only region where Southland has a major road crossing. However, the patterns are based on available data and local nuances, such as higher per-capita demand in Southland could mean that local production services Southland demand patterns. At the same time, the relative productivity of Southland quarries could be marginally lower, suggesting that the estimated output gap in Southland and Otago could be close to zero – negating the need for inter-regional transportation.

Table 4-2 contains the outputs delivered using Approach 2, i.e., using the major urban centre as destination for each region. The demand and production are therefore the same. How much is exported or imported, however, changes due to the adjusted relative distances of quarries to the destinations.

Table 4-2. City Outputs Results (Million Tonnes)

Region	Production (P)	Population weighted demand: Demand (D)	Output gap (P - D)	Exports (X)	Imports (M)
North Island					
Northland	4.6	1.8	2.7	2.7	0.0
Auckland	11.3	15.5	-4.1	0.0	4.1
Waikato	7.4	4.7	2.7	3.0	0.4
Bay of Plenty	2.3	3.2	-0.9	0.0	0.9
Gisborne	0.4	0.5	0.0	0.0	0.0
Taranaki	1.5	1.2	0.3	1.1	0.8
Hawke's Bay	2.1	1.7	0.4	0.4	0.0
Manawatu/Wanganui	1.5	2.4	-0.8	0.3	1.1
Wellington	4.6	5.0	-0.3	0.0	0.3
South Island					
Nelson/Tasman	1.1	1.1	-0.1	0.0	0.1
Marlborough	0.5	0.5	-0.1	0.1	0.2
Canterbury	6.7	6.6	0.1	0.2	0.1
Otago	2.2	2.5	-0.3	0.1	0.4
West Coast	0.3	0.3	0.0	0.0	0.0
Southland	1.4	1.0	0.4	0.4	0.0
Total	47.9	47.9	0.0	8.3	8.3

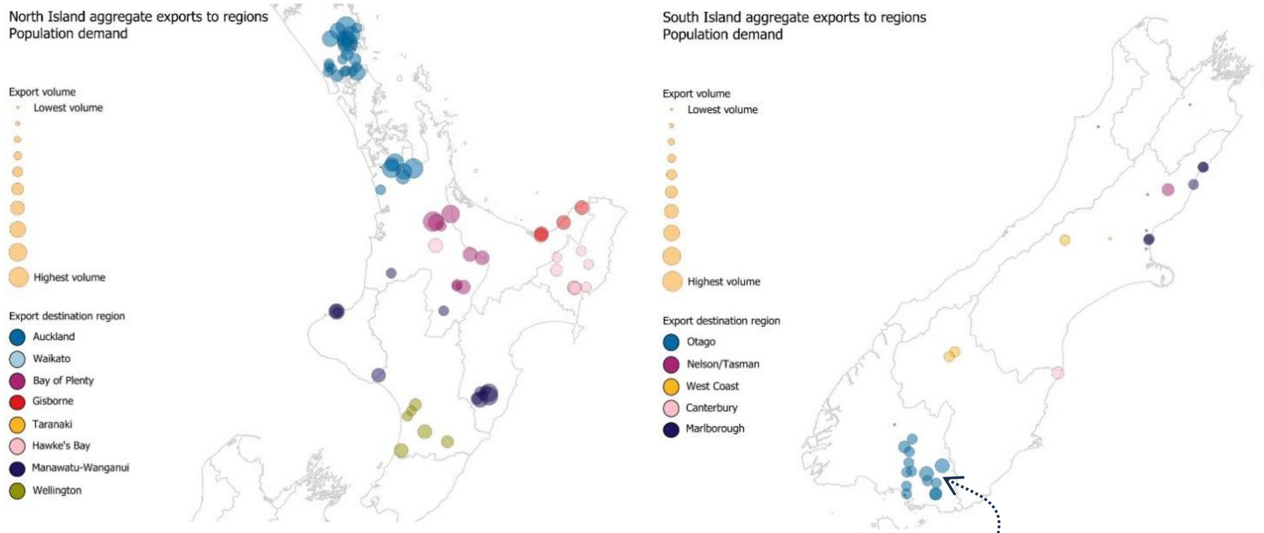
When using Approach 2, there are some key differences in the quantum of exports and imports required to address the local surplus or nearby deficit for various regions. The exports and imports interactions between cities are spatially dependent. These differences are observed as a result of the distance in which the output has to travel.

The export movements to different regions quarries from which the aggregate would be delivered under the modelling scenarios are shown below using maps. Figure 4-1 reports the results for Approach 1, and Figure 4-2 reports Approach 2. In the maps, the bubbles represent quarries which export some of their production beyond their host region. The size of the dot indicates the amount being exported. Each importing region is assigned a colour to show where the aggregate is being sent with a legend showing the key.

The tables and maps above are built from individual data frames containing each exporting quarry, its distance to the region border or urban centre, and the quantum being exported. From these individual rows, we estimate the total number of loads and travel distances, based on the distance from the quarry to destination point. It is these distances that are used to estimate the transport costs, emission costs and social costs.

These outputs are shown in Table 4-3 and Table 4-4. These tables show the delivered distance. In practice, under any delivery or collection system, it is reasonable to account for the total travel distance being an outbound journey plus a return one, with no stops on the way. This fits the methodological objective, which is seeking to isolate the costs of delivering to a regional border or urban centre. If the aggregate was to be collected, it would still be reasonable to assume that the collector would drive from the destination location, making the total travel distance equal to the delivered distance multiplied by 2. There would be opportunities for cross-hauling (i.e., transport another good for the return trip), though estimating this would be overly uncertain. For the environmental cost calculations, the delivered distance and return distance are treated separately due to differences in truck weights, which affect emissions.

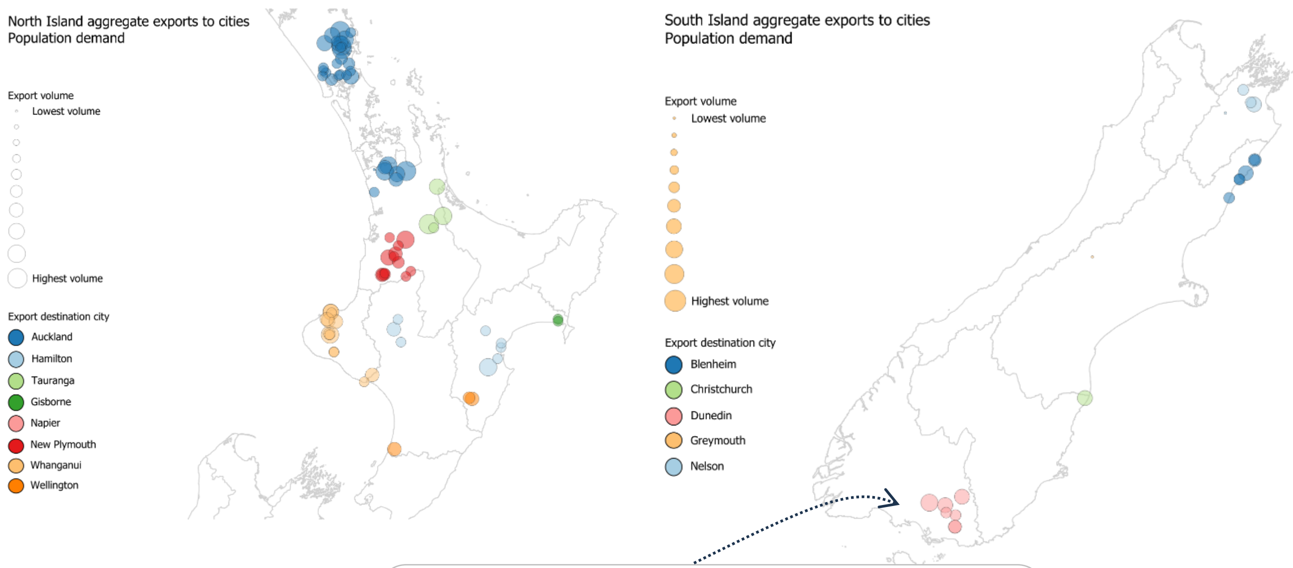
Figure 4-1: Approach 1: Export patterns



Important caveat:
The spatial patterns are based on available data, but this is limited and does not reflect local nuances. Additional, work is needed to refine the underlying information. These flows are likely to overstate the interregional (Southland-Otago) flows and could be due to either Southland's demand patterns differing from observed patterns, or Otago's production patterns being higher than estimated.

Figure 4-2: Approach 2: Export patterns

Population weighted



Important caveat:
The spatial patterns are based on available data but this is limited and does not reflect local nuances. Additional, work is needed to refine the underlying information. These flows are likely to overstate the interregional (Southland-Otago) flows, and could be due to either Southland's demand patterns differing from observed patterns, or Otago's production patterns being higher than estimated.

Table 4-3. Region Models Loads and Distances

Region	Exported To	Loads	Delivered Distance (kms)	Km Tonnes
Northland	Auckland	94,871	6,751,125	390.9m
Waikato	Auckland	46,547	793,002	46.9m
Waikato	Bay of Plenty	40,035	698,231	40.5m
Bay of Plenty	Gisborne	9,715	9,853	0.6m
Gisborne	Hawke's Bay	10,043	684,165	35.1m
Waikato	Hawke's Bay	3,458	341,455	20.5m
Hawke's Bay	Manawatu/Wanga	27,106	964,521	55.8m
Taranaki	Manawatu/Wanga	10,993	75,120	4.3m
Waikato	Manawatu/Wanga	1,253	39,028	1.9m
Manawatu/Wanganui	Wellington	10,315	440,625	26.4m
Canterbury	Nelson/Tasman	1,986	187,456	9.1m
Marlborough	Nelson/Tasman	394	104	0.0m
West Coast	Nelson/Tasman	151	6,101	0.2m
Canterbury	Marlborough	3,652	256,531	9.4m
Otago	Canterbury	1,104	155	0.0m
Southland	Otago	14,998	651,445	31.6m
Canterbury	West Coast	1,200	93,139	3.4m
Otago	West Coast	1,567	254,795	9.2m
Total		**279,389**	**12.2m**	**685.9m**

Table 4-4. Urban Centres Models Loads and Distances

Region	Exported To	Loads	Delivered Distance (kms)	Km Tonnes
Northland	Auckland	94,871	14,767,474	851.1m
Waikato	Auckland	46,547	2,549,419	151.1m
Hawke's Bay	Waikato	8,517	2,554,312	137.2m
Manawatu/Wanganui	Waikato	4,900	1,017,632	52.9m
Waikato	Bay of Plenty	29,694	1,712,392	101.6m
Hawke's Bay	Gisborne	1,541	101,080	3.6m
Waikato	Taranaki	27,843	4,954,395	277.2m
Taranaki	Manawatu/Wanganui	38,209	4,859,303	282.9m
Hawke's Bay	Wellington	5,417	1,348,764	80.9m
Manawatu/Wanganui	Wellington	4,898	420,344	25.2m
Marlborough	Nelson/Tasman	4,273	380,191	19.0m
Canterbury	Marlborough	6,485	864,196	46.9m
Otago	Canterbury	2,044	458,005	27.5m
Southland	Otago	13,578	2,396,563	137.3m
Canterbury	West Coast	219	8,545	0.3m
Total		**289,035**	**38.4m**	**2,194.6m**

There is a large increase in the delivered distance when using the point in urban centres, compared with the regional border. Total delivered distances increase by around 3 times. This is not universal, however. The increase is larger when urban centres are particularly far from regional boundaries with no alternative quarries.

We calculate the kilometre tonnes for the total journey distance of trucks, which equals the delivered distance * the truck load weight * 2, where the truck load weights are determined by the quarry size and are either 30 tonnes or 18 tonnes.

Even before adding costs to these figures, their size should be noted. The extra delivered distance is clearly going to impose an array of burdens. The potential delivered distances are vast when using the urban centres model across both the construction employment and population demand model. As distance delivered increases, the costs associated with drivers (monetary), emissions and social risks also increase. Overall, there are significant costs associated with getting the input to the required destination, and the ongoing road infrastructure needs to deliver the material.

4.2 Costs and Benefits

The distances and supply patterns (volumes) shown in the preceding sections are combined with cost parameters to estimate the total costs associated with delivering aggregate to the points where it is used.

The cost parameters are described, followed by the estimated costs. Putting the data in these terms helps to demonstrate the scale of impact attributable to additional travel distance. They do not capture all impacts, however, necessitating a discussion of those factors which we do not monetize in section 4.4.

4.2.1 Cost parameters

The costs and benefits are based on the transport values (volume and distance), which are then used to estimate:

- The direct transport costs,
- Environmental costs, and
- Social costs.

Transport costs

The transport costs for aggregate are calculated on a per tonne basis. Although there is likely to be slightly higher costs for extremely short travel distances, we have assumed that moving aggregate 1km will incur a cost of $0.38/tonne/km, which is at the bottom end of the costs range used in similar studies – some transport costs can be as high as $0.60/t/km. Costs are not homogenous and depend on many factors such as the attributes of the quarry, quantity, quality, production methods and destination. However, quarries must compete on price and $0.38 has been identified as a reliable representation of a value at the lower end of delivered prices at present. The cost is assumed to be based on the truck load and is an average for the delivery and return journey.

Emissions costs

A set of emissions factors are used to translate the vehicle kilometres into emission-related costs. These factors and the associated methodology are sourced from New Zealand Transport Agency's Vehicle Emissions

Prediction Model (VEPM v6.3) and the Monetised Benefits and Costs Manual[55]. Table 4-5 shows these values. For the cost per tonne we use the rural cost, given nearly all the distance travelled in this analysis will occur in rural areas. Costs in urban areas are significantly higher. Depending on the pollutant, the urban costs are between 17 and 644 times higher than the rural ones, due to population densities experiencing the pollution. All the values are shown in 2023 prices and in the base year 2023.

Table 4-5. Emissions factors

	Emission costs and factors				
	CO	NOx	PM2.5	VOC	CO2-e
Cost/tonne (Rural)	$0.23	$28,843	$58,880	$73	$94
Cost/tonne (Urban)	$5.84	$1,038,788	$1,024,422	$47,193	$94
Emissions factors 2023 (g/tonne) Diesel Articulated	1.36-1.37	4.58-4.67	0.17-0.18	0.13	675.78-720.13

It is important to delineate between the emissions factors and what they capture. Other than the carbon dioxide price, the pollutant costs are those attributed to their damaging effect on human health. The carbon dioxide price listed is the shadow price of carbon, which places a value on emissions, incorporating the marginal cost of achieving New Zealand's emissions targets. It is based on the cost of emission abatement and keeping emissions consistent with international agreements, rather than being a social cost of carbon. This price is agreed across government to represent the economic impact of carbon for transport activities.

Social costs

Each additional vehicle on the road increases the chance of crashes, injuries and fatalities. The Ministry of Transport produces a report on the Social Cost of Road Crashes and Injuries[56], which is used alongside other data published by the Ministry to derive a social cost per 100 million km driven by trucks – the cost per instance factor is the risk factor multiplied by the social cost per incidence. Table 4-6 reports the estimated values. These values only incorporate a few of the social costs associated with additional travel distances. Some others are listed in the unmonetized section, such as the noise and pollution. These unmonetized costs are therefore excluded from our calculations but should be noted as additional impacts which will increase if aggregate transport distances are higher. Wear and tear on roads also affect subsequent users and must be repaired, requiring government spending to be diverted from other uses.

Table 4-6. Social Costs

	Death	Serious injury	Minor Injury
Social cost ($ per instance @2023 prices)	$5.2m	$0.5m	$0.03m
Deaths/Injuries per 100 million km (risk factor)	2.5	5.3	22.8

[55] Version 1.6.1, June 2023 and Monetised benefits and costs manual
[56] Ministry of Transport report

4.2.2 Current costs

The costs associated with transporting aggregate around NZ is estimated for the two approaches to illustrate the potential spread of costs. The costs are reported for the three monetised cost items and show annual values in 2023 prices.

Direct transport costs

The additional direct transport cost associated with cross-region aggregate transport is considerable. Table 4-7 shows the results. For the regional lens approach, the transport costs – those incurred by quarries located outside of regions where demand is – are estimated at $261 million per year. This represents the transport costs associated with inter-regional aggregate exports: the extra costs of not having sufficient aggregate within a region to cater for local demand. It is important to note that this is the cost estimate to get the aggregate to the regional border, not the final delivery point, which makes this a minimum estimate. It is also assuming maximum efficiency in material allocation. Given the spatial distribution across regions, the actual transport costs are likely to be greater. This is illustrated using the urban economy lens (approach 2) that includes the transport costs associated with transporting aggregate to the main urban economies within regions. Under this approach, the transport cost associated with transporting aggregate from other regions due to limited local (within region supply) is estimated at $834m.

Table 4-7. Transport Costs Summary - Annual

	Region Borders	Urban Centres
Kilometre Tonnes	686m	2,195m
Transport costs	$261m	$834m

Emission costs

The emissions costs are estimated using the VPEM-parameter introduced earlier. A conservative position is maintained. The annual emissions costs are estimated below.

- $5.7m for the regional lens approach.
- $18.1m for the major urban economy lens approach.

Importantly, these emission costs relate to the wider effects of emissions, including health effects. A part of these effects includes the contribution to climate change and the associated environmental effects and risks. The NZTA provides a methodology to estimate the monetary impact associated with emissions and uses CO2 equivalents (CO_2e) for this process. Using this metric ensures that the overall climate change potential of different emissions is considered in the analysis i.e., CO_2e accounts for carbon dioxide and all the other gases. The CO_2e estimates are based on the VEPM as published by NZTA.

The second element that is used to indicate the monetary value of emissions is the value of carbon. A shadow price, or $-value, is placed on future emissions emitted or reduced. This is usually concerning international and/or national emissions goals, and typically a shadow price is applied to each future year over a given period, creating a 'shadow price path'. The price path is continuously updated to reflect new information relating to the costs and benefits of emissions reductions. The shadow price can be used to show the estimated value of damage caused by each additional tonne of CO_2e (social cost of carbon), or alternatively, to show the full marginal cost of achieving a given domestic or international emissions reduction target (target consistent shadow price). The latter approach is more widely used because it has a stronger empirical basis and link to defined targets. Shadow prices are different from market traded prices in the Emissions Trading Scheme (ETS) and should not be confused.

Importantly, many emissions remain in the atmosphere for a long time – some over 100 years. When discounting is used to express future values in current terms, more weight is assigned to short term effects relative to effects that are anticipated over the long term. This means that impacts anticipated in the long term are reduced and little value ($) is assigned to those effects. This current analysis considers a twenty-year period, meaning that only a portion of the total value of emissions is considered. Using the medium NZTA price path and a 5% discount rate suggests that the value of emissions across the different modelled approaches as:

- $77.3m (Regional lens approach)
- $244.2m (Major urban economy lens)

Isolating the cost of carbon emissions using the shadow price of carbon path with a 1.5% discount rate over 100 years, gives an indication of long-term impacts. The cost of carbon emissions in this case is:

- $105.7m (Regional lens approach)
- $336.1m (Major urban-economy lens)

These estimates point to the considerable economic value (potential cost) that is associated with ensuring that quarrying activities can occur as close as practical to destination markets (where aggregate is used).

Social costs

The social costs per incident reported earlier (in Table 4-6) are multiplied by the total transport distance to estimate the social cost per incident type. This distance is the delivered distance multiplied by two. The social costs associated with the transport of aggregate for the different approaches are summarised in Table 4-8.

Table 4-8. Social Costs Summary

	Cost per 100 million km	Region Borders	Urban Centres
Delivered distance (km)		12.2m	38.4m
Social Cost - Deaths	$13.2m	$3.2m	$10.2m
Social Cost - Serious Injury	$2.9m	$0.9m	$2.7m
Social Cost - Minor Injury	$0.7m	$0.2m	$0.7m
Total		$4.3m	$13.6m

The annual social costs associated with importing aggregate across regional boundaries are estimated as:

- $4.3m (Regional lens approach)
- $13.6m (Major urban economy lens approach)

Looking past the $-costs associated with an inefficient supply network, there are other social costs. These costs relate to those associated with infrastructure and development costs. The direct financial burden of higher transport costs flows through into infrastructure and development budgets, affecting the available set of policy options. These changes arise through higher costs and a financial burden falling on households (ratepayers or taxpayers). These costs can have a disproportionate impact on low-income households, and thereby exacerbate inequality. The affordability of infrastructure spending is a function of all costs, and these are then reflected in the associated value for money assessment (e.g., cost-benefit analysis and business case processes). However, these assessments tend to prioritise system-wide improvements and might not directly seek to address social inequalities. Such projects can then increase spatial disparities or inequalities.

Another important effect of higher costs arises through the trade-offs that decision-makers face. Expensive infrastructure means that different types of priorities must reflect a range of essential services such as healthcare, education, and social welfare. Clearly, minimising infrastructure costs, through limiting costs associated with all inputs have wide ranging impacts.

Total costs

Combining the three monetised cost elements shows that the total costs are considerable. For the regional lens, our estimate is that annualised costs come to $271m. For the major urban economy lens, the estimate is $866m. Most of the overall costs are associated with the direct transport costs. It is a considerable amount and has major implications for construction – a sector that faces significant productivity challenges. The extensive logistics component with interregional exports means that there are other, intangible costs that are borne by end users of infrastructure, too. The increased operational costs are reported, but there are other intangible costs, such as:

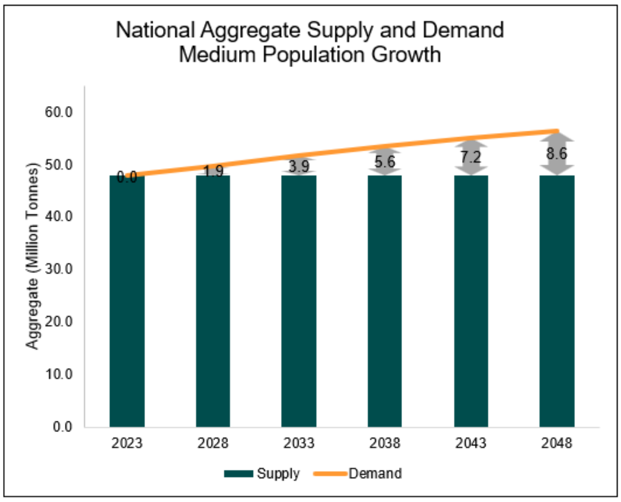
- Declining customer service due to late deliveries arising from a congested transport network,
- Requiring additional investment in trucks due to high milage
- Loss of competitive advantage for the overall sector due to high costs and poor relative performance
- Additional costs through compliance and regulatory requirements (e.g., WoF and driver related requirements),
- Risk of supply chain disruptions and quality control considerations.

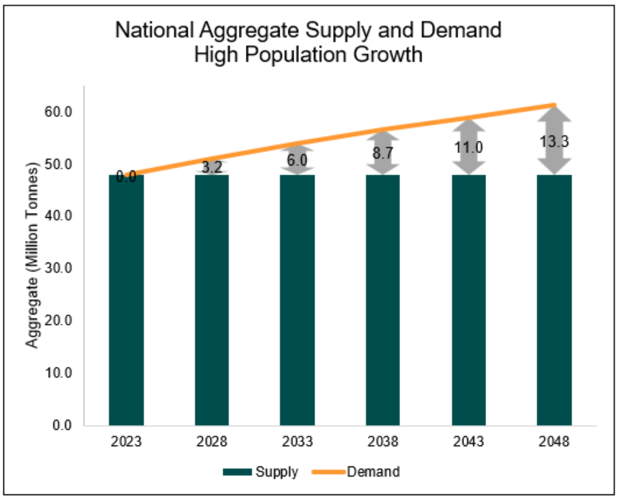
The preceding discussion illustrates the annual costs incurred by the aggregate and construction sectors as part of the current distribution process. If current delivery patterns with interregional imports/export pattens persist, then the costs associated with the aggregate movements will continue too. The present value (using 5% discount rate) of these costs over a 20-year period are:

- $3.6bn (Regional lens approach)
- $11.7bn (Major urban-economy lens approach)

Importantly, demand for aggregate is not static and will expand in response to factors such as population or economic growth. It is therefore unrealistic to assume that the annual values will remain the same. Figure 4-3: National Deficits with Population Growth to 2048 Figure 4-3 shows the size of the deficit at five-year intervals to 2048 if per capita demand remains constant and supply remains at the current levels. By 2048 there will be a deficit of between 9 and 13 million tonnes. Existing quarries' finite life span and operating capacity suggests that total production will fall, making this deficit larger. The implications of an aggregate shortfall would be higher prices, effectively pricing out some demand, or shortages, whereby projects simply cannot access sufficient quantities of the resource.

Figure 4-3: National Deficits with Population Growth to 2048





Our methodology for estimating transport, environmental and social costs relies on demand and supply-side data, identifying operational quarries and production quantum. It is therefore difficult to estimate the future demand and supply levels using a 'top-down' approach. A fine-grained, quarry level analysis is required to understand the within region net position over time. Such an analysis is however beyond the scope of this analysis. The aggregate sector can respond to growth in several ways:

- Expand production to meet growing demand from within a region,
- Increase export/import activities,
- Establish new operations in a region.

All options assume that there is sufficient resource that can be accessed and that a consenting pathway is available to ensure that the expansion of existing quarries or new quarries can be bought online with sufficient lead tome to (at least) ensure the demand can be met by production levels. Without these conditions, growth-driven shortages will abound.

4.3 Key regions' focus

Auckland and Wellington provide interesting insights and help to conceptualise the distribution and scale of impacts. Auckland is New Zealand's commercial and economic hub; accordingly, it imports more aggregate than any other region. Just under half of total inter-regional imports are estimated to flow into Auckland, making it the key region in the national equation of regional sufficiency. Wellington, meanwhile, is an interesting case study owing to both its role as a major city and the recent aggregate supply issues during major infrastructure construction.

Projecting the aggregate deficits forward using the StatsNZ medium population growth estimates for the given regions suggests that:

- By 2048, Auckland will have a shortfall of around 8.0 million tonnes.
- By 2048, Wellington will have a shortfall of around 0.9 million tonnes.

4.3.1 Auckland

A few large quarries in Auckland comprise most of the local supply, which amounts to 11 million tonnes in total. To supplement this supply, Auckland currently imports an estimated 4.1 tonnes of aggregate from Northland and Waikato. The average distance for aggregate travelling from Northland to the region border is 62 km; from the Waikato quarries it is 16 km, on average. This translates into 438 million km just to get the aggregate to the regional border. Of course, this distance excludes the distance to delivered locations such as, concrete plants, and areas where construction activity is occurring – infill, redevelopment or greenfield developments. Using $0.38 as the price per km tonne implies that the additional transport costs to the border are $166 million per year. This suggests that if new quarries were established at the border, to replace the imported volumes, then this pattern would deliver the stated cost-savings.

Enabling Auckland quarries to expand would also save this value, and realistically more, given the product is transported within the region and not only to the border. The urban centre approach illustrates the anticipated costs based on delivery to a more central location.

The environmental and social costs of getting aggregate to the Auckland border are also significant. The social costs of injuries and deaths are estimated as $2.5 million, while the emissions costs are estimated at $3.6 million, making the total costs $172m. In Auckland it would also be appropriate to use urban emissions factors for part of the journey. If the imported aggregate was delivered to a central location and applying urban emissions factors for just the final 10% of that total travel distance, the environmental costs leap to $26m. These increases are because of the significant health impacts resulting from pollutants being released in cities where population densities are high. Changing the factor and adding in transport and social costs yield total costs of $398m.

Many quarries in Auckland are constrained from expanding, increasing the importance of enabling those which can, to do so. Given its role as a hub of activity and business, ensuring sufficiency in the Auckland market is imperative. Without action, Auckland's growth will require aggregate from increasingly far away, raising prices and hampering adjacent local markets, which themselves rely on a portion of their local aggregate supply. Much of Auckland's imported aggregate comes from Waikato, which is forecast to be the fastest growing region (by population %) over the next two decades. This will place additional pressure on sources of aggregate in the region which currently makes up Auckland's shortfall. It will also give rise to other pressures such as transport infrastructure and mixing aggregate transport with other road users.

Using a twenty-year appraisal period, **the present value of savings (r = 5%) from establishing quarries on the Auckland border would be at least $2.3bn**. Several large quarries in Auckland and Waikato play a significant role in supporting infrastructure delivery in Auckland. Changing the imported share of aggregate will have widespread effects.

4.3.2 Wellington

Wellington's estimated demand of 4.95m tonnes exceeds its production of 4.64m tonnes, leading to a deficit of 300,000 tonnes. Importantly, the proximate regions, Manawatu/Wanganui and the bottom of Hawke's Bay, are not big producers of aggregate either. This means that spikes in demand are likely to significantly disrupt the market, as was observed with demand for the construction of the Transmission Gully Project.

The annual costs of Wellington's imports in the population model are $10.3m. Over twenty years, the present value of these costs is $138m.

4.4 Unmonetized Costs and Benefits

The costs presented above represent a share of the total cost associated with sourcing aggregate from other regions, and then transporting it around New Zealand. The costs that are directly associated with the transport function can be quantified and monetised using an array of different information sources that show the market values either directly or using proxies. There are other costs and benefits that are too complex (or inappropriate) to monetise – or where market values do not exist – and that have indirect links to aggregate. These wider economic, social and environmental costs include:

- **Aggregate prices and unimplemented projects:** One of the key effects of enabling more supply, making it easier to increase output or locating supply closer to demand, is to lower the price of aggregate. Lower prices make projects which would otherwise have been unfeasible viable. Equally, higher prices, which result from supply shortfalls or extensive transport, can make critical projects either uneconomical or very expensive. The higher costs reduce the total number of projects that can be delivered based on available budgets. In effect, this means that society must apply strict prioritisation and selection processes to identify the worthiest projects. This process means that in some instances required projects cannot be afforded, and the issues that those projects would have addressed remain. The social and environmental benefits that the community would derive from those projects remain unrealised potential.
- **Employment:** Quarries and their operations employ staff to carry out their day-to-day activities. There are also feed-through impacts on transport operators, machinery manufacturers and employees in roles which support the industry. Though a downstream impact, the construction projects which aggregate enables will also employ workers.
- **Productivity:** The projects which affordable aggregate enables will facilitate production in the economy. High-quality infrastructure reduces average travel times and lessens delays. Effective built environments generate commerce and amenity benefits. Increased quarrying activity will increase traffic by introducing more vehicles onto the road to deliver the product, which could have a dampening effect on productivity gains, but this is likely to be much smaller than the benefits obtained. Heavy trucks do themselves also place additional strain on roads, adding to their deterioration. A direct consequence of transporting aggregate across regions is the contribution this makes to road surface depreciation. Avoiding or reducing the transport requirement lessens the impact on roading infrastructure, in turn reducing the maintenance budget.
- **The natural environment:** like many other land uses, establishing or expanding quarries can damage the natural environment. Extracting aggregate can result in ecosystems disruptions, and damage to areas of natural fauna and flora. Steps to mitigate the effects form part of operation plans and regulatory approvals. Activities to offset the impacts are often carried out at alternative locations as part of regulatory approvals. Valuing the environmental effects, and the acceptability of offset proposals, are controversial processes and often highly contested.
- **Nuisance, noise pollution and dust:** Extracting and moving aggregate can create nuisance, including noise and dust. Consents stipulate quarry operating hours to limit the duration of these impacts. They still occur, however. Moreover, the closer quarries are to population centres, the more people will possibly experience these impacts. The potential implications and values of such nuisance are often tied to land value effects. In some cases, quarries are competing for the same land as urban

developments. Both seek to be close to existing urban centres by locating on their immediate periphery. Quarries can lower the land value of nearby settlements due to the noise, dust, and visual implications of a site.

4.5 Concluding remarks

The distance aggregate must travel has as much to do with the delivered price as the gate price. In New Zealand, due to the acute shortfalls in many regions, aggregate must travel significant distances. This introduces costs for the construction industry, end users, the environment and society. The experimental modelling approach presented in this analysis provides a framework for understanding the flows of aggregate within New Zealand's islands, quantifying the travel distances involved.

The analysis illustrates the importance of enabling existing supply to expand and doing so as near as possible to demand. This is because the current spatial distribution network means that there is considerable cost embedded in the logistics structure – especially for the Auckland market. The analysis suggests that enabling more supply that is located closer to key markets would greatly improve the functioning of the aggregate market and efficiency of New Zealand's economy.

One clear effect is the re-balancing of where aggregate is sourced from due to competing demands. The simulation models require some regions to be both importers and exporters of aggregate when optimised. Large-scale projects, which divert aggregate away from local demand, will force the baseline demand to source aggregate from further afield. The integrated nature of the aggregate market means that shifts in one region can influence and impacts users in other regions. The role of several large suppliers in the Auckland and Waikato regions play a significant role in supporting infrastructure delivery and maintenance across a critical part of the New Zealand economy.

Importantly, our analysis neglects transport flows within regions. A large proportion of total aggregate will be transported within region, which our model does not capture. This means that the total costs are higher. These costs would also be lowered with more quarries, located closer to demand centres.

5 Conclusion

Addressing the challenges in the aggregate sector is imperative for sustaining and enhancing New Zealand's economic development and aspirations. As one of the most consumed resources – by volume – in New Zealand, and one which enables and unlocks so much economic activity, aggregate should be at the forefront of policy makers' agenda. Aggregate and the infrastructure it enables influences many parts of New Zealand's society and economy. A well-functioning and efficient sector will yield a host of downstream benefits for all areas of society. With government budgets being constrained, policy makers should alleviate rising input costs by facilitating expansions of supply. The benefits would improve project viability in both the public and private sectors, which feeds through into the overall health and growth of the economy. At the same time, it will reduce other environmental (emissions) and social costs.

New Zealand faces a severe infrastructure challenge in the coming years, which will require large quantities of aggregate. Without action, this infrastructure requirement, in conjunction with population growth and historic inertia towards the aggregate market, will manifest as chronic shortages and soaring costs. Moreover, action should be taken promptly because of the lead-in time required for any meaningful responses to occur in the sector. A transparent and more effective consenting pathway is essential. Supply is so deeply constrained because of the difficulties in obtaining consents and the processes surrounding this. It is in New Zealand's interest to provide a framework that aligns policy objectives with effective regulation so that compliance brings benefits.

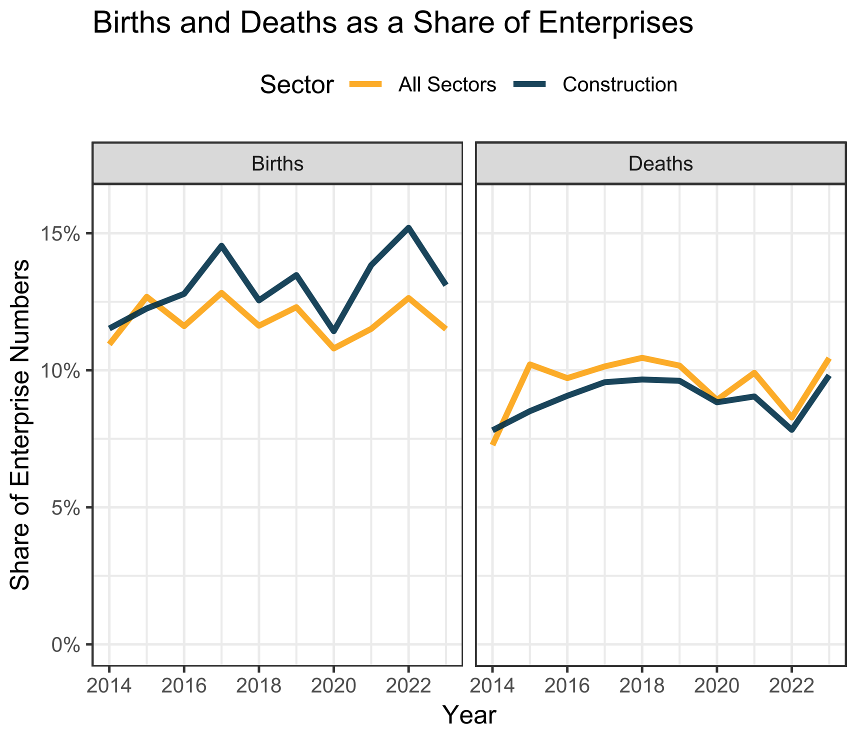
At present, supply is both insufficient and located too far from demand centres. As such, it must be transported large distances, which incurs direct and indirect costs. In Auckland, the deficit is estimated to be 4.1m tonnes per year, and this is only projected to widen as demand grows faster than supply. Across New Zealand, the regional deficits are estimated to be 6.7m tonnes, necessitating compensatory flows from far away quarries. Our analysis shows that even under perfect coordination, where supply is allocated with maximum efficiency, this realignment leads to 12m of additional kilometres driven just to deliver aggregate to the borders of regions where it is demanded. If that aggregate is demanded in the main urban centres of each region, the travel required is 38m kilometres. Reducing these excessive journey distances will bring a host of benefits to New Zealand. The direct transport cost savings that would manifest is substantial. So too are the environmental, social and intangible cost savings that could be achieved with a more efficient sector.

Appendices

Appendix 1: Additional information about the construction sector

New Zealand's construction industry is growing, supporting growth and improving the country's built infrastructure and environments. As shown in the figure, between 11% and 13% of construction businesses were newly incorporated in each year between the years ending February 2014 and 2023. Meanwhile, between 7% and 10% of construction enterprises ceased existing in each year. The number of births exceeded the number of deaths in each year, meaning the sector expanded to 80,613 units in the year ending February 2023.

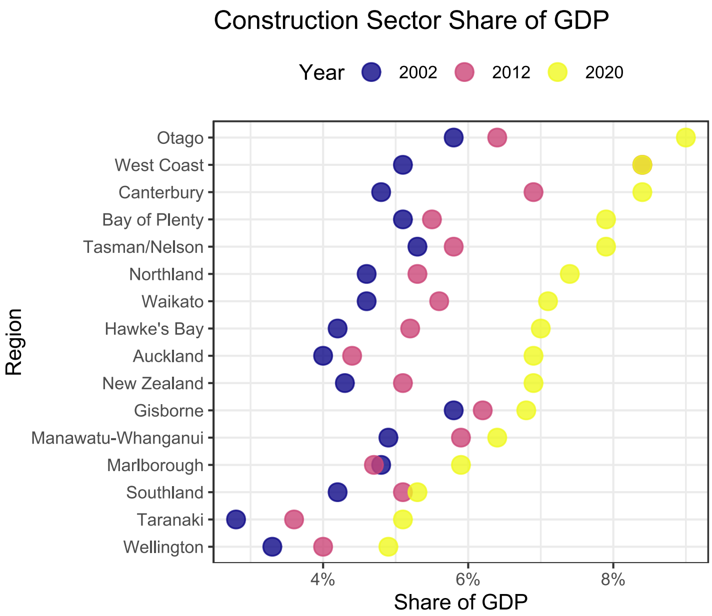
Compared with other industries, births as a percentage of total enterprises were higher in construction. Deaths, too, were lower than the average across all industries, rejecting the possible notion that the sector is merely subject to more churn than others, and highlighting the growing role of construction in the economy.



Notwithstanding the dip following the Global Financial Crisis in 2008, the share of Gross Domestic Product (GDP) generated by the construction industry has grown in each year since 2001. At the start of the century, construction contributed 4.6% of GDP; today it accounts for 6.9%.

The share of GDP by region shows considerable variation. In all but two regions, construction's share of GDP was higher at each interval, emphasising the importance of the industry across the country to support growth.

Given the sector's reliance on aggregate as an input, ensuring a reliable supply is essential for the sector to continue to flourish.



Appendix 2: Estimating production values and filling data gaps.

Triangulating the NZP&M data against alternative (unofficial) sources suggest that the survey undercounts production. A more comprehensive 2017 Fulton Hogan assessment of aggregate production in Auckland found the NZP&M tonnage to be 28% below true levels. Furthermore, a report for the New Zealand Infrastructure Commission, published in 2021, estimated the 2017 quantum using data from the Aggregate and Quarry Association (AQA), which suggested that the NZP&M tonnage was 29% below the true figure[57].

These data are all backwards looking, meaning that forward planning must take place on the basis of historic rather than current trends. The latest year for which data are published is 2021[58]. This data is not only outdated, but covers a period where economic activity was affected by extraordinary conditions. In both 2020 and 2021, Covid-19 affected aggregate production through supply constraints and changing demand patterns.

Data from Inside Resources has the crucial advantage of recency, which enables a more refined understanding of the current situation to be developed. It is also available at a quarry level, rather than grouped by region, which is crucial for a spatial analysis. This data does, however, suffer from other limitations, which we outline here. Again, submission of information by quarries is voluntary, meaning production figures are not available for every quarry. Where it is, the data might be slightly outdated or not representative, but we assume that these are not major deviations from reality. In some cases, a range is given for production, from which we take the lower bound value. The tonnage data does not delineate production by material, meaning where quarries report producing aggregate (rock) as well as materials that would not be used for aggregate, the total tonnage includes each element. This combination is rare, however. In nearly all cases, all the materials listed could be used for aggregate. Production values tend to be given in tonnes, but for some quarries the value is cubic metres, which necessitates conversion. Depending on the material, square meters are converted to tonnages based on standardised weights of loose material, ranging from 1.04 – 1.65m^3. Where multiple materials are listed, an average factor is applied. Production data are available for all the largest quarries in New Zealand.

Where data are unavailable, an estimate of production is derived using employment data[59]. Across the industry, each full-time employee classified as working in quarrying and construction material mining, as defined by 6-digit ANZSIC06 codes[60], is associated with around 27,000 tonnes of aggregate production. Quarries employee many more people than reported in the employment data but under classifications that group them with other activities, so we cannot identify them. For example, drivers of trucks or site managers are likely to have different codes. This is evident in that some quarries do not have any employee counts in their SA1 or SA2. Production per employee is therefore expected to be higher than it would be with a complete employment record. We calculate the tonnes per employee for SA1s with only one quarry, and in which we have a reported production quantum. This ignores SA1s where we cannot isolate the share of employment attributed to the known production figures. We impute remaining quarries' tonnages based on the MECs and count of quarries in the SA1. Where there is more than one quarry in a given SA1 and no production data are known, the assumed tonnage associated with that employment count is divided evenly. Where tonnages are known for the other quarries, the known quantum is subtracted from the estimate for that employment level, with the remaining tonnes split between the quarries without data. Based on an assessment of the sizes of

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[57] Aggregate opportunity modelling for New Zealand – Infrastructure Commission. This report also estimated that average production per capita was 8.4 tonnes in 2017.
[58] Correct as of 04/12/2023
[59] Statistical Area 1 – the finest spatial area defined by StatsNZ.
[60] ANZSIC06 codes used in the definition: gravel and sand quarrying (B091100), other construction material mining (B091900), other non-metallic material mining B099000.

quarries without data, an upper limit of 150,000 tonnes is assigned to any single quarry. For the remaining quarries – those with no employment data in their SA1 – a conservative posture is assumed by assuming that these produce at the 10^{th} percentile level: 14,100 tonnes. These quarries tend to be smaller operations.

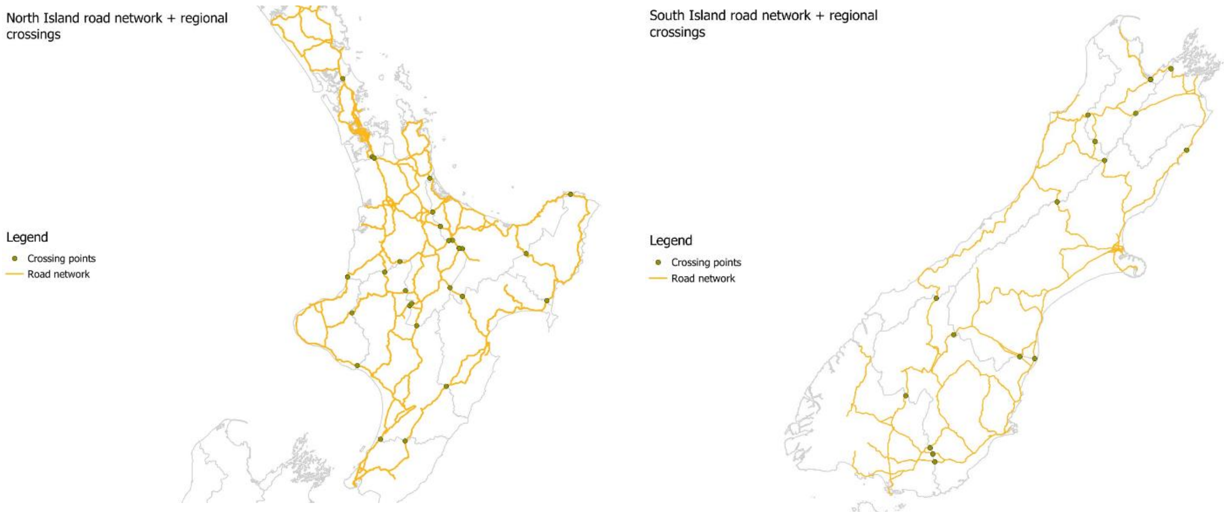
Appendix 3: Modelling approach and settings

We begin by geotagging the 487 quarries identified as producing aggregate in New Zealand. This is done by a combination of address lookups and, where possible and conditional on the quarry still being operational, using the locations recorded in the Infrastructure Commission's aggregate opportunities report. In some cases, where address data for the quarry is unavailable, a manual look up using the site or local area is conducted.

Next, we map the road network. Roads tagged as "motorway," "trunk," or "primary" by OpenStreetMap[61] form the core road network, along which we assume most aggregate is transported. These describe state highways and important local roads. Given its bulky nature, the vehicles moving the product tend to be large and therefore travel along roads that accommodate this.

For each major road, we identify where it crosses a regional boundary, geotagging this as a node. For roads which follow or, in some cases are themselves, a regional boundary, points are set along the boundary. We also geotag a point within each region's primary urban centre and assume that all imported aggregate is delivered there, for example, we tag Penrose in Auckland.

Road Network and Crossings



Each quarry is allocated its production quantum and treated as an individual entity within its region. Demand is modelled in two ways, using population and proportion of construction workers in each region, as detailed in section 3.2. Only the approach using population is contained in the report. The construction estimates are detailed in the final section of the appendix.

To calculate the costs of transporting aggregate, the distances between origin and destination, in conjunction with the total tonnages being delivered, are converted into a number of journeys, and travel distances, split by load sizes and vehicle weights. We assume that aggregate coming from the most quarries (production pf +15,000 tonnes per annum) is moved in loads of 30 tonnes, on average. Those coming from small quarries is moved in loads of 18 tonnes, on average. The vehicles used are therefore different. Many smaller quarries are likely to have demand from many smaller clients too, who might collect product in smaller vehicles. Without

[61] OSM is updated by Land Information New Zealand (LINZ)

appropriate data on these journeys, however, we use a general assumption. The weight of large quarries' articulated trucks is assumed to be 50 tonnes when loaded and 20 tonnes when empty. For small quarries, we assume these are 32 tonnes when loaded and 14 tonnes when empty.

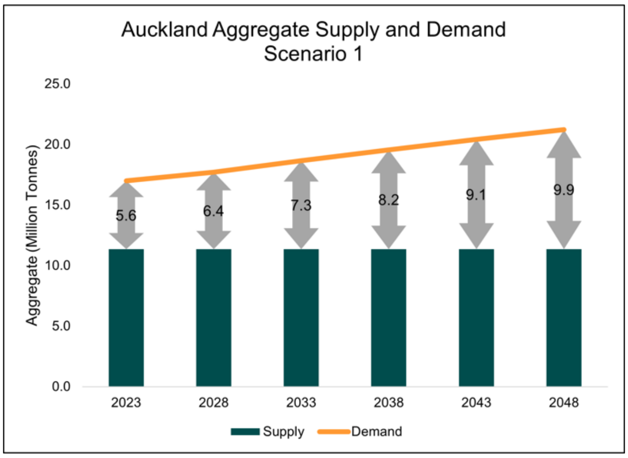
Appendix 4: Regional output gaps

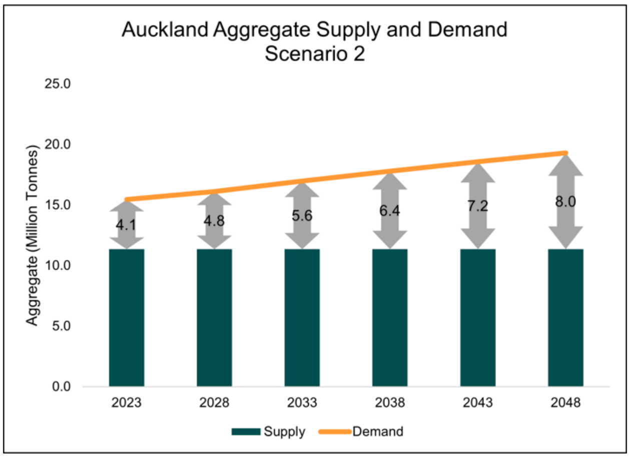
Projecting the 2023 demand and supply levels forward, we show the size of the growing output gaps in Auckland and Wellington at five-year intervals until 2048. Due to the current limitations on the sector, we assume that supply does not increase over this period. Indeed, it is possible that supply would actually reduce as consents expire on existing sites. For future demand, we use three scenarios to illustrate possible pathways.

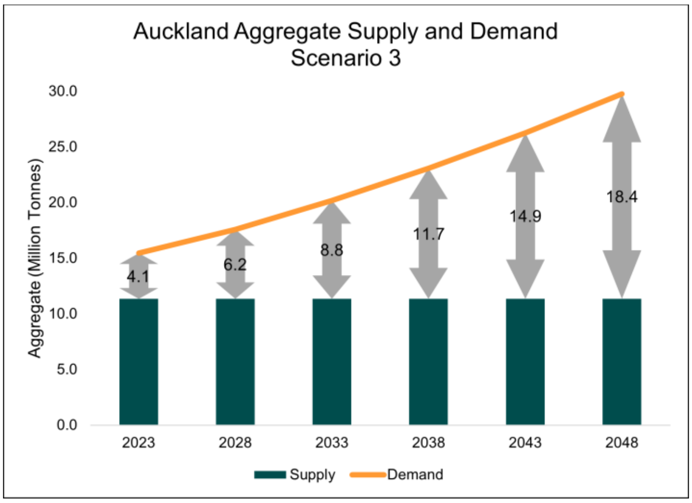
- Scenario 1 increases the construction MEC demand estimates by the medium population growth projections from StatsNZ.
- Scenario 2 increases the population demand estimates by the medium population growth estimates from StatsNZ. This scenario is also contained in the main report.
- Scenario 3 increases the population demand by the medium population growth estimates from StatsNZ and an economic growth factor of 1.75% per annum.

The output gaps reflect the wedge between demand and supply. In each region, population growth will only exacerbate the existing shortages. At a national level, under the medium StatsNZ growth scenario, population is estimated to be 18% higher in 2048 than in 2023. If coupled with (compound) economic growth of 1.75% per annum, this would reach 82% higher. Even under the optimistic assumption that New Zealand has enough aggregate at present to satisfy demand, by 2048 there will be critical shortages.

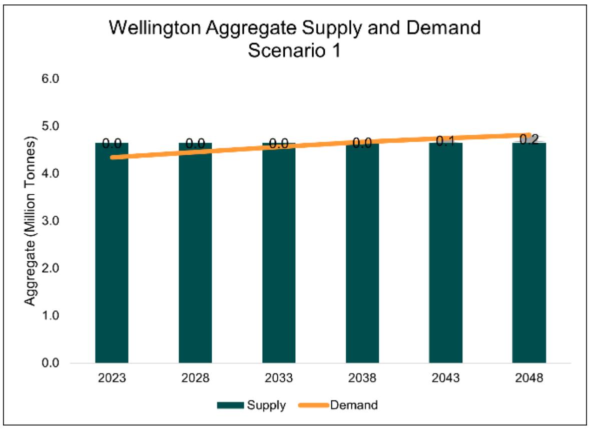
Auckland Output Gaps

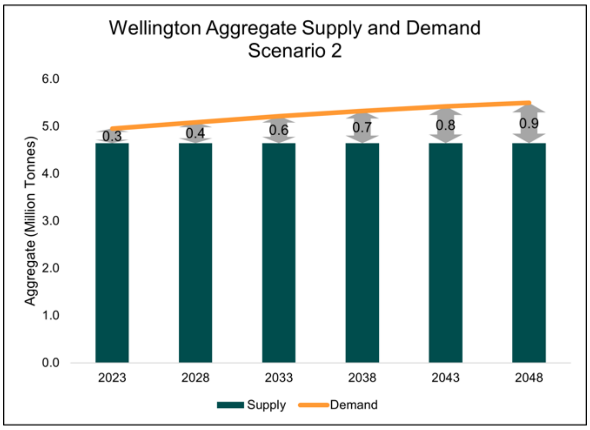


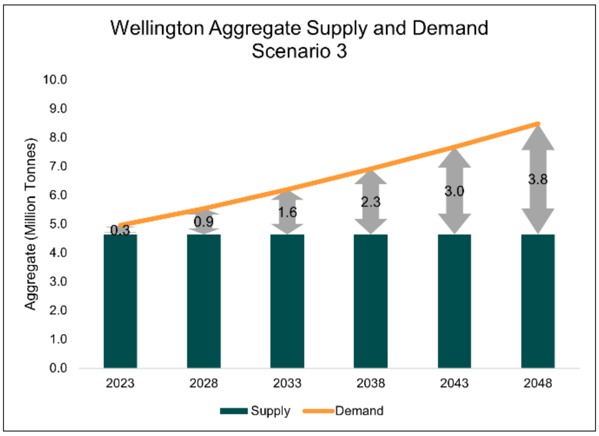




Wellington Output Gaps







Appendix 5: Construction MEC-based demand sensitivity analysis

In addition to estimating demand using population numbers, we conduct sensitivity analysis using regional shares of workers in the construction industry. The methodology is detailed in Section 3.2. The results are summarised in the section below. Some key differences see certain regions flip from being net importers (exporters) to net exporters (importers). Wellington, though an importer when using population, becomes an exporter under this method. Its share of construction workers is comparatively lower than its share of population.

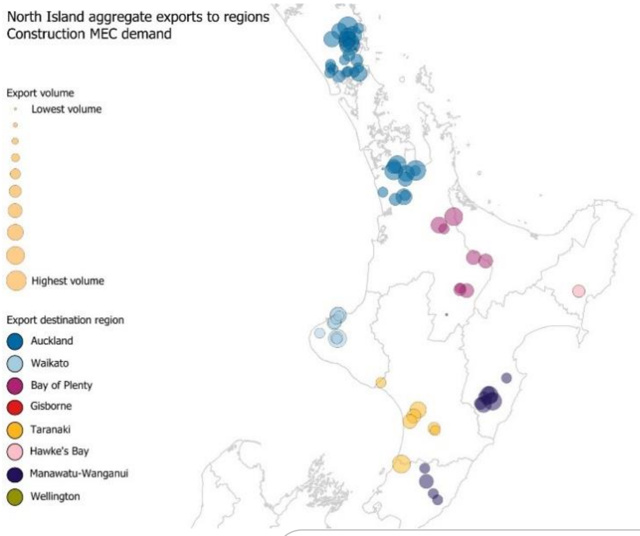
Regional lens output results

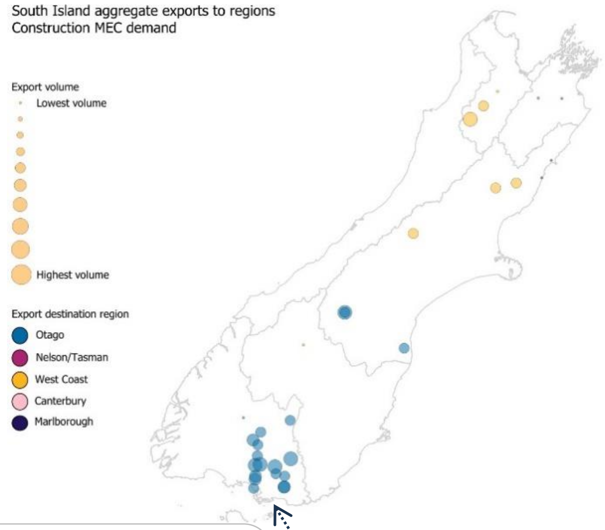
		Construction MEC weighted demand			
Region	Production (P)	Demand (D)	Output gap (P - D)	Exports (X)	Imports (M)
North Island					
Northland	4.6	1.7	2.8	2.8	0.0
Auckland	11.3	17.0	-5.6	0.0	5.6
Waikato	7.4	4.6	2.8	3.6	0.8
Bay of Plenty	2.3	3.1	-0.8	0.0	0.8
Gisborne	0.4	0.4	0.1	0.1	0.0
Taranaki	1.5	1.3	0.2	0.8	0.6
Hawke's Bay	2.1	1.3	0.7	0.8	0.1
Manawatu/Wanganui	1.5	2.1	-0.5	0.4	1.0
Wellington	4.6	4.3	0.3	0.3	0.0
South Island					
Nelson/Tasman	1.1	1.0	0.1	0.1	0.0
Marlborough	0.5	0.4	0.0	0.0	0.0
Canterbury	6.7	6.6	0.2	0.2	0.0
Otago	2.2	2.9	-0.7	0.0	0.7
West Coast	0.3	0.4	-0.1	0.0	0.1
Southland	1.4	0.8	0.6	0.6	0.0
Total	47.9	47.9	0.0	9.8	9.8

Major urban economy lens output results

		Construction MEC weighted demand			
Region	Production (P)	Demand (D)	Output gap (P - D)	Exports (X)	Imports (M)
North Island					
Northland	4.6	1.7	2.8	2.8	0.0
Auckland	11.3	17.0	-5.6	0.0	5.6
Waikato	7.4	4.6	2.8	3.6	0.8
Bay of Plenty	2.3	3.1	-0.8	0.0	0.8
Gisborne	0.4	0.4	0.1	0.1	0.0
Taranaki	1.5	1.3	0.2	0.2	0.0
Hawke's Bay	2.1	1.3	0.7	0.8	0.1
Manawatu/Wanganui	1.5	2.1	-0.5	0.2	0.7
Wellington	4.6	4.3	0.3	0.7	0.4
South Island					
Nelson/Tasman	1.1	1.1	0.1	0.1	0.0
Marlborough	0.0	0.5	0.0	0.0	0.0
Canterbury	0.0	6.7	0.2	0.2	0.0
Otago	0.0	2.2	-0.7	0.0	0.7
West Coast	0.0	0.3	-0.1	0.0	0.1
Southland	0.0	1.4	0.6	0.6	0.0
Total	36.8	47.9	0.0	9.4	9.4

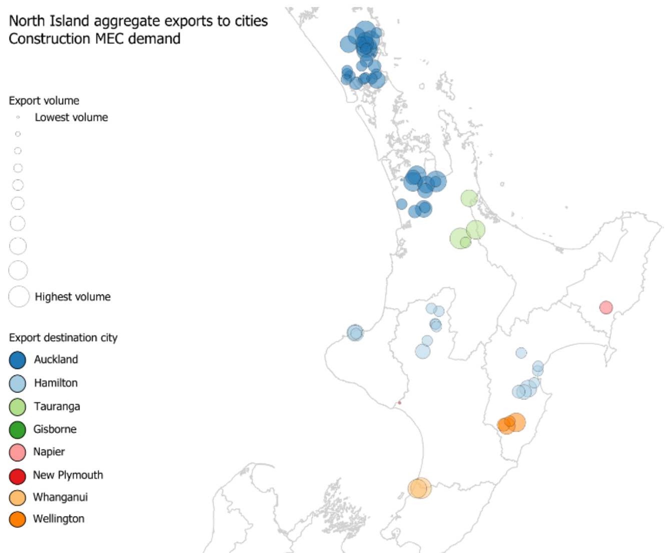
Graphical results. Regional Lens

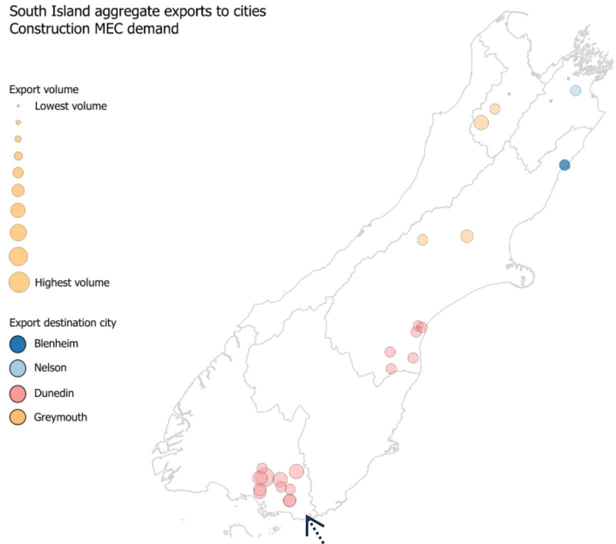




Important caveat:
The spatial patterns are based on available data, but this is limited and does not reflect local nuances. Additional, work is needed to refine the underlying information. These flows are likely to overstate the interregional (Southland-Otago) flows and could be due to either Southland's demand patterns differing from observed patterns, or Otago's production patterns being higher than estimated.

Graphical results. Major urban economy lens





Important caveat:
The spatial patterns are based on available data, but this is limited and does not reflect local nuances. Additional, work is needed to refine the underlying information. These flows are likely to overstate the interregional (Southland-Otago) flows and could be due to either Southland's demand patterns differing from observed patterns, or Otago's production patterns being higher than estimated.

Results table, regional lens

Region	Exported To	Demand Type	Loads	Delivered Distance (kms)	Km Tonnes
Northland	Auckland	Construction MEC Demand	98,794	7,083,854	410.9m
Waikato	Auckland	Construction MEC Demand	94,595	3,077,366	182.4m
Taranaki	Waikato	Construction MEC Demand	27,745	675,049	39.2m
Waikato	Bay of Plenty	Construction MEC Demand	27,797	368,947	20.0m
Manawatu/Wanganui	Taranaki	Construction MEC Demand	14,278	723,617	41.9m
Wellington	Taranaki	Construction MEC Demand	5,532	648,523	38.9m
Gisborne	Hawke's Bay	Construction MEC Demand	2,244	125,115	7.5m
Hawke's Bay	Manawatu/Wanga	Construction MEC Demand	32,199	1,201,681	59.4m
Waikato	Manawatu/Wanga	Construction MEC Demand	428	9,817	0.4m
Wellington	Manawatu/Wanga	Construction MEC Demand	5,595	13,034	0.7m
Marlborough	Nelson/Tasman	Construction MEC Demand	809	22,351	1.3m
Canterbury	Marlborough	Construction MEC Demand	630	2,702	0.2m
Canterbury	Otago	Construction MEC Demand	3,926	150,453	7.6m
Southland	Otago	Construction MEC Demand	23,487	1,237,400	66.6m
Canterbury	West Coast	Construction MEC Demand	2,331	146,869	6.8m
Nelson/Tasman	West Coast	Construction MEC Demand	3,346	211,383	11.5m
Otago	West Coast	Construction MEC Demand	423	68,723	2.5m
Total			**344,159**	**15.8m**	**897.8m**

Results table, major urban economy lens

Region	Exported To	Demand Type	Loads	Delivered Distance (kms)	Km Tonnes
Northland	Auckland	Construction MEC Demand	98,794	15,431,617	891.0m
Waikato	Auckland	Construction MEC Demand	94,595	6,652,272	394.3m
Hawke's Bay	Waikato	Construction MEC Demand	13,500	4,094,774	229.7m
Manawatu/Wanganui	Waikato	Construction MEC Demand	8,033	1,444,342	68.3m
Taranaki	Waikato	Construction MEC Demand	8,149	1,867,294	107.7m
Waikato	Bay of Plenty	Construction MEC Demand	26,645	1,514,203	89.7m
Manawatu/Wanganui	Taranaki	Construction MEC Demand	357	56,054	2.0m
Gisborne	Hawke's Bay	Construction MEC Demand	2,244	467,198	28.0m
Wellington	Manawatu/Wanganui	Construction MEC Demand	24,511	2,894,592	173.7m
Hawke's Bay	Wellington	Construction MEC Demand	14,638	3,722,945	218.6m
Marlborough	Nelson/Tasman	Construction MEC Demand	1,762	124,854	4.5m
Canterbury	Marlborough	Construction MEC Demand	1,263	166,987	7.5m
Canterbury	Otago	Construction MEC Demand	5,076	959,448	34.5m
Southland	Otago	Construction MEC Demand	22,378	4,182,650	240.6m
Canterbury	West Coast	Construction MEC Demand	1,801	234,190	13.3m
Nelson/Tasman	West Coast	Construction MEC Demand	3,816	623,118	32.4m
Total			**327,560**	**44.4m**	**2,535.7m**

Cost summary

	Description	Region Borders	Urban Centres
Transport costs	Kilometre Tonnes	897,806,326	2,535,744,885
	Transport costs	$341.2m	$963.6m
Social costs	Delivered distance (km)	15,766,885	44,436,539
	Social Cost - Deaths	$4.2m	$11.8m
	Social Cost - Serious Injury	$1.1m	$3.1m
	Social Cost - Minor Injury	$0.3m	$0.8m
Environmental costs	Total	$7.4m	$21.0m
Total		**$354.2m**	**$1000.3m**