MAHI | JOBS
MŌ TE TAIAO | FOR NATURE

Economic Impacts – Technical Report

Kaipara Moana Remediation

Disclaimer

The information in this publication is, according to the best efforts of the Jobs for Nature Secretariat, accurate at the time of publication. The Secretariat will make every reasonable effort ahead of programme closure to keep it current and accurate. However, users of this publication are advised:

- The information does not alter the laws of New Zealand, other official guidelines, or requirements.
- It does not constitute legal advice, and users should take specific advice from qualified professionals before taking any action based on information in this publication.
- The Secretariat does not accept any responsibility or liability whatsoever whether in contract, tort, equity, or otherwise for any action taken as a result of reading, or reliance placed on this publication because of having read any part, or all, of the information in this publication or for any error, or inadequacy, deficiency, flaw in, or omission from the information in this publication.
- All references to websites, organisations, or people are for convenience only and should not be taken as endorsement of those websites or information contained in those websites nor of organisations or people referred to.
- This report contains economic modelling prepared by a student from ENSAE Paris, the École nationale de la statistique et de l'administration économique de Paris, part of the Polytechnic Institute of Paris and a member of IP Paris. The modelling was completed as part of the student’s internship at the Ministry for the Environment, undertaken between July and September 2024. While every effort has been made to ensure accuracy, this work reflects the student’s academic and professional development and may not represent the official views or policies of the Ministry for the Environment.
- In February 2025, this report was independently peer-reviewed by Martin, Jenkins & Associates Limited (MartinJenkins). They confirmed that the methodology used to produce the results was accurate at the time and is supported by detailed analysis in the report. MartinJenkins provided minor factual corrections in an annotated version of the report shared with the Ministry.
- The report also explored alternative scenarios and sensitivities to test the reliability of the findings, including:
  - Adjusting assumptions in input-output tables using sensitivity tests and Monte Carlo simulations.
  - Conducting sensitivity tests on the benefit-cost ratio (BCR), using different discount rates (referred to as "interest rates" in the report).
- As of March 2025, MartinJenkins updated the model with recommended sensitivity tests, including applying Treasury's new discount rates for cost-benefit analysis, which were revised in October 2024 after the initial analysis was undertaken.
- Other recommendations for improving cost-benefit analysis are being addressed separately, but this work remains valid.

Published in March 2025 by the Ministry for the Environment on behalf of the Jobs for Nature Inter-Agency Secretariat

ME 1878
ISBN: 978-1-991140-70-8 (online)

Table of Contents

Executive Summary

The Kaipara Moana Remediation (KMR) initiative, a cornerstone of the Jobs for Nature (J4N) programme, is New Zealand's largest landscape restoration effort. This 10-year, $200 million programme—co-funded by the Ministry for the Environment—targets sediment reduction, water quality improvement, and local job creation in New Zealand's largest harbour.

A refreshed economic assessment using an enhanced Input-Output model estimates a benefit-cost ratio (BCR) of **3.94:1**, equating to **$423.9 million** in total benefits over 2020–2031. These include:

- **$121.0M** in economic gains (jobs, local business, spending)
- **$196.0M** in environmental benefits (cleaner water, biodiversity, carbon)
- **$106.9M** in wellbeing outcomes (health, recreation, cultural values)

The KMR initiative is projected to deliver $423.872 million in total benefits over 10 years (2020–2031), with $3.94 returned for every $1 invested. These benefits span contribution to economic growth, environmental protection, and community wellbeing.

Modelling results show:

- **Total benefits**: $423.872 million
- **Benefit-to-cost ratio**: 3.94:1 (for every $1 spent, $3.94 is generated)
- **Net Present Value (NPV at 5%)**: $316.219 million
- **Payback period**: Approximately 3.63 years (benefits begin to outweigh costs permanently after this period).

.

Introduction

The J4N programme, with a $1.18 billion budget, is a key part of New Zealand's COVID-19 recovery plan. The programme had three objectives:

Create approximately 11,000 employment opportunities in regions which need work the most

Establish enduring benefits for healthy waterways, biodiversity, climate change, and cultural values

Support sustainable land use and the implementation of regulatory requirements, including for freshwater, biodiversity, and climate change.

Overseen by the J4N Secretariat, the programme incorporates monitoring, risk management, and evaluation of long-term benefits.

The cost-benefit analysis of the KMR initiative, a flagship initiative under the J4N programme, is part of a wider effort by public authorities to evaluate the impact of their investments and demonstrate responsible use of public funds. Balancing economic and environmental goals makes the evaluation more challenging, as it requires measuring both financial returns and ecological benefits.

With an investment of $200 million, the initiative aims to tackle sedimentation in the Kaipara Harbour. Earlier economic assessments of the initiative have been undertaken using a traditional Input-Output (I/O) model. While this approach is valid, it has limitations, such as assuming stable production over time and not accounting for uncertainties in environmental factors or local economic changes.

To address these gaps, this report refines the I/O model by incorporating random variables, historical data (since 1996), and Monte Carlo simulations to provide a more accurate estimation of the economic and wellbeing benefits

The report is structured as follows:

Section I: Problem definition, modelling approach and data overview. Introduces the KMR initiative and outlines the study's methodology

Section II: Estimation of environmental and social benefits. Details the framework for the key analytical models

Section III: Results. Presents updated economic benefit estimates

Section IV: Conclusion

I. Problem definition, modelling approach and data overview

Sedimentation problem in Kaipara Harbour

The need to address sedimentation in Kaipara Harbour was highlighted in 2008 by the Auckland Regional Council. Since European settlement in 1829 and the subsequent deforestation, land use changes have significantly accelerated natural sedimentation processes. The volume of sediment entering the water has increased sevenfold since human activities began in the early 19th century (Green & Daigneault, 2018).

This sedimentation is problematic due to the presence of heavy metals, such as iron, manganese, magnesium, and aluminium, in the estuary's soils (Grace, 1996; Hume, 2003), which have been further contaminated by agricultural and urban activities. Local agriculture uses harmful pesticides such as DDT, and urbanisation has increased copper and zinc levels in the soil due to infrastructure and housing development (Kennedy & Sutherland, 2008). These contaminants are washed into the estuary, posing environmental and public health risks.

Kaipara Harbour has faced substantial environmental stress due to excessive sedimentation, with an estimated 700,000 tonnes of sediment accumulating annually, seven times higher than natural levels. This sediment build-up has degraded water quality, threatened biodiversity, and weakened the harbour's ecological resilience.

The Kaipara Moana Remediation (KMR) initiative is the largest landscape restoration effort currently underway in New Zealand. It represents a pioneering model of co-governance, planning, collaboration, and problem-solving aimed at restoring the health and mauri (life force) of Kaipara Moana[1]. This transformative 10-year effort addresses critical environmental degradation in New Zealand's largest harbour, focusing on reducing severe sedimentation, improving water quality, and creating local employment opportunities.

To achieve these goals, KMR focuses on reducing sedimentation through measures such as wetland restoration, river fencing, tree planting, and the regeneration of forests on erosion-prone land. The initiative also trains local advisors to assist landowners in improving soil quality. These measures have been proven effective in reducing sedimentation and enhancing soil health (Wilcock et al., 2013).

This initiative is supported by a total budget of NZ$200 million—half provided by local councils, landowners, industry groups, and community organisations, and the other half by the Ministry for the

---

[1] Kaipara Moana Remediation Programme. (n.d.). Programme overview. Retrieved October 30, 2024, from https://kmr.org.nz/programme-overview/

Environment. The Ministry is accountable to the government and the public for assessing the direct, indirect, and induced benefits of this investment.

Purpose and scope of the Kaipara Moana Remediation initiative

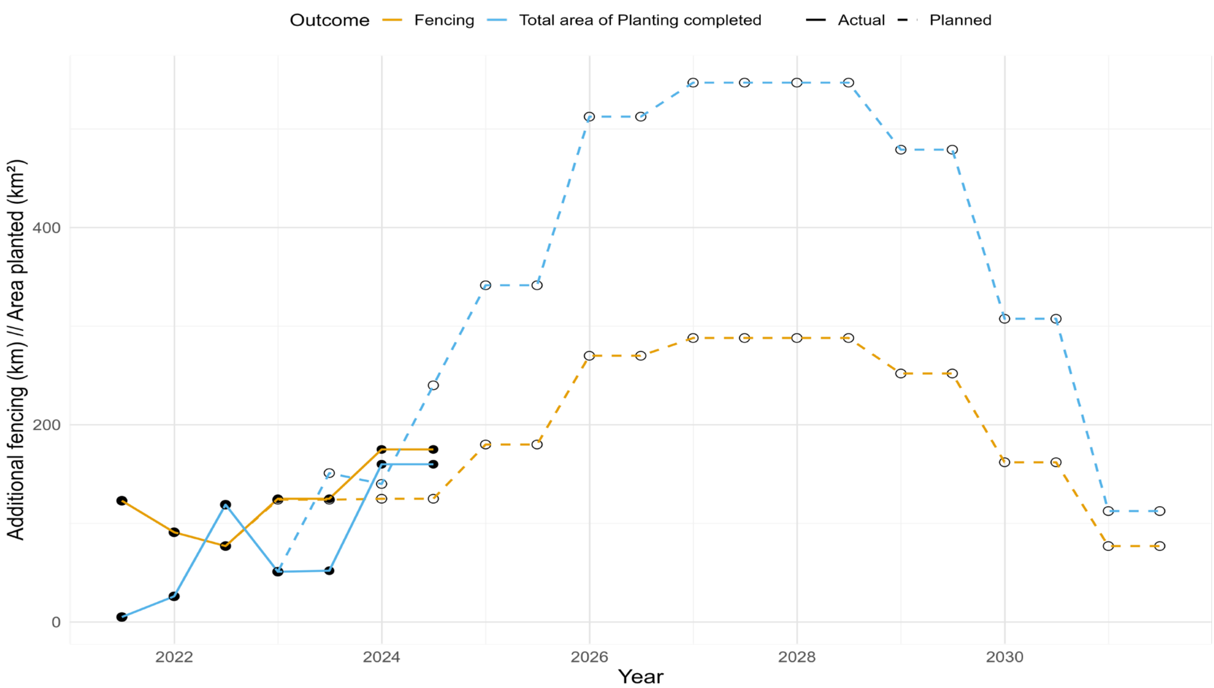
The KMR initiative is expected to deliver significant economic, environmental, social, and cultural benefits across Northland, Auckland, and the wider country. By addressing the harbour's severe sedimentation problem, the initiative seeks to improve water quality, support biodiversity, and promote sustainable land and water practices. Additionally, the initiative will create local employment opportunities and contribute to regional and national development.

The focus of this report will be the calculation of the Benefit-Cost Ratio (BCR), which compares the total discounted benefits of the initiative to the investment amount. The economic impacts and anticipated return on investment from the NZ$200 million commitment to Kaipara Moana's restoration are assessed, offering insights into the projected benefits for New Zealand's regional and national interests.

Statistical overview of KMR results

Before delving into the modelling framework, it is essential to understand the key issues associated with KMR. This includes describing the allocation of funds, the jobs created through KMR, and the environmental outcomes of its initiatives.

Graph 1 – Measured and Expected environmental benefits of the KMR initiative



KMR addresses the risks posed by sedimentation through initiatives such as planting local vegetation and installing fencing along the coastlines of the Kaipara Estuary. It is important to note the impact of these planting efforts varies depending on soil types. Currently, most planting projects are in afforested areas (80%), with the remainder in riparian zones along the coastlines.

A limited number of indicators are available to assess the environmental benefits of KMR. Every six months, the total length of fencing installed, and the area of planting projects are measured, as illustrated in graph 1. There is little information available about the quality of planting projects or the plant species being used at this early stage, even though these factors could have a major impact on restoring local ecosystems.

As of June 2024 (the end of the fourth financial year), some funded sub-initiatives remain in the preparatory stages. To date, KMR has supported 693 which have resulted in the addition of 891 km of fencing and approximately 573 hectares of planting. Annual outputs in the initial years are relatively modest compared to the overall targets for 2030. Projections suggest the environmental contributions of KMR will peak between 2026 and 2028, with over 1,000 hectares of additional planting anticipated annually. Thus far, KMR has adhered closely to its projected timeline. Fencing targets for the 2023–2024 financial year were exceeded by nearly 40 km, a 40% surplus. Planting projects experienced delays in late 2023 due to Cyclones Gabrielle and Hale hammering the region in January 2023, as well as severe flooding.

The modelling of added value from the Ministry for the Environment's (MfE) investment[2] in KMR assumes a distinction between the initiative's expenditure categories. This is crucial as the return on investment for each NZ$1 varies depending on whether it is spent on the agricultural sector (e.g., fencing or machinery) or on data processing and governance. These variations arise due to the differing production functions of these sectors, which influence:

- The allocation of intermediate consumption across national sectors; and
- The share of value added (and, consequently, GDP) which these sectors generate.

As illustrated in Graph 2, initiative expenditure has increased sharply as the number of project grants awarded rises and more landowners engage with the KMR programme. This trend is expected to persist in subsequent years. To maximise environmental outcomes, KMR has established long-term partnerships whose benefits will unfold progressively. To date, 16.7% of the MfE's total allocated budget has been spent.

The distribution of KMR expenses reflects the initiative's organisational priorities. In the early years, approximately one-third of expenses were allocated to governance activities, including partnership

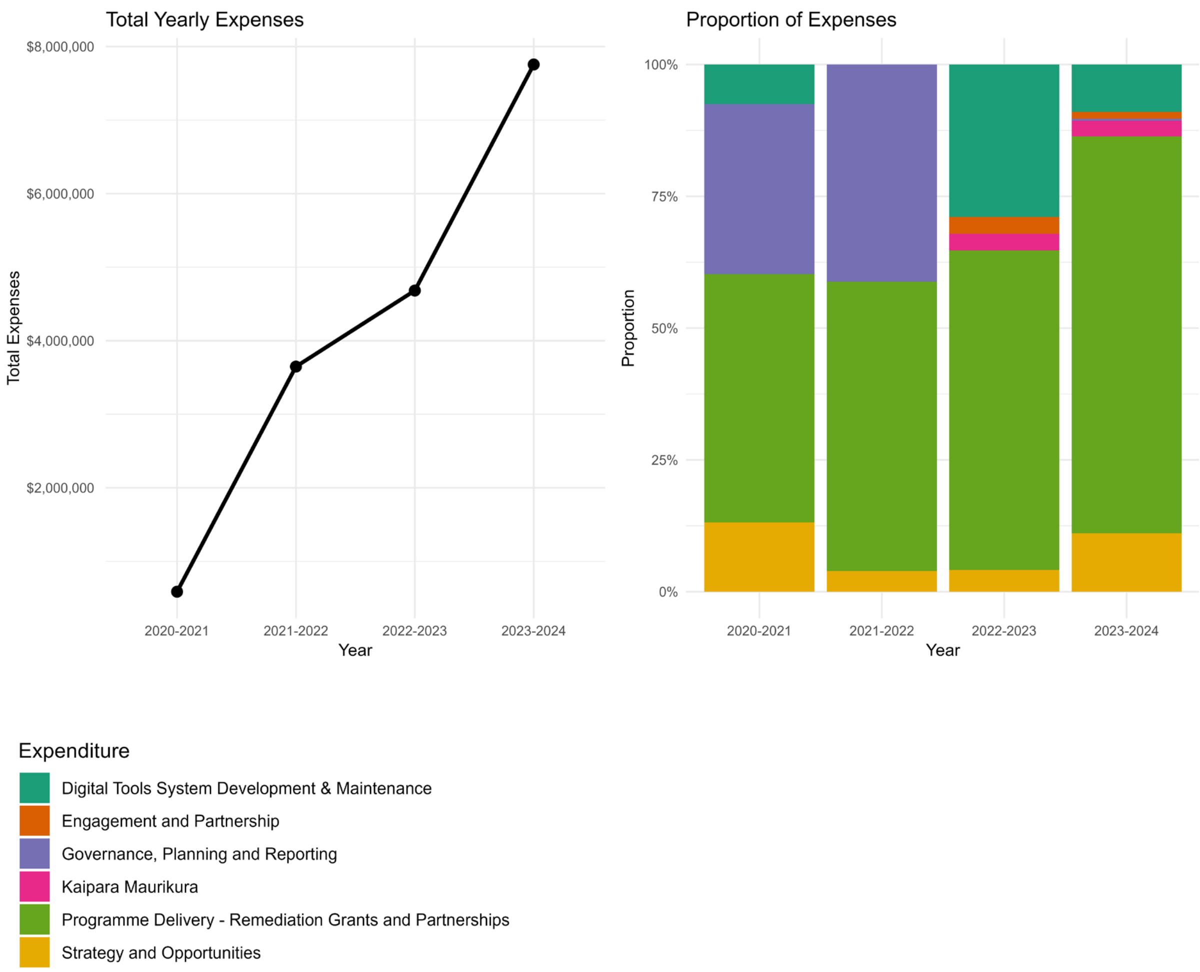
---

[2] Please note initial modelling was undertaken for Mfe's portion of $100 Million and some of the results have also incorporate the total investment.

establishment and mission management. The implementation of initial projects has also necessitated increased spending on data processing.

The most recent financial year provides a representative breakdown of expenditure for the years ahead. Most funds (75.2%) were allocated to grants and partnerships, which will deliver on the initiative's core objective of achieving environmental outcomes. The remainder was spent on mission management (i.e. strategy and opportunities, 11%) and information processing (i.e. digital tools system development and maintenance, 13.8%), which support public communication and project oversight.

Graph 2 – Annual expenditure trends



Job creation outcomes

In partnership with J4N, KMR also seeks as a secondary outcome to create employment opportunities by recruiting and training local advisors. Employment outcomes are measured through several indicators, with the Ministry's preferred metric being the total number of hours worked, expressed as Full-Time Equivalent (FTE). Over the first four years, more than 300,000 hours of work have been completed, representing 27.5% of the estimated 1,090,000 total hours for the initiative's 10-year duration.

Modelling economic and environmental impacts

To calculate the benefit-cost ratio (BCR) monetary values are assigned to all initiative outcomes. For environmental outcomes, where exact monetary values cannot be determined, research suggests using the willingness-to-pay method. As explained earlier, the specific case of KMR requires identifying links between key indicators (such as fenced kilometres, planted areas, and trained employees) and measurable benefits. The economic benefits are estimated using an enhanced I/O model. Further details on this model's formalisation are provided in Section IV.

Data sources

Several data sources are available to support the analysis, including internal documents from the J4N Secretariat and public databases from New Zealand. The internal documents deemed sufficient for the integration of KMR into the cost-benefit model are as follows:

- A database documenting the various transactions between the Ministry and KMR, detailing the expenditure categories for the allocated amounts.
- A database containing KMR's activity projections and results, including both environmental and economic outcomes.

It is important to note these internal databases, while useful, are relatively limited considering the scale of the initiative and its total funding. While the documentation of transactions between the Ministry and KMR are comprehensive, the documentation between KMR and their sub-projects is sufficient for reporting but not in enough detail to which makes it challenging to establish a clear link between the grants awarded and the sub-projects implemented. Additionally, the projected expenditure amounts are not sufficiently detailed and lack a structured breakdown of expected costs. In addition, due to the early stage of the initiative, it is too early for environmental outcomes to be realised. Given these constraints, it may be difficult to draw a direct connection between the investment and the actual outcomes of the initiative. However, the estimation of economic benefits is less hindered by data limitations as it is a broader and less specific area of focus.

To address these challenges and calibrate the I/O model upon which this analysis relies, several publicly accessible data sources have been utilised. Most of these datasets are produced by Statistics New Zealand - Tatauranga Aotearoa (Stats NZ).

The following data sources are employed:

- The reference national accounts I/O table for 2020[3].
- The Household Income and Housing-Cost Statistics (HIHC) survey, which provides estimates of total household income in New Zealand[4].
- GDP and value-added estimates by industry for the years 2020 to 2023[5]. These data enable the calibration of predictive models for future I/O tables and enhance Autoregressive integrated moving average (ARIMA)[6] models for forecasting value-added figures.
- Demographic projections[7], which are crucial for estimating environmental benefits using willingness-to-pay measures, calculated on a per capita basis.
- Three additional national accounts I/O tables (1996[8], 2007[9], 2013[10]) which are required for the predictive model. The 1996 table is the oldest publicly available digital version.
- The regional industrial structure for Auckland and Northland[11], facilitating discussion on the potential regionalisation of the model.
- The national CBAx model[12], which adopts the same cost-benefit approach as outlined in the following section. This model provides reference values acknowledged by various national stakeholders, including real interest rates, environmental measures, and taxation prices.

---

[3] Stats NZ. (2020). National accounts: Input-Output tables year ended March 2020. Retrieved from https://www.stats.govt.nz/information-releases/national-accounts-input-output-tables-year-ended-march-2020

[4] Stats NZ. (2023). *Household income and housing-cost statistics year ended June 2023*. Retrieved from https://www.stats.govt.nz/information-releases/household-income-and-housing-cost-statistics-year-ended-june-2023

[5] Stats NZ. (2020). *National accounts: Industry production and investment year ended March 2020*. Retrieved from https://www.stats.govt.nz/information-releases/national-accounts-industry-production-and-investment-year-ended-march-2020

[6] ARIMA models predict future values based on past values.

[7] Stats NZ. (2022). *National population projections 2022 (base)-2073*. Retrieved from https://www.stats.govt.nz/information-releases/national-population-projections-2022base2073/

[8] Stats NZ. (1996). *National accounts: Input-Output tables year ended March 1996*. Retrieved from https://ndhadeliver.natlib.govt.nz/webarchive/20190215112312/http://archive.stats.govt.nz/browse_for_stats/economic_indicators/NationalAccounts.aspx

[9] Stats NZ. (2007). *National accounts: Input-Output tables year ended March 2007*. Retrieved from https://www.stats.govt.nz/information-releases/national-accounts-input-output-tables-year-ended-march-2007

[10] Stats NZ. (2013). *National accounts: Input-Output tables year ended March 2013*. Retrieved from https://www.stats.govt.nz/information-releases/national-accounts-input-output-tables-year-ended-march-2013

[11] Stats NZ. (2023). *Regional gross domestic product year ended March 2023*. Retrieved from https://www.stats.govt.nz/information-releases/regional-gross-domestic-product-year-ended-march-2023/

[12] The Treasury. (n.d.). *CBAx tool*. Retrieved from https://www.treasury.govt.nz/information-and-services/state-sector-leadership/investment-management/investment-planning/treasurys-cbax-tool

II. Estimation of environmental and social benefits

Cost-benefit model

The evaluation of the KMR initiative's economic impact is conducted using a cost-benefit analysis (CBA) framework, a widely accepted methodology for assessing the relative merits of public projects. Central to this analysis are two key indicators: the Net Present Value (NPV) and the Benefit-Cost Ratio (BCR). These indicators enable the comparison of the discounted value of benefits and costs over time, providing a clear measure of the initiative's economic viability.

1. **Net present value (NPV)**

The net present value (NPV) of the KMR initiative is calculated as follows:

$$NPV = \sum_{t=0}^{T} \frac{B_t}{(1+r)^t} - \sum_{t=0}^{T} \frac{C_t}{(1+r)^t} \qquad (1)$$

Where:

$\mathbf{B_t}$ denotes the benefits received at period,

$\boldsymbol{C_t}$ denotes the costs incurred at period,

$\boldsymbol{r}$ is the interest rate,

$\boldsymbol{T}$ is the time horizon.

The hypothesis guiding the evaluation is straightforward:

- If $\boldsymbol{NPV > 0}$, the initiative **is** considered economically viable.
- If $\boldsymbol{NPV < 0}$, the initiative is **not** considered economically viable.

In other words, the cost-benefit theoretical framework compares the discounted value of benefits over time with the discounted value of costs over time.

2. **Benefit-cost ratio (BCR)**

An additional key metric used to assess the economic viability of the KMR initiative is the BCR. The BCR is calculated as:

$$BCR = \frac{\sum_{t=0}^{T} \frac{B_t}{(1+r)^t}}{\sum_{t=0}^{T} \frac{C_t}{(1+r)^t}} \qquad (2)$$

This ratio indicates the present value each $1 invested in the initiative will yield in benefits. A BCR of 2, for example, suggests for every $1 invested, $2 in benefits are returned. If the BCR is less than 1, the initiative is considered economically unviable.

Cost considerations and counterfactual assumptions

When assessing the total costs of the initiative, defining the counterfactual scenario (the hypothetical alternative to the project) is methodologically critical. The opportunity cost approach assumes the indexed $200 million (2020 dollars) allocated to KMR could have funded other public priorities. Whereas the Tax burden approach considers a scenario where the $200 million was never collected through taxes, requiring calculation of deadweight loss, this is the economic inefficiency caused by taxation reducing private-sector productivity.

Methodological limitations

Whilst this approach provides valuable insights for decision-makers, it is not without its limitations. A key constraint is the reliance on partial equilibrium models which, although less computationally intensive, may not fully capture the broader economic dynamics or interdependencies within the economy. However, given the relatively small scale of the KMR initiative compared to New Zealand's overall budget, it is reasonable to assume these limitations would not significantly affect the results.

Another challenge lies in defining the counterfactual for cost estimation. The model assumes either the $200 million allocated to KMR could have been used for alternative purposes or these funds would not have been collected through taxation. Despite these limitations, the partial equilibrium framework remains appropriate given the relatively minor significance of the KMR initiative in the context of New Zealand's broader economy.

The forecasting process in some places lacks sufficient data to produce consistently reliable estimates (including at a regional level). A broader limitation of this study is that it uses a partial equilibrium framework, which does not fully account for how economic agents respond to investments. While microeconomic foundations are crucial for such modelling, we were unable to compare our findings with a computable general equilibrium (CGE) model, such as NZ-TERM, due to lack of access to the model.

Monetary valuation of environmental benefits

Approach to valuing environmental benefits

The environmental benefits of the KMR initiative present a unique challenge for monetary valuation, as these benefits do not have a direct market price. Several methods exist to estimate their value, including assessing future costs avoided (such as water treatment expenses), gauging the willingness of local residents to pay for similar environmental improvements, or calculating the minimum compensation required once damages have occurred. In the context of this analysis, and consistent with the CBAx model, willingness-to-pay (WTP) is the chosen approach for monetising these benefits.

Willingness-to-pay methodology

The WTP method typically involves conducting surveys to estimate how much beneficiaries value improvements in the environment. Respondents are asked how much they would be willing to pay for a certain environmental gain. While this approach is effective in capturing public preferences, it often faces challenges in integrating the full scope of environmental benefits into the model. This is because the survey questions must be general enough to ensure accessibility for a broad range of respondents. For example, in the National Stock Exclusion Study (Grinter & White, 2016), a WTP for a 1% increase in marine biodiversity quality is recorded, but the concept of "marine biodiversity" is not explicitly defined. This ambiguity makes it necessary to choose a proxy variable can represent this concept. From there, econometric models can be applied to link these proxy variables to the specific outcomes of the KMR initiative.

Once a relationship between the proxy variable and the KMR outcomes is established, the monetary value of the environmental benefit can be calculated using the following formula:

$$B_{i,j} = P_r \times Z \times W\text{TP}_r + P_{-r} \times Z \times W\text{TP}_{-r} \qquad (3)$$

Where:

$\mathbf{B_{i,j}}$ denotes the value of benefit *i* created by environmental action *j,*

$\boldsymbol{P_t}$ (resp. P_{-r}) denotes the total population of region r (resp. the rest of the country),

$\boldsymbol{Z}$ is the proportion of respondents placing a monetary value on the benefit,

$\boldsymbol{WTP}$ is the willingness to pay, differing depending on the respondent's place of residence.

Thus, the total valuation of a benefit is equal to the sum of the valuations of the benefits from each action:

$$B_i = \sum_j B_{i,j} \qquad (4)$$

It is also essential to recognise the benefits of the KMR initiative may not be realised immediately and could extend over multiple years. Therefore, the temporal nature of these benefits must be incorporated into the model, and their discounted value calculated. The time lag between the realisation of benefits and their corresponding valuation is critical, as it can have a significant effect on the BCR depending on the real interest rate chosen. Treasury's recent update to discount rates includes the use of the Social Rate of Time Preference (SRTP) for proposals with mainly non-commercial benefits. This approach better reflects long-term societal impacts by applying lower, declining discount rates over time. Including a payback period alongside the Benefit-Cost Ratio (BCR) can also help clarify whether benefits are short-term or long-term.

Estimation of economic benefits in partial equilibrium: Input-Output model

Model principle

The primary focus of the modelling work centres on the limitations of the economic impacts of the initiatives. Specifically, the total impact of the investment on GDP and employment in the regions affected by KMR and the channels through which this investment stimulated economic activity.

The total impact of the investment on national output can be divided into three components:

- **Direct:** The GDP generated to meet the increased final demand from KMR.
- **Indirect:** The GDP generated by the industrial production required to fulfil the rise in intermediate consumption.
- **Induced:** The GDP generated from the additional consumption following the payment references

To quantify these effects, several models can be used. The Ministry has traditionally used an I/O model based on the work of Leontief (1941). This model is described using accounting equations which outline the distribution of production between intermediate consumption and final demand:

$$x_1 = z_{1,1} + z_{1,2} + \cdots + z_{1,n} + f_1$$

$$x_2 = z_{2,1} + z_{2,2} + \cdots + z_{2,n} + f_2$$

$$\vdots \qquad (5)$$

$$[x_n = z_{n,1} + z_{n,2} + \cdots + z_{n,n} + f_n$$

In matrix form, the system can be written as:

$$\boldsymbol{AX} + \boldsymbol{Y} = \boldsymbol{X} \qquad (6)$$

Which simplifies to:

$$(\boldsymbol{I} - \boldsymbol{A})\boldsymbol{X} = \boldsymbol{Y} \qquad (7)$$

Where:

X is the vector of total production,
I is the identity matrix,
A is the matrix of technical coefficients, where each element $a_{i,j}$ is defined as:

$$a_{i,j} = \frac{z_{i,j}}{X_j} \qquad (8)$$

and $z_{i,j}$ representing the monetary value of goods from sector i used to produce one unit of goods in sector j,

Y is the vector of final demand.

Defining this model requires the existence of the table $Z = (z_{i,j})_{1 \le i,j \le n}$, which captures inter-industry transactions, final demand, and value-added allocation. Stats NZ publishes these tables every seven years.

Given the invertibility of $(\boldsymbol{I} - \boldsymbol{A})$.[13] total output can be expressed as a function of final demand. The matrix $(\boldsymbol{I} - \boldsymbol{A})^{-1}$ is known as the **Leontief inverse:**

$$\boldsymbol{X} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{Y} \tag{9}$$

Which is crucial for determining the overall economic impact of the investment.

Household integration

To improve the model's accuracy, households are integrated as an independent sector. Households receive wages from firms and spend part of this income on consumption. The transaction matrix is updated to include household wages and consumption. This approach is critical for estimating the induced effect, as it allows for the inclusion of wage-driven demand in the economy. The extended transaction matrix becomes:

$$Z = \begin{pmatrix} z_{1,1} & z_{1,2} & \cdots & z_{1,n} & c_1 \\ z_{2,1} & z_{2,2} & \cdots & z_{2,n} & c_2 \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ z_{n,1} & z_{n,2} & \cdots & z_{n,n} & c_n \\ w_1 & w_2 & \cdots & w_n & y_0 \end{pmatrix} \tag{10}$$

Where:

$\boldsymbol{z_{i,j}}$ is the value of goods from sector i used in sector j,
$\boldsymbol{w_j}$ is wages paid by sector j,
$\boldsymbol{c_i}$ is household consumption of goods from sector i,
$\boldsymbol{y_0}$ represents the total production of the household sector, which is typically considered as total household income.

Incorporating households as an independent industrial sector allows the induced effect to be quantified. This is achievable because consumption and wage vectors are typically available in I/O tables. Models which endogenise households are referred to as Type II (as opposed to Type I models, where households are not endogenised).

A key question concerns the computation of y_0, which represents the total output of the household sector, often equated with national household income. Its value is critical as it determines the proportion of household wages allocated to consumption. Importantly, total income differs from total

---

[13] A discussion on the condition of invertibility is provided in Appendix. (Hawkins, Simon, 1949)

wages. Emonts-Holley et al. (2021) highlight the need to account for exogenous household income sources (e.g., capital, rent) when calculating Type II multipliers. A more realistic formulation is:

$$y_0 = (a_W + r \cdot a_\Pi)x_0 + f_{Y,0} \quad (11)$$

Where:

$\boldsymbol{a_W}$ is household income from wages,
$\boldsymbol{r}$ is the share of value added distributed to households,
$\boldsymbol{a_\Pi}$ is the value-added vector,
$\boldsymbol{f_{Y,0}}$ is household final demand for household-provided services (e.g., personal care).

Only a_W is available in I/O tables, making rigorous estimation of y_0 challenging without additional data. The HIHC survey of New Zealand household income distribution is used to estimate y_0. Higher y_0 values reduce household consumption as a proportion of total income, diminishing the induced effect. Assuming total labour income equals total household income overestimates consumption, leading to inflated effects.

An advantage of the I/O model is its ability to calculate Type I and Type II multipliers

- **Type I Multipliers:** Represent the amount of production required to meet a unit increase in final demand.
- **Type II Multipliers:** Account for additional demand generated by wage payments.

These multipliers measure the interdependencies between sectors. They are calculated using the Leontief inverse as follows:

For **Type I**:

$$M_I^j = \sum_{i=1}^{n} \alpha_I^{i,j}$$

For **Type II**:

$$M_{II}^j = \sum_{i=1}^{n} \alpha_{II}^{i,j}$$

Where M_j^k represents the multiplier of type k for sector j, and $(\boldsymbol{I} - \boldsymbol{A})^{\boldsymbol{1}}$ = $\left(\alpha_{i,j}\right)_{1 \le i,j \le n}$.

Initial estimations

To estimate the GDP created by the KMR investment, we begin by using the most recent I/O table available (2020), within the traditional I/O framework. This table is calculated on a national scale: the inter-industrial transactions and sector distribution within GDP represent an average for the entire country. It is the result of an optimisation problem under constraints, designed to balance the supply and demand of standardised products, calculated through surveys.

The I/O table lists all transactions between the 109 sectors of the New Zealand economy, using the New Zealand Input-Output Classification (NZIOC) industrial classification system, which is shared between Australia and New Zealand. The final demand is broken down into exports, household consumption, NPISH (Non-Profit Institutions Serving Households), government spending, and investment.

The model then allocates KMR expenditures across the relevant industrial sectors. Table 2 shows the distribution of KMR expenses across different industries for the first four years of the initiative, based on the NZIOC classification.

Table 1– KMR expenditure by industry, 2020-2024

Industry	Industry Code	2020-2021	2021-2022	2022-2023	2023-2024
Agriculture, forestry, and fishing support services	AA321, AA322	$276,667	$2,002,769	$2,837,258	$5,837,000
Advertising, market research, and management services	MN113	$266,898	$1,645,643	$491,671	$1,221,000
Computer system design and related services	MN115	$44,020		$1,353,578	$698,000
Total		$587,585	$3,648,412	$4,682,507	$7,756,000

66% of KMR's expenditure is allocated to the agricultural services sector (AA321, AA322), reflecting the nature of KMR initiatives which benefit farmers, particularly those involved in land management and planting activities. A smaller portion is allocated to data processing (MN115), communication, and management services (MN113). It's important to note the first few years of the initiative are not fully representative of future investment patterns, due to initial setup costs.

Modifying final demand

With KMR's expenditures categorised by industrial sector, we can adjust the final demand accordingly. By using the relationship between final demand and total production, we can calculate the impact on production and GDP from this investment using the following equation:

$$\Delta X = (I - A)^{-1}\Delta Y, \quad \Delta GDP = a\Pi \cdot \Delta X \qquad (12)$$

Where:

$\mathbf{\Delta X}$ is the change in output across all sectors,
$\mathbf{I}$ is the identity matrix,
$\mathbf{A}$ is the technical coefficient matrix representing inter-industry flows,
$\mathbf{\Delta Y}$ is the change in final demand,
$\mathbf{a\Pi}$ is the vector of value-added coefficients.

Total GDP impact

The decomposition of total benefits into direct, indirect, and induced impacts can be calculated by comparing the results obtained from Leontief inverses of Types I and II. Direct Impacts can be calculated by multiplying the direct changes in final demand by the value-added rates. Indirect and induced impacts can be inferred using the relationship in equation.

Table 2 – Nominal GDP created by KMR investment (standard approach)

Year	Expense	Direct	Indirect	Induced	Total
2020-2021	$590K	$290K	$220K	$200K	$720K
2021-2022	$3,650K	$1,770K	$1,400K	$1,210K	$4,380K
2022-2023	$4,680K	$2,470K	$1,710K	$1,680K	$5,850K
2023-2024	$7,760K	$3,790K	$2,940K	$2,530K	$9,260K

These initial estimates appear reasonable but are subject to the inherent limitations of the I/O model. Some of these limitations are intrinsic to its general structure, and it is challenging to propose new approaches to address them effectively. The model assumes linear production functions and homogeneous sectoral outputs, which simplifies but also limits its applicability. The relationships we rely on do not allow for agents to modify their behaviour. The capital stock is not endogenised. In the absence of dynamic behaviour, the issue of prices is not accounted for in the model.

Despite these limitations, the usual approach can be refined to increase rigor and adapt more closely to KMR's specific characteristics. As highlighted by Temurshoev (2015), integrating stochastic elements into the I/O model is crucial. Many results regarding the role of uncertainty in these models suggest, at a minimum, sensitivity tests should be performed.

Additionally, a significant body of literature has explored how national tables can be transformed into regional ones. The Kaipara Harbour spans the regions of Northland and Auckland, and it is essential to account for their specific characteristics. The following section proposes these enhancements in more detail.

Integration of the stochastic dimension and regionalisation test

The objective of transforming the current table into a regional format is to trace the capital flows originating from the initiative and its stakeholders, thereby decomposing value creation across various regions of the country. Multi-regional models also hold particular interest for decision-makers, as local authorities contribute significantly to KMR’s funding and seek to understand the impact of the initiative within their respective regions.

However, transitioning to a multi-regional model is not feasible due to the challenges in estimating interregional transactions without additional surveys. By cross-referencing the available tables with the structure of regional industries, it is possible to estimate intra-regional coefficients using location quotients, defined by the following equation:

$$LQi,r = \frac{\left(\frac{Pi,r}{Pr}\right)}{\left(\frac{Pi,n}{Pn}\right)} \tag{13}$$

where:

$\boldsymbol{Pi,r}$ is the production in industry i of region r,
$\boldsymbol{Pr}$ is the total production in region r,
$\boldsymbol{Pi,n}$ is the production in industry i of reference region n,
$\boldsymbol{Pn}$ is the total production in reference region n.

Location quotients adjust regional transactional coefficients, assuming industry distribution defines intermediate consumption patterns. For example, if KMR produces half of the national agricultural output, firms purchase half of their agricultural products from the region. This is unrealistic, as KMR prioritises local suppliers. The final demand of KMR could be adjusted to reflect this, but the behaviour of neighbouring firms is unknown.

The drawback of this method is, without intra-regional coefficients, transactions between regions are treated as losses to national output, leading to significant underestimates. As a result, regionalisation was not pursued in this report.

The model would also benefit from incorporating stochastic coefficients. New Zealand's I/O tables are derived from Stats NZ's survey methods. The results are then used to determine supply and demand for standardised goods across the territory. An optimisation problem under constraint helps generate an I/O table compatible with the results, where all coefficients are positive or zero. These results are sensitive to both in-sample and out-of-sample errors. Stats NZ highlights errors of the latter type are more significant, as some companies report figures of incorrect magnitude, distorting estimates.

The most sensitive coefficient is the total household output. Equation 13 shows its estimation is complex due to unreported value-added income in the I/O tables. We address this by using the HIHC survey, which provides confidence intervals on household income estimates and the number of households. These can be incorporated into the model to reflect uncertainty.

Using the notation from Equation 11, we obtain:

Table 3 – Estimation of parameters for $\boldsymbol{y_0} = (\boldsymbol{a_W} + \boldsymbol{r} \cdot \boldsymbol{a_\Pi})\boldsymbol{x_0} + \boldsymbol{f_{Y,0}}$

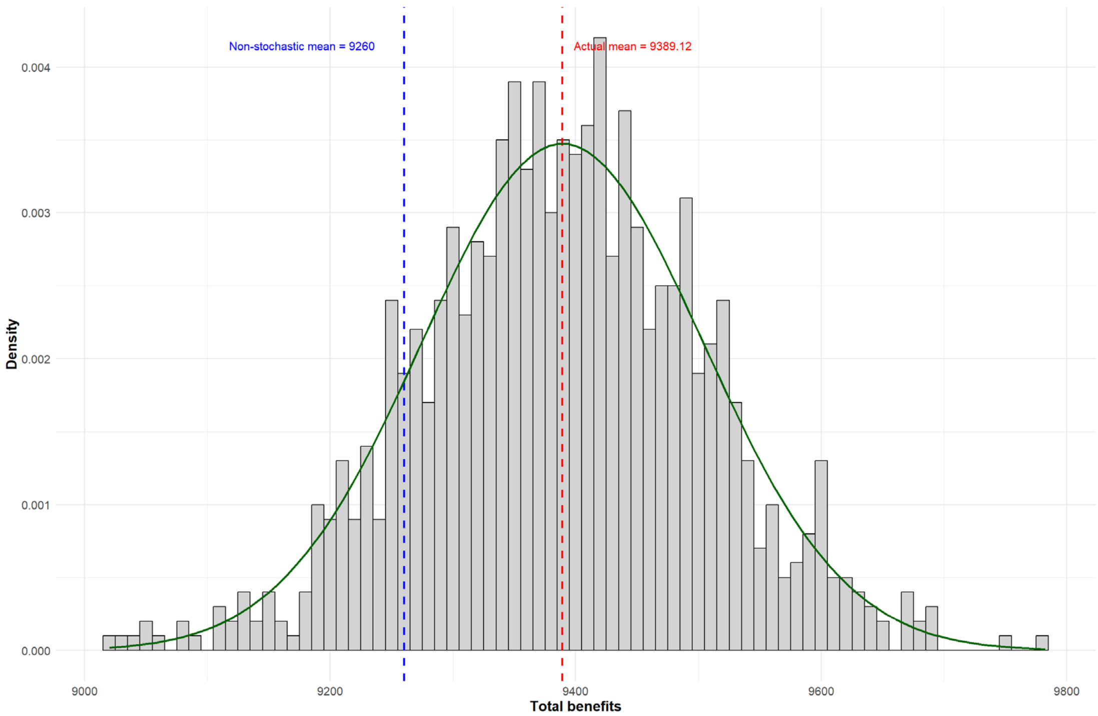
Parameter	μ	σ	95% CI
y_0	190000	9500	[171,390; 208,610]
r	0.194	0.0097	[0.175; 0.213]
$f_{Y,0}$	0	–	–

In the absence of additional data, we follow the methodology proposed by Rose and Stevens (1991), which suggests setting $f_{Y,0}$ to zero in order to reduce the number of parameters to estimate. This choice is also motivated by the presence of domestic service sectors (RS212, RS215) in the table, as the portion of household services provided by households is already captured within an existing industrial sector. The value of r is derived directly from the equation, as y_0 is provided indirectly by the HIHC survey via average salary and household data. The resulting variation of approximately 20% is consistent with Stats NZ's estimates. It is worth noting excluding this portion of income from the model results in an increase of approximately 42% in the technical coefficients, leading to a significant overestimation of household consumption and, consequently, Type II multipliers.

While some of the uncertainty in the model pertains to household income, transactional coefficients should also be considered as random variables with observed realisations. StatsNZ does not provide sampling error estimates for the technical coefficients, which leads us to initially assume these coefficients follow a Gaussian distribution. In the absence of quantifiable errors, we introduce a 5% variation for each technical coefficient via simulations. This approach allows us to assess the sensitivity of the final results to variations in the original I/O table.

As illustrated in graph 3, the introduction of stochastic dimensions into the I/O matrix results in a significant bias compared to the deterministic approach. On average, the total nominal benefits arising from the fiscal 2023-2024 expenditures are approximately 1.4% higher than the estimates derived from the previous (non-stochastic) approach. Variations in transactional coefficients affect total benefits to different extents. The national economy is represented by a set of linear production functions, and each sector is assumed to produce a homogeneous good. The analysis of the elasticities of transactional coefficients reveals the coefficient with the most significant influence on the outcome is total household income, as it drives consumption and, therefore, the magnitude of induced effects. The portion of wages paid by industries involved in the initiative (e.g., agricultural services, data processing, and project management) also plays a critical role. Indirectly, the share of income allocated to housing represents a significant portion of the flows originating from households.

Graph 3 – Simulations of total nominal benefits for the year 2023-2024



Although assuming transactional coefficients are Gaussian random variables is well-established in the literature, the choice of coefficient variation is inherently arbitrary. The predictive model for technical coefficients developed in the subsequent section enables us to determine these coefficients through regression analysis, facilitating the calculation of standard deviations and refining the simulations.

Prediction of future I/O tables

In the standard I/O approach, the calculation of investment-added value is based on a table representing the national industrial structure at a specific point in time. However, this approach does not account for potential changes in the national industry during the course of the initiative. Such changes result in a violation of the assumption technical coefficients remain stable over time.

To address this limitation, we have developed a predictive model for future New Zealand I/O tables. The aim is to forecast transaction volumes, added value, and final demand for the years following 2020. However, two structural constraints within the I/O tables prevent direct predictions of transaction dynamics. Specifically:

1. The accounting identity between the purchases and sales of each industrial sector k must hold:

$$\underbrace{\sum_{j=1}^{n} z_{k,j}}_{\text{Sales to other sectors}} + \underbrace{f_k}_{\text{Final demand for the good}} = \underbrace{\sum_{i=1}^{n} z_{i,k}}_{\text{Intermediate consumption}} + \underbrace{a_{\Pi} x_0}_{\text{Total added value}} \tag{14}$$

2. The sum of the added value vector must equal the sum of the final demand vector:

$$\text{GDP} = \sum_{i=1}^{n} a_{\Pi,i} = \sum_{i=1}^{n} f_i \tag{15}$$

The Multi-Regional Technique (MTT)[14], as developed by Zheng et al. (2018), allows us to relax these constraints and construct a predictive model. The only exogenous variable in the model is GDP, which is publicly available for New Zealand. To transform the I/O matrix, we define:

$$y_{i,j} = \frac{x_{i,j}}{x_{i,(n+1)}}, \quad i,j = 1,2,\dots,n+1 \tag{16}$$

Thus, the matrix ***Y*** is expressed as:

$$\text{Y} = \begin{pmatrix} y_{1,1} & y_{1,2} & \cdots & y_{1,n} & 1 \\ y_{2,1} & y_{2,2} & \cdots & y_{2,n} & 1 \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ y_{n,1} & y_{n,2} & \cdots & y_{n,n} & 1 \\ y_{(n+1),1} & y_{(n+1),2} & \cdots & y_{(n+1),n} & 1 \end{pmatrix} = \begin{pmatrix} Y_{n\times n} & I \\ Y_{(n+1)\cdot} & 1 \end{pmatrix} \tag{17}$$

The elements of $Y_{n\times n}$ can be predicted without any constraints. The vector $Y_{(n+1)\cdot}$ remains subject to constraints, which necessitate a final transformation:

$$z_j = \frac{y_{(n+1),j}}{y_{(n+1),1}}, \quad j = 1,2,\dots,n \tag{18}$$

At this stage, all elements of the I/O matrix—total transaction values, final demand, and added value can be predicted without constraints. Two distinct models are developed:

[14] Refer to Appendix C.

- ARIMA models for the coefficients of the added value vector, as they are crucial for calculating the technical coefficients and the final demand vector.

- A standard regression model for the transaction coefficients, which must be automated due to the large number of coefficients (1,102 in total).

Given the limited data available for model training—Stats NZ publishes new I/O tables every 5 to 10 years. The oldest available digitised table dates back to 1996, providing only four observations per coefficient (1996, 2005, 2013, 2020). Despite this limited dataset, the transaction coefficients follow relatively simple trends, and this is not considered a significant issue for model development. The main challenge arises from the evolution of industrial classifications over time. Under certain assumptions, we are able to standardise the tables for comparison, enabling us to use four observations per coefficient to parameterise the model.

Once the models are trained, the predicted matrix is transformed back to its standard format by fixing the exogenous variable (GDP) and following the back-transformation steps outlined in Appendix C: The back-transformation process of the predicted matrices.

III. Results

As outlined earlier, the prediction of added value is made using ARIMA models, which are particularly suited to this context for time series forecasting. Their scalability is an added benefit, as the number of models to be specified remains relatively low. For our study, one model is required per industrial sector, excluding the reference sector, which allows us to relax certain constraints. This results in 108 models for the Type I matrix and 109 for the Type II matrix.

The model selection procedure uses the auto.arima function from the forecast package, based on the Hyndman-Khandakar algorithm. Each model is specified by minimising the AIC (Akaike Information Criterion), while the number of differences is determined using the KPSS test (Kwiatkowski-Phillips-Schmidt-Shin). The specified models are summarised in the table below:

Table 4 – Specifications of ARIMA models

Models	(0,0,0)	(0,2,0)	(1,1,0)	(2,0,0)	(2,0,2)
Number of Specifications	2 (1.85%)	74 (68.52%)	16 (14.81%)	14 (12.96%)	2 (1.85%)

The results align with the structure of the data, where the models generated by the algorithm remain relatively simple. This simplicity arises from the small number of data points available for each series, mitigating concerns about overfitting. As a result, the added value vector for each industrial sector can be reliably predicted for the years covered by the KMR initiative, though data limitations impose certain constraints.

This approach could have been applied to the final demand vector coefficients, but using added value avoids the issue of negative predicted coefficients. The I/O table, by definition, should contain only non-negative coefficients. Since the MTT method does not guarantee positivity, the final demand vector often includes negative values, particularly due to foreign trade impacts. Handling these sign changes prevents the reversal of row signs during back-transformation, ensuring the consistency of the results.

However, this method cannot be extended to interior coefficients due to the large number of variables involved. We address this by comparing three models: linear, quadratic, and logarithmic regression, using adjusted R^2 values to select the best-fitting model. In cases where data from recent years (2013, 2020) are particularly important, such as for digital sectors, we adjust the procedure to give more weight to these values.

To respect positivity constraints, we set coefficients to zero if the null hypothesis cannot be rejected by the t-test. This adjustment ensures the model's integrity and prevents small or negative coefficients from distorting the final demand vector. It also helps maintain consistency and prevents anomalous results when projecting future years (2021–2031).

Table 5 – Projected coefficients for the 2021 I/O table

Industries	AA111	AA121	AA131	AA141	AA211	AA311, AA312	...	Final Demand
AA111	73.96	29.71	0	13.8	0	0	...	3953.01
AA121	53.19	1236.71	485.82	102.31	0	0	...	-129.67
AA131	4.64	0	24	4.47	0	0	...	-885.4
AA141	8.56	34.42	10.03	47.69	0.27	0	...	701.96
AA211	0	0	0	0	1137.38	1.82	...	2408.35
AA311, AA312	0	0	0	0	0	0	...	940.68
...	...	...	...	...	...	...	...	...
Added Value	**2079.83**	**4121.84**	**7577.75**	**570.77**	**1672.26**	**543.78**	**...**	**327991**

Note: The coefficients presented here are expressed in millions of New Zealand dollars. We present the results obtained for the first six industrial categories, the meanings of which are available in Appendix D: New Zealand Input-Output Classification (NZIOC) industrial classification system.

Projected benefits

To calculate the total benefits of the KMR initiative, we follow a procedure which quantifies and categorises programme expenditures, estimates the average direct, indirect, and induced impacts, and runs simulations on multiple I/O tables to create confidence intervals for results.

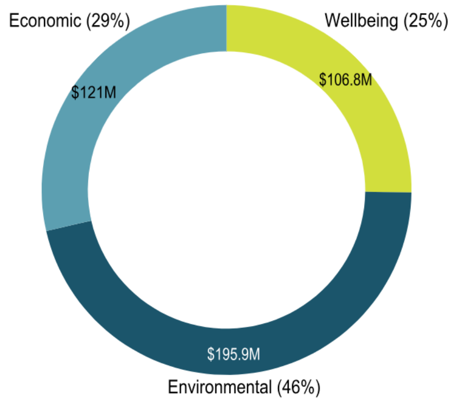
The total return is estimated at $423.8 million in total benefits over 10 years (2020–2031), with a total

BCR of 3.94:1, meaning for every $1 invested, $3.94 in benefits are expected[15]. Based on the BCR, the programme is expected to reach its payback period 3,63 years meaning the benefits begin to outweigh costs permanently after this period.

The breakdown of benefits are as follows:

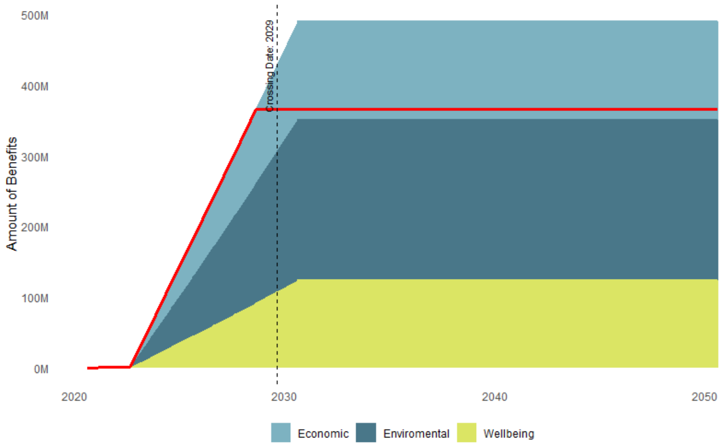
- **Economic Impact:** $121 million, contributing directly to financial growth and development.
- **Environmental Impact:** $195.9 million, focused on preserving and improving natural resources.
- **Wellbeing Impact:** $106.8 million, enhancing community and social well-being.

Graph 4 – Benefits distribution – Scenario 1 (5% annual interest)



[15] The benefit-cost ratio (BCR) calculation presented here includes only Crown funding. When the costs contributed by other parties are included, the total BCR increases to 1.76 overall.

Graph 5 – Total benefits of KMR (Scenario 1)



According to the model, KMR's primary benefits are economic, followed by environmental and social benefits (see graph 5). The costs slightly exceed the benefits until 2029, which marks the payback period. After this point, the total benefits surpass the initial investment cost, and any further benefits contribute to the overall positive impact without additional costs. The discount rate scenario (S1-S4) considered is crucial to estimate the total return on investment of the initiative as shown in the table below.

Table 6 - Total EIA results (in $000s) – Additional GDP

	Economic	Environmental	Wellbeing	Total
S1 - 5% annual r	$121,003	$195,981	$106,888	$423,872
S2 – 4% annual r	$190,568	$132,943	$65,553	$389,065
S3 – 6% annual r	$167,924	$101,864	$48,719	$318,507
S4 – 5% and halved benefits	$89,459	$58,033	$28,171	$175,663

Additional benefits post-expenditure are predominantly environmental, such as carbon sequestration and reduced sedimentation. A higher discount rate reduces the value placed on these benefits, pushing the payback period further into the future. In the worst-case scenario (with halved benefits), the payback period may never be reached, and the BCR would remain below 1.0.

The interpretation of these figures must consider the initiative’s financing structure. The graph above is based on a total expenditure of $200 million, as we cannot determine the environmental outcomes had the funding been sourced entirely from Government.

Economic benefits

To assess the value created by KMR's investment in the Northland and Auckland regions, we used I-O tables to estimate the return on investment (ROI). This method examines how spending impacts GDP, breaking down into direct, indirect, and induced impacts.

- Direct Impact: These occur when KMR allocates funds to maintain projects and support landowners.
- Indirect Impact: These arise from business-to-business purchases made using KMR funding.
- Induced Impact: These stem from wages paid, which lead to increased consumer spending.

The KMR initiative contributes to the local and national economy by stimulating final demand. From 2020 to 2031, it's estimated KMR's total spending of $200 million will result in the following economic impacts:

- Direct Impact: $73.5 million
- Indirect Impact: $52.8 million
- Induced Impact: $52.5 million.

In total, these effects contributed to a $178.8 million net boost to the Kaipara District's economy.

Table 7 - Economic benefits breakdown (Scenario 1 – 5% annual interest rate)

Year	Expenses	Direct Impact	Indirect Impact	Induced Impact	Total Impact	BCR
2020-2021	$1,175	$608	$450	$403	$1,461	1.24
2021-2022	$7,297	$3,591	$2,270	$2,293	$8,154	1.11
2022-2023	$9,365	$4,332	$2,819	$2,834	$9,985	1.07
2023-2024	$15,512	$6,745	$4,508	$4,516	$15,768	1.02
2024-2025	$20,420	$8,345	$5,715	$5,726	$19,786	0.97
2025-2026	$28,774	$11,056	$7,841	$7,756	$26,653	0.93
2026-2027	$30,941	$11,176	$8,122	$8,055	$27,353	0.88
2027-2028	$31,454	$10,682	$7,944	$7,895	$26,521	0.84
2028-2029	$28,209	$9,008	$6,863	$6,868	$22,739	0.81
2029-2030	$19,076	$5,728	$4,480	$4,461	$14,669	0.77
2030-2031	$7,776	$2,197	$1,768	$1,734	$5,698	0.73
Total	**$200,000**	**$73,467**	**$52,781**	**$52,541**	**$178,789**	**0.89**

The table above summarises the economic benefits of KMR investment under Scenario 1, using a 5% annual discount rate. It highlights how the programme supported economic resilience during years heavily impacted by COVID-19. The discount rate influences the net BCR.

The discount rate adjusts future benefits to present-day values, ensuring meaningful comparisons over time. Expenses are expressed in real terms based on their value in 2020 dollars, while outcomes accrue from subsequent years. The total net BCR is 0.89, meaning that out of the total investment of

NZD200 million, approximately NZD22 million will not directly contribute to national GDP through economic impacts alone.

The BCR exceeded 1.00 during 2020–2022 (2020–21: 1.24; 2021–22: 1.11), indicating positive returns where benefits outweighed costs. From 2024 onwards, the BCR fell below 1.00, reflecting diminishing returns as expenses increased while benefits plateaued.

While the economic BCR is below 1.00, it is important to note that environmental and wellbeing benefits are calculated separately and may elevate the overall value of the programme above 1.00. These include improved biodiversity outcomes for Kaipara Harbour ecosystems and cultural values for local iwi.

Environmental and wellbeing benefits

KMR delivers significant environmental and wellbeing benefits beyond its direct economic impacts. The table below shows the monetary value of these benefits, with biodiversity improvements ($203.07 million) and cultural values ($106.07 million) providing the largest contributions. Together, these environmental and wellbeing benefits total over $389 million, representing the substantial long-term value this restoration work brings to ecosystems, communities, and future generations.

Table 8 – Environmental and wellbeing benefits breakdown (Scenario 1 – 5% discount rate)

Benefit	Explanation	Total Value
Improved water quality	Measures the economic value of cleaner water, leading to better health outcomes, reduced treatment costs, and enhanced aquatic ecosystems	$25.10 million
Decreased risk of sickness	Measures the benefits of reducing health risks, leading to lower healthcare costs and improved public health outcomes	$5.05 million
Improved biodiversity	Reflects the value of preserving biodiversity, which supports ecosystem services and provides cultural and recreational benefits	$203.07 million
Improved water clarity	Measures the economic value of enhancing water clarity in waterways and lakes	$16.73 million
Avoided loss of topsoil	Indicates the economic value of preventing soil erosion, which maintains land productivity and reduces sedimentation in waterways	$0.07 million
Reduced stock loss	Measures the average yearly cost of stock loss in waterways	$0.09 million
Aesthetic appeal	Reflects the value of improved aesthetic appeal, which can increase property values and enhance quality of life	$0.11 million
Improved cultural values	Measures the benefits of being able to protect and promote Māori culture and practice	$106.07 million
Increase in fish catch	Reflects the value of additional fish caught for recreational fishing due to improved water quality	$21.95 million
Avoided flood damage	Measures the prevention of harm to people, property, and infrastructure from floodplain restoration	$11.16 million

The total value of each benefit depends on its valuation by the public, as most benefits are calculated according to a willingness-to-pay measure.

To calculate the value of each benefit mentioned above, we establish a relationship between the metrics (e.g., kilometres of fencing, hectares of plantations) and a specific economic valuation. Most national standards rely on the willingness-to-pay of residents when this information is available; otherwise, avoided costs are used. To improve accuracy, we differentiate between the views of people living in the Kaipara district and those of other New Zealanders.

This means the calculations reflect what society considers harmful. For example, the most highly valued benefit is the reduced risk of illness, as the targeted E. coli bacteria result in significant medical costs.

However, some considerations are not valued highly enough by the public to have a major impact in the model:

- The educational value of ecosystems, marine biodiversity quality, and cattle loss make up only 1% of the total benefits.
- Carbon sequestration from riparian and afforestation planting represents just 5% of the total benefits due to the low price of carbon per tonne assumed in the calculations.

IV. Conclusion

The KMR initiative is a flagship initiative under the J4N programme and the largest landscape restoration effort currently underway in New Zealand. It is a transformative 10-year effort addresses critical environmental degradation in New Zealand's largest harbour, focusing on reducing severe sedimentation, improving water quality, and creating local employment opportunities. To achieve these goals, KMR focuses on reducing sedimentation through proven measures such as wetland restoration, river fencing, tree planting, and the regeneration of forests on erosion-prone land.

Given the large investment in the initiative ($200 million—half of which came from the Ministry for the Environment) an assessment of its direct, indirect, and induced benefits are warranted. Previous assessments have been undertaken, but the Ministry has taken the opportunity to improve the accuracy. An enhanced Input-Output model has been developed, allowing for a more rigorous assessment of KMR's benefits than previous estimates conducted when less information was available. The refinements introduced in this report also help ease some of the restrictive assumptions in earlier models.

Central to this analysis is the BCR of 3.94:1. The total return is estimated at $423.872 million over 10 years (2020–2031) meaning for every $1 invested, $3.94 in benefits are expected. The breakdown of benefits is as follows:

- Economic Impact: $121.003 million, contributing directly to jobs, business growth & consumer spending.
- Environmental Impact: $195.981 million, on cleaner water, carbon sequestration & ecosystem protection.
- Wellbeing Impact: $106.888 million, reduced health risks and improved quality of life and enhanced recreational and cultural values

The Kaipara Moana Remediation Programme will deliver significant environmental and social benefits. Improved water quality and biodiversity restoration make up around 46% of the total benefits, reducing sedimentation and improving aquatic ecosystems.

Wetland restoration provides long-term gains, including better flood protection and lower water treatment costs, which accumulate over time as ecological health improves. Fencing and riparian planting help reduce E. coli contamination, valued at $4,313 per kilometre of fencing, improving community health. Cultural restoration strengthens Māori wellbeing, offering an annual benefit of $160 per resident, highlighting the importance of protecting Māori cultural values.

These benefits address immediate environmental issues while creating lasting social and economic advantages, positioning the programme as a leading example of collaborative remediation efforts in New Zealand.

References

Bullard, C. W., & Sebald, A. V. (1977). Effects of parametric uncertainty and technological change on Input-Output models. Review of Economics and Statistics, 59(1), 75–81.

Chandrakumar, C., McLaren, S. J., Malik, A., et al. (2020). Understanding New Zealand's consumption-based greenhouse gas emissions: An application of multi-regional Input-Output analysis. International Journal of Life Cycle Assessment, 25, 1323–1332.

Emonts-Holley, T., Ross, A., & Swales, K. (2021). Estimating induced effects in IO impact analysis: Variation in the methods for calculating the Type II Leontief multipliers. Economic Systems Research, 33(4), 429–445.

Grace, R. V. (1996). Kaipara Harbour sand extraction: Biological monitoring programme for proposed extraction at Fitzgerald Bank. Report for Winstone Aggregates Limited and Mount Rex Shipping Limited.

Grady, P., & Muller, R. A. (1988). On the use and misuse of Input-Output based impact analysis in evaluation. Canadian Journal of Program Evaluation, 3(2), 49–61.

Green, M. O., & Daigneault, A. (2018). Kaipara Harbour sediment mitigation study: Summary (Report NRC1701–1, minor revision). Streamlined Environmental.

Grinter, J., & White, J. (2016). National stock exclusion study: Analysis of the costs and benefits of excluding stocks from New Zealand waterways. Report for the Ministry of Primary Industries.

Hicks, B., & others. (2016). Sediment attributes stage 1 (Report CHC2016-058). National Institute of Water & Atmospheric Research Ltd.

Hume, T., Green, M., Nichol, S., & Parnell, K. (2003). Kaipara sand study final report: Sand movement, storage and extraction in the Kaipara tidal inlet (NIWA Client Report HAM2002-064).

Ivanova, G., & Rolfe, J. (2011). Using Input-Output analysis to estimate the impact of a coal industry expansion on regional and local economies. Impact Assessment and Project Appraisal, 29(4), 277–288.

Kennedy, P., & Sutherland, S. (2008). Urban sources of copper, lead and zinc.

Lenzen, M., Murray, S. A., Korte, B., & Dey, C. J. (2003). Environmental impact assessment including indirect effects—a case study using input–output analysis. Environmental Impact Assessment Review, 23(3), 263–282

Leontief, W. (1951). The structure of American economy, 1919–1939: An empirical application of equilibrium analysis. Oxford University Press.

Quandt, R. E. (1958). Probabilistic errors in the Leontief system. Naval Research Logistics Quarterly, 5(2), 155–170.

Reeve, G., Swales, A., & Reed, J. (2008). Kaipara Harbour sediments: Information review.

Rose, Adam Z., and Benjamin H. Stevens. 1991. Transboundary Income and Expenditure Flows in Regional Input-Output Models. Journal of Regional Science 31 (3): 253–272.

Spörri, C., Borsuk, M., Peters, I., & Reichert, P. (2007). The economic impacts of river rehabilitation: A regional input–output analysis. Ecological Economics, 62(2), 341–351.

Temursho, U. (2017). Uncertainty treatment in Input-Output analysis. https://doi.org/10.4337/9781783476329.00018

Ten Raa, T., & Kop Jansen, P. (1998). Bias and sensitivity of multipliers. Economic Systems Research, 10(3), 275–284.

Wang, K., Wang, J., Hubacek, K., Mi, Z., & Wei, Y.-M. (2020). A cost-benefit analysis of the environmental taxation policy in China: A frontier analysis-based environmentally extended Input-Output optimization method. Journal of Industrial Ecology, 24(4), 564–576.

Wilcock, B., & others. (2013). Trends in water quality of five dairy farming streams in response to adoption of best practice and benefits of long-term monitoring at the catchment scale. Marine and Freshwater Research, 64(5), 401–412.

Williams, S. K., Acker, T., Goldberg, M., & Greve, M. (2008). Estimating the economic benefits of wind energy projects using Monte Carlo simulation with economic input/output analysis. Wind Energy, 11(4), 397–414.

Zheng, H., Fang, Q., Wang, C., Jiang, Y., & Ren, R. (2018). Updating China's Input-Output tables series using MTT method and its comparison. Economic Modelling, 74(1), 186–193. https://doi.org/10.1016/j.econmod.2018.05.011

Appendices

Appendix A: Method for evaluating environmental benefits - benefits considered

Type of Benefit	Variable Considered	Valuation (in NZ$)	Unit	Cumulative Benefit	Timeframe (years)	Success Rate	Source
Water Quality Improvement	Fencing	0.0024	$\$ \cdot Km^{-1} \cdot Hab^{-1}$	No	3	100%	NIWA + WTP survey
Disease Risk Reduction	Fencing	4313	$\$ \cdot Km^{-1}$	No	0	62%	CBAx
Biodiversity Improvement	Fencing	0.00017	$\$ \cdot Km^{-1} \cdot Hab^{-1}$	No	0	100%	WTP + Waikato
Avoided Land Loss	Total Planted Area	86	$\$ \cdot ha^{-1}$	No	0	25%	CBAx
Educational Value Improvement	Total Planted Area	0.02	$\$ \cdot household^{-1}$	No	0	100%	CBAx
Livestock Loss Reduction	Fencing	449	$\$ \cdot Km^{-1}$	No	0	10%	CBAx
Natural Aesthetic Improvement	Total Planted Area	110	$\$ \cdot ha^{-1}$	Yes	0	100%	Dittrich et al. (2018)
Water Quality Improvement	Total Planted Area	0.0024	$\$ \cdot Km^{-1} \cdot Hab^{-1}$	No	3	100%	Monaghan, Quinn (2010)
Avoided CO_2 Emissions	Riparian Planted Area	221	$\$ \cdot ha^{-1}$	Yes	3	50%	3.4t/ha
Avoided CO_2 Emissions	Afforested Area	3250	$\$ \cdot ha^{-1}$	Yes	3	50%	CBAx
Riparian Area Restoration	Riparian Planted Area	50000	$\$ \cdot ha^{-1}$	Yes	5	25%	RIA: Action for Healthy Waterways, MfE

Note: For Monaghan, Quinn (2010), plantations double the effectiveness of fencing on average.

Appendix B: The Hawkins-Simon Condition

The Hawkins-Simon Condition (Hawkins, Simon, 1949) is a necessary and sufficient condition for the existence of non-negative solutions in Input/Output (I/O) models. It ensures the proper definition of the equilibrium between supply and demand for goods. Formally, the goal is to determine whether

$$\mathrm{X} = \mathrm{AX} + \mathrm{Y}$$

admits a solution, i.e., whether

$$(I - A)$$

is invertible. To do so, the following theorem is used:

Theorem 1 (Hawkins-Simon) Let $\boldsymbol{A} = \left(a_{i,j}\right)$ be an $n \times n$ matrix whose coefficients correspond to the technical coefficients of an economy. The following two conditions are equivalent:

1. Each leading principal minor of the matrix $\boldsymbol{I} - \boldsymbol{A}$ is strictly positive, meaning that for all $\forall k \in \{1, 2, \ldots, n\}$, the determinant of the leading principal submatrix of $\boldsymbol{I} - \boldsymbol{A}$ dimension $k \times k$, denoted $\boldsymbol{B_k}$, satisfies

$$det(B_k) > 0$$

2. There exists a vector $x \geq 0$ such that:

$$(I - A)x > 0.$$

The first condition is more commonly referred to as the Hawkins-Simon condition.

In practice, referring to this theorem is complex due to the increasing number of leading principal minors as the dimension of A grows. Several other, less general, results have been established. Dietzenbacher (2005) demonstrates that, under the assumption that final demand is non-negative and that all transactions are positive, the Leontief inverse exists and is positive.

Appendix C: The process of back-transformation for predicted matrices

The MTT method enables the prediction of new I/O matrices without constraints, through several transformations. Once the predictions have been made, it is necessary to back-transform the predicted matrix to use it in our analysis framework. The process by which we perform this back-transformation is detailed here, based on Zheng et al. (2018).

The added-value vector must first be transformed as follows:

$$\begin{cases} y_{(n+1)n} = \dfrac{z_j}{\frac{n-1}{n} + \sum_{j=1}^{n} z_j}, \mathrm{j} = 1,2, \dots, \mathrm{n}-1 \\ \mathrm{y}_{(\mathrm{n}+1)\mathrm{n}} = \dfrac{1}{\frac{\mathrm{n}-1}{\mathrm{n}} + \sum_{\mathrm{j}=1}^{\mathrm{n}} \mathrm{z_j}}. \end{cases}$$

Next, this same vector $\hat{Y}_{(n+1)}^{T+l}$ become $\hat{X}_{(n+1)}^{T+l}$ after multiplication by the GDP:

$$X_{(n+1)} = x_{(n+1)\{(n+1)}. Y_{(n+1)\cdot},$$

The value-added vector $\hat{X}_{(n+1)}^{T+l}$ gives us the final demand vector $\hat{X}_{(n+1)}^{T+l}$

$$X_{\cdot(n+1)} = B^{-1} X_{(n+1)\cdot},$$

Where B is defined by:

$$B = \mathrm{Diag}\left(1 + \sum_{j=1}^{n} y_{1j}, 1 + \sum_{j=1}^{n} y_{2j}, \dots, 1 + \sum_{j=1}^{n} y_{nj}\right) - YI^T.$$

To transition from $\hat{Y}^{T+l}$ to $\hat{X}^{T+l}$, multiply the internal coefficients by the associated final demand:

$$x_{ij} = y_{ij} \cdot x_{i(n+1)}, \quad i, j = 1,2, \dots, n.$$

The I/O matrix has now been predicted for the forthcoming years in a standardised format.

Appendix D: New Zealand Input-Output Classification (NZIOC) industrial classification system

Table 9 – Industry groupings for Input-Output tables and national accounts

Input-Output tables industry	National accounts working industries
Horticulture and fruit growing	AA111
Sheep, beef cattle, and grain farming	AA121
Dairy cattle farming	AA131
Poultry, deer, and other livestock farming	AA141
Forestry and logging	AA211
Fishing and aquaculture	AA311, AA312
Agriculture, forestry, and fishing support services	AA321, AA322
Coal mining	BB111
Oil and gas extraction	BB112
Metal ore and non-metallic mineral mining and quarrying	BB113
Exploration and other mining support services	BB114
Meat and meat product manufacturing	CC111
Seafood processing	CC121
Dairy product manufacturing	CC131
Fruit, oil, cereal, and other food product manufacturing	CC141
Beverage and tobacco product manufacturing	CC151
Textile and leather manufacturing	CC211
Clothing, knitted products, and footwear manufacturing	CC212
Wood product manufacturing	CC311
Pulp, paper, and converted paper product manufacturing	CC321
Printing	CC411
Petroleum and coal product manufacturing	CC511
Basic chemical and basic polymer manufacturing	CC521
Fertiliser and pesticide manufacturing	CC522
Pharmaceutical, cleaning, and other chemical manufacturing	CC523
Polymer product and rubber product manufacturing	CC531
Non-metallic mineral product manufacturing	CC611
Primary metal and metal product manufacturing	CC711

Input-Output tables industry	National accounts working industries
Fabricated metal product manufacturing	CC721
Transport equipment manufacturing	CC811
Electronic and electrical equipment manufacturing	CC821
Machinery manufacturing	CC822
Furniture manufacturing	CC911
Other manufacturing	CC912
Electricity generation and on-selling	DD111
Electricity transmission and distribution	DD112
Gas and water supply	DD113, DD121
Sewerage and drainage services	DD122
Waste collection, treatment, and disposal services	DD123
Residential building construction	EE111, EE112
Non-residential building construction	EE113
Heavy and civil engineering construction	EE121
Construction services	EE131
Basic material wholesaling	FF111
Machinery and equipment wholesaling	FF112
Motor vehicle wholesaling, including parts	FF113
Grocery, liquor, and tobacco product wholesaling	FF114
Other goods and commission-based wholesaling	FF115, FF116
Motor vehicle retailing, including parts	GH111
Fuel retailing	GH112
Supermarket and grocery stores	GH121
Specialised food retailing	GH122
Furniture, electrical, and hardware retailing	GH131
Recreational, clothing, footwear, and personal accessory retailing	GH132
Department stores	GH133
Pharmaceutical and other store-based retailing	GH134
Non-store and commission-based retailing	GH135
Accommodation	GH211
Food and beverage services	GH212

Input-Output tables industry	National accounts working industries
Road transport	II111
Rail transport	II121
Water transport	II122
Air and space transport	II123
Other transport	II124, II125
Postal and courier services	II131
Transport support services	II132
Warehousing and storage services	II133
Publishing (except internet and music publishing)	JJ111
Motion picture and sound recording activities	JJ112
Broadcasting and internet publishing	JJ113
Telecommunications services	JJ121
Internet service providers, web search portals, and data processing services	JJ122
Library and other information services	JJ123
Banking and financing; financial asset investing	KK111, KK112
Life insurance	KK121
Health and general insurance	KK122
Superannuation and individual pension services	KK123
Auxiliary finance and insurance services	KK131
Rental and hiring services (except real estate)	LL111
Non-financial asset leasing	LL112
Residential property operation	LL121
Non-residential property operation	LL122
Real estate services	LL123
Owner-occupied property operation	LL211
Scientific, architectural, and engineering services	MN111
Legal and accounting services	MN112
Advertising, market research, and management services	MN113
Veterinary and other professional services	MN114
Computer system design and related services	MN115
Travel agency and tour arrangement services	MN211

Input-Output tables industry	National accounts working industries
Employment and other administrative services	MN212
Building cleaning, pest control, and other support services	MN213
Local government administration services	OO111
Central government administration services	OO211
Defence	OO212
Public order, safety, and regulatory services	OO213
Preschool education	PP111
School education	PP112
Tertiary education	PP113
Adult, community, and other education	PP114
Hospitals	QQ111
Medical and other health care services	QQ112
Residential care services and social assistance	QQ113
Heritage and artistic activities	RS111
Sport and recreation services	RS112
Gambling activities	RS113
Repair and maintenance	RS211
Personal services; domestic household staff	RS212, RS215
Religious services; civil, professional, and other interest groups	RS213, RS214

Glossary

TERM	DEFINITION
Biodiversity	The variety of all living organisms, including plants, animals, and microorganisms, within an ecosystem.
Benefit	The measurable improvement (change) resulting from a policy, project or programme perceived as positive by one or more stakeholders and contributes to stated objectives.
Benefit-cost ratio (BCR)	The ratio of total discounted benefits to the total discounted costs. A BCR greater than 1.0 indicates the benefits exceed the costs.
Carbon pricing	A policy tool which assigns a monetary cost to carbon emissions to incentivize reductions. In New Zealand, this is implemented through the Emissions Trading Scheme (ETS).
Carbon sequestration	The process of capturing and storing atmospheric carbon dioxide in natural reservoirs such as forests or soil. In New Zealand, forestry is a significant method of carbon sequestration.
Cost-benefit analysis	A systematic approach used to evaluate the financial and economic desirability of a policy, project or programme by comparing its costs and benefits over a specified period.
Cumulative benefits	The total positive outcomes accrue over time from a policy, project or programme, such as long-term environmental improvements from wetland restoration in New Zealand.
Ecological resilience	The ability of ecosystems to recover from disturbances like storms or human activities. Protecting native bush areas helps maintain ecological resilience in New Zealand.
Direct impacts	Impacts generated by the initial expenditure associated with a policy, project or programme.
Economic benefit	Measurable improvement to the financial aspects of an economy resulting from a policy, project or programme.
Economic impact assessment (EIA)	Analysis which quantifies the contribution an activity makes to a geographical area in terms of output, GDP and employment.
Employment starts	Number of new people employed over a given period.
Environmental benefit	Measurable improvement to the natural world and its ecosystems resulting from a policy, project or programme.
Environmental degradation	The deterioration of natural environments due to human activities like deforestation or pollution. Examples in New Zealand include waterway pollution from agricultural runoff.
Full-time equivalent (FTE)	Unit of measurement of the number of full-time hours worked by all employees in a business. It provides a measure of total labour demand associated with expenditure.
Indirect impacts	Impacts which occur when businesses or people directly involved in the project or programme purchase materials, goods and services from suppliers, who in turn make further purchases from their suppliers, and so on.

TERM	DEFINITION
Induced impacts	Impacts which occur when employees in those businesses providing the materials, goods and services are paid wages and the enterprises generate profits spent on consumption within the region.
Input-Output table	A representation of national or regional economic accounting which records the way industries both trade with one another and produce for consumption and investments.
Interest rate impact	The influence of interest rate changes on investments or borrowing costs, affecting housing affordability and business loans in New Zealand.
Intervention logic	Depiction of the logic which underpins an investment.
National gross domestic product (GDP)	The total value of goods and services produced within New Zealand over a specific period.
Net present value (NPV)	A financial metric which represents the difference between the present value of benefits and the present value of costs. A positive NPV indicates the benefits outweigh the costs.
Payback period	The amount of time it takes to recover the cost of an investment.
Present value (PV)	The discounted value of future cash flows.
Public health	The health outcomes of populations influenced by policies and environments, such as clean water initiatives improving public health in New Zealand.
Return on investment (ROI)	A measure of profitability which calculates the return relative to the cost of an investment.
Sedimentation	The accumulation of soil particles in waterways caused by erosion or human activity like construction.
Soil erosion prevention	Measures taken to prevent the loss of topsoil due to wind or water erosion, such as planting native vegetation on hillsides prone to erosion.
Water quality improvement	Efforts made to enhance the cleanliness and safety of water bodies for ecosystems and human use.
Wetland restoration	Rehabilitating wetlands to their natural state to support biodiversity and ecosystem services like flood control and water purification.