National Freight Demand Study

Scoping Report

Ministry of Transport

27 June 2024

The Power of Commitment

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Options are high level in nature for the purposes of a relative assessment. Option descriptions are not exhaustive due to each option having many variants, which could lead to differing views about the prevailing methods.

NFDS delivery cost estimates are high level estimates only and include various assumptions regarding internal Ministry resources and should be viewed as direct costs only for gathering data, analytics and modelling. A more detailed budget would need to be developed with engagement from relevant agencies and departments.

Terminology and descriptions have been aligned, to the greatest extent, with commonly accepted language for ease of understanding. However, this approach may occasionally lead to oversimplification, resulting in minor variations in descriptions compared to other literature.

GHD has prepared this report on the basis of information provided by the Ministry and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The outcomes presented in this report are based on findings and data available up to and including 27th June 2024. Any developments or changes in the field of study that have occurred after this date are not reflected in the conclusions of this report.

Accessibility of documents

If this report is required to be accessible in any other format, this can be provided by GHD upon request and at an additional cost if necessary.

Executive Summary

The NFDS is critical for not only understanding freight movements in New Zealand but also for determining how to improve economic outcomes and energy transition.

The Ministry of Transport has previously published three versions of the National Freight Demand Study (NFDS) in 2008, 2014 and 2018 respectively. The NFDS is a key research report published by the Ministry which has been actively used by Waka Kotahi, KiwiRail, local government and across the private sector. The NFDS provides statistics on freight movement in New Zealand, providing current and future insights on commodity flows, mode share, productivity, and infrastructure use. However, the broad application of the NFDS has revealed areas for improvement and gaps in information. For example, the previous NFDS had limited scope relating to intra-regional freight flows, infrastructure investments insights, and ability to identify decarbonisation opportunities. The Ministry also recognised the NFDS lacked the depth, completeness, and alignment to established practices exemplified in other jurisdictions. It is these drivers that have led the Ministry to commission this NFDS Scoping and Methodology Study.

The purpose of this Study is to outline the feasibility and implications of alternative options to updating the NFDS. Each approach has been assessed with consideration of data requirements in a New Zealand context. Eleven sub-options within four broad option classes or 'typologies' were identified and assessed.

It was identified that the objective for the NFDS should be to:

01	02	03
Inform investment decision making	**Increase usability and reliability of the NFDS**	**Enable supply chain resilience outcomes**
04	**05**	**06**
Support decarbonisation outcomes	**Inform policy decisions**	**Increase value to private sector and study participation**

There are data and modelling complexities which means that there is no 'one size fits all' approach.

The research and engagement task confirmed that there is no single uniform dataset which can perfectly describe the movement of freight. Datasets will only be able to represent a certain component of the freight movement picture (e.g. consignment data) or be a sample across the sector at any given period of time (e.g. survey data) which needs to be accurately extrapolated.

Two key datasets have been identified which have the greatest potential to close data gaps, Firstly, the Commodity Flow Survey (CFS) is the most typical freight survey method used internationally, this is a survey targeted at businesses in the freight sector, with the purpose of collecting data on freight movements. Secondly, New Zealand is in an advantageous position (relative to other jurisdictions) with access to EROAD telematics data, which has a high sample rate and coverage of commercial vehicle movements.

These data types create inconsistencies with how freight movements are measured and captured resulting in data gaps. One way to address these gaps is by exploring modelling methods to close or account for this gap.

During the research, it was observed that not all models are uniform and follow only one methodology or function, hence why we have categorised based on prevailing method/function. For example, some commodity flow and four-step models may use elements of simulation, i.e. a commodity flow model could use some system balancing (adjusting system level parameters) as opposed to linear extrapolation, and a four-step model could use simulation to conduct truck tour modelling. Specifically, the research task identified that:

1. There is an interconnected relationship between data availability and the most suitable modelling approaches selected.
2. Although capturing freight data can be costly and challenging, the adoption of telematics and new technologies is reducing reliance on data from industry players. This can help decrease costs and lessen the burden on the industry.
3. A commodity flow survey and baseline commodity flow are critical components of national freight demand model.
4. The Four-step model is currently the most utilised approach, though limited in its ability to address complex questions.
5. National freight models are often modular with several model types integrated, which of these model types are selected depends on the use-case. Therefore, there is no single approach (beyond the four-step) which is the most commonly used.

Drawing on research and industry engagement, GHD identified high level modelling typologies and then undertook a Multi-Criteria Assessment to evaluate a set of options within each typology. The following options were the highest-scoring option from each modelling typology approach, and have been selected as potential approaches to update the NFDS:

- Commodity Flow – Intra-Regional with high level vehicle/mode flows
- Four Step Model – with enhanced route assignment
- Supply-Chain Simulation and System Balancing Models
- Dynamic Simulation – Agent Based and Discrete Event Simulation

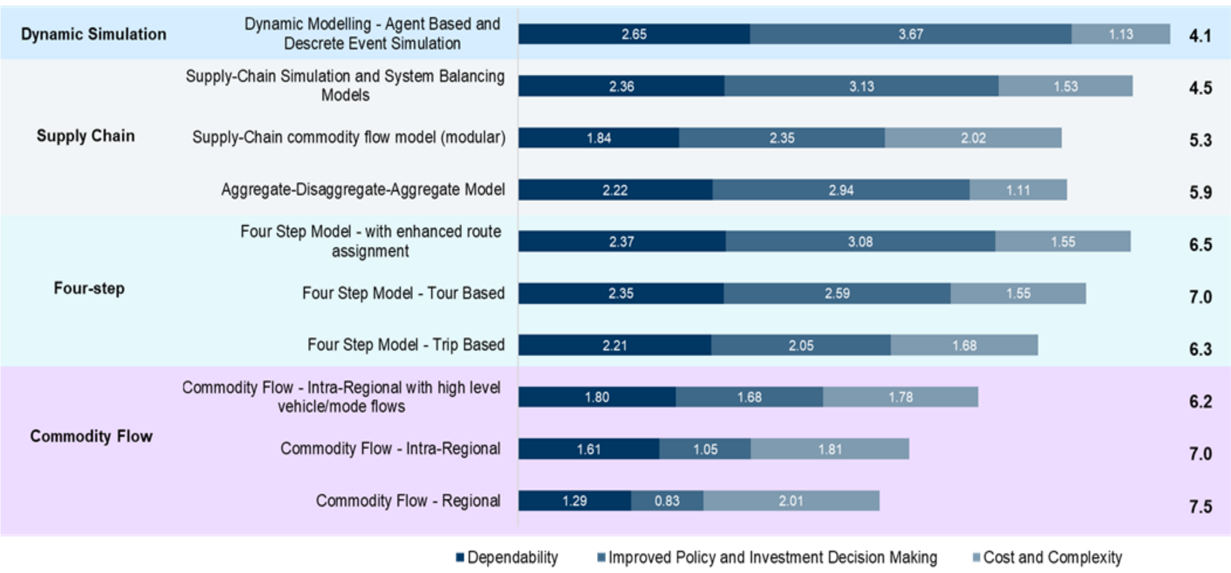


Figure 1: NFDS model options assessment by criteria category group

In any complex data, analytics, and modelling project there are unknowns at the outset which mean there needs to be a degree of adaptability in the pathway taken. This is primarily due to the below:

- Prior to new data being gathered the true nature of the data and its sample size is not known.
- Data can only truly be tested for appropriateness once it is gathered, this is especially true for the econometrics approach which relies on gaining valid regression outputs.

– Data gaps once identified may take time to fill, there are likely gaps which may favour some modelling methodologies over others therefore having an adaptive approach regarding modelling choice may be beneficial.

However, aside from inherent need for adaptability there is also a need based on exogenous factors such as budget and time constraints and social/economic factors. Over the course of any program these factors can change and may influence approach options and preferences.

To reflect the need for adaptability, GHD has provided a set of adaptive pathways for implementing an updated NFDS, as outlined in Table 1.

Table 1: Overview of adaptive pathways options

Pathway Options	Overview
Pathway 1: Best possible outcome approach	This approach seeks to maximise the value of available data by deferring the model methodology decision until most unknowns are removed. This deferral of the model approach methodology means that there is very limited parallel development, i.e. developing the NFDS model alongside data collection and therefore there is a longer delivery timeline associated with this pathway. Additionally, as this approach has a few additional avenues which are exhausted prior to delivery there would be additional cost associated with this pathway as compared to others.
Pathway 2: Forge to the end	This development pathway prioritises delivery timelines by enabling parallel delivery of modelling and data capture. This option requires that a decision is made early regarding the approach method and the most adaptable method is chosen. This option has limited avenues of exploration and will do the best with what is available in terms of data.
Pathway 3: No Commodity Flow Survey	This approach is relevant if it is determined that a CFS is not possible, practical, or preferred. This pathway also defers the method decision until there are less unknowns. Largely, the decision regarding approach depends on the efficacy of the use of telematics (i.e. EROAD) to also gather accompanying commodity designation by transport operator type.[1]
Pathway 4: Enable and delegate	This pathway is offered if it is decided that the role of the Ministry is largely as an enabler or value to ultimately be derived by others. This approach is similar to that of the Federal US Government whereby they collect data and make it available for others but do not generate insight beyond general commodity flows themselves. This approach works where there are sufficient counter-parties to undertake such value-additive work and that there is not a concern regarding potential duplication of effort and a lack of interoperability i.e. Councils all doing their own thing.

Based on assessing these approach pathways and their higher performing attributes an option 'optimisation' process was undertaken which resulted in two distinct approach options being developed and recommended. These pathways are hybrid variants of pathway 1 and 3, and 2 and 4 respectively.

Table 2: Optimised Pathways

Optimised Pathways	Overview
Pathway 1A: Best outcome & minimise CFS (Hybrid of 1 & 3)	This option balances the prudent approach of pathway 1 where the decision regarding approach method is deferred until there are minimal unknowns and also the risk mitigating benefits of pathway 3 which strives ahead without a total reliance on the CFS. In this pathway the EROAD commodity attribution is tested and the CFS minimised to reflect residual data gaps.
Pathway 4A: Truncated enable and delegate (Hybrid of 2 & 4)	This pathway is a balance between the expediency of the forge ahead pathway and the practicality of the enable and delegate pathway. This pathway commits early to System Balancing as the most adaptive[2] modelling methodology and then makes data available for others to generate insight.

[1] The ability to proceed without a CFS will also depend on other complementary data sets such as Statistics NZ Business Registry data.
[2] Adaptive in the sense that System Balancing can be reflective of full system macro level flows early on and improve in accuracy and granularity as more data becomes available.

The pathways to implementation need to adapt to what data is available

The purpose of the Ministry seeking scope options to deliver an enhanced NFDS was not strictly to gain a third-party view on how the NFDS should proceed. Therefore, a recommended approach is offered only as a point of reference if useful.

1. GHD recommends that the need for a CFS is properly tested by progressing the only identified alternative which is gaining a transport operator-specific commodity designation via telematics aggregator EROAD. It is currently unknown as to whether this would be accurate or indeed possible, however an informed decision on how to proceed is not possible until this is investigated further. If this approach proves highly effective, then the 'No CFS' adaptive pathway could be followed. However, the project team believes that even if this method is effective, it likely would not replace the need for at least a highly tactical CFS.
2. If it is needed, the CFS can be administered by the Ministry and/or Statistics NZ. This may need to be a fully representative survey every 3 or so years, or it can be continuous via small randomised stratified samples (or a combination of these options).
3. The top three ranked methodology options are all high performing options which represent a significant step up in understanding current and future freight movements in New Zealand. It appears that there is potential synergy between the NFDS and a major people movement model being developed under the name 'Project Monty'. Project Monty is a nationwide Agent-Based Model which may have a suitable modelling environment for the inclusion of the Dynamic Simulation option as defined in this report. The GHD team have no knowledge of the workings of Project Monty however it is suggested this option is assessed further.
4. If the commodity designation via telematics approach proves to be effective but not to the extent that a reliable econometrics approach is possible then this leaves either the Supply-Chain Simulation and System Balance approach or the Dynamic Simulation approach. If there are synergies between the NFDS and Project Monty, this would preference the Dynamic Simulation approach. This recommended approach is detailed below.

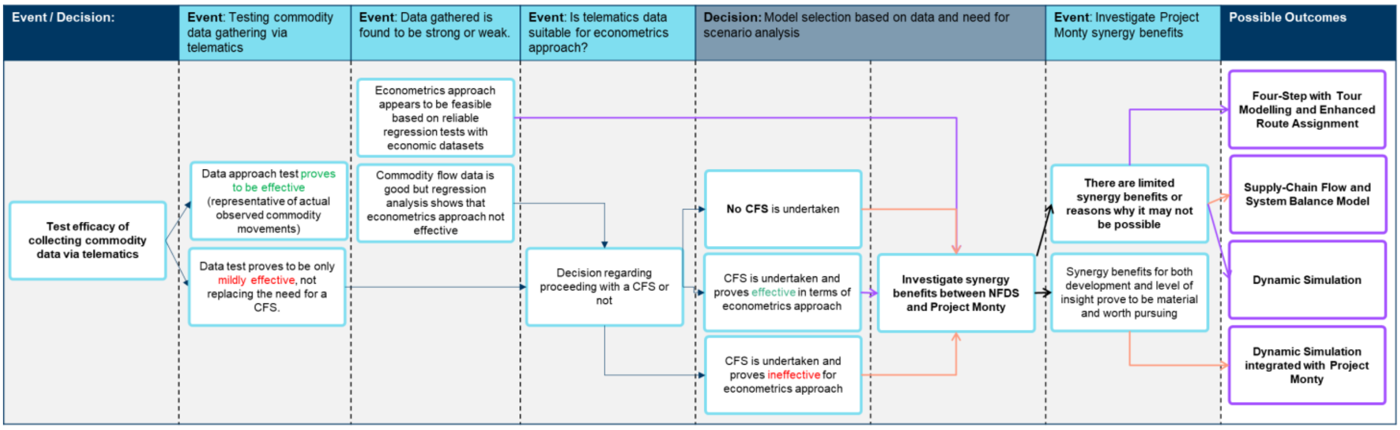


Figure 2: Recommended adaptive delivery pathway 1A

5. In developing recommended options based on pathways assessed it is recognised that there may also be a need to expedite results under an '*Enable and Delegate*' variant which would accelerate the delivery of up-to-date commodity flow data to inform more urgent needs. The below variant is also recommended by GHD if time is of the essence.
6. The role of delegates within the Enable and Delegate delivery model is important and the presence of these 'counterparties' needs to be considered in selecting this option.

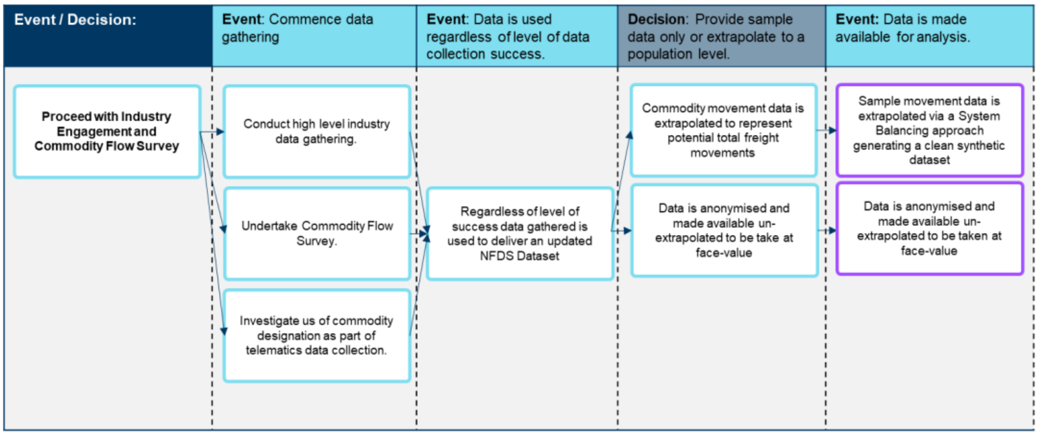


Figure 3: Expedited adaptive pathway recommendation 4A[3]

7. The above alternative does not preclude the ultimate delivery of the recommended option in Figure 2. In addition, it enables interoperability with Project Monty to be assessed in parallel to progressing with data gathering which is essential under any NFDS option.

[3] Appendix D under 'System balancing as a means of CFS sample extrapolation' outlines how system balancing can be used as an effective means of scaling or extrapolating a CFS sample data into usable synthetic data more representative of system-wide movements.

Glossary

The below table provides definitions for terminology that is used throughout this Report.

Table 3: Definitions of modelling terminology

Terminology	Definition
Deterministic model	A Deterministic model calculates a future event exactly, without any randomness. If something is deterministic, all the data necessary to predict (determine) the outcome with certainty is available.
Dynamic model	A Dynamic model features discrete events (where events occur at distinct points in time triggering changes in the system's state) and can demonstrate feedback loops whereby an event can impact a preceding event.
Freight Flow System	A catch-all term to describe the movement of freight nationally.
Generalised cost	Sum of the monetary and non-monetary costs of a journey.
Linear model	A linear model is an equation that describes a relationship between two quantities that show a constant rate of change.
Observed data	A record of an actual event or measure that has occurred.
Stochastic model	In contrast to deterministic models, stochastic models deal with uncertainty. They handle variations and randomness in inputs and estimate the probability of various outcomes (as an output).
Stock and Flow model	This may also be referred to as a mass balance model whereby there are stocks which represent quantities that accumulate over time and flows which are movements over an interval of time.
Transport chain	The sequence of legs that make up the freight origin-destination journey. Each leg in the transport chain can have a different mode, vehicle type, shipment size etc.

Table 4: Acronyms

Acronym	Description
AI	Artificial Intelligence
ATAP	Australian Transport Assessment and Planning
BoD	Basis of Design
CDC	Commodity Data Collection
CFS	Commodity Flow Survey
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DES	Discrete Event Simulation
DNA	Dynamic Network Assignment
EBFS	Establishment-based Freight Survey
EFT	Equivalent Full Time
FIGS	Freight Information Gathering System
GPS	Global Positioning System
HCV	Heavy Commercial Vehicle
ITS	Intelligent Transport Systems
LRIS	Land Research Information Systems
MCA	Multi-Criteria Assessment
MDCEV	Multiple Discrete-Continuous Extreme Value
MNL	Multinomial Logit model

Acronym	Description
ML	Machine Learning
The Ministry	Ministry of Transport
NEFD	National Exotic Forest Description
NFDS	National Freight Demand Study
NRC	National Road Carriers
NZCCO	New Zealand Council of Cargo Owners
NZTA	New Zealand Transport Agency
OD	Origin-Destination
PC	Production-Consumption
RUC	Road User Charging
SOPI	Situation and Outlook for Primary Industries
TSIG	Te Uru Kahika Transport Special Interest Group
VHT	Vehicle Hour Travelled
VTK	Vehicle Tonne Kilometres
ZEV	Zero Emissions Vehicles

1. Introduction

The Ministry of Transport has previously published three versions of the National Freight Demand Study (NFDS) in 2008, 2014 and 2018 respectively. The NFDS is a key research report published by the Ministry which has been actively used by Waka Kotahi, KiwiRail, local government and across the private sector. The NFDS provides statistics on freight movement in New Zealand, providing current and future insights on commodity flows, mode share, productivity, and infrastructure use. However, the broad application of the NFDS has revealed areas for improvement and gaps in information. For example, the previous NFDS had limited scope relating to intra-regional freight flows, infrastructure investments insights, and ability to identify decarbonisation opportunities. The Ministry also recognised the NFDS lacked the depth, completeness, and alignment to established practices exemplified in other jurisdictions. It is these drivers that have led the Ministry to commission this NFDS Scoping and Methodology Study.

1.1 Purpose

The purpose of this Study is to outline the benefits and feasibility of options to improve and update the NFDS. Each approach has been defined with consideration of data requirements in a New Zealand context. Eleven sub-options within four broad option classes or 'typologies' were identified and assessed.

The Study has been undertaken by GHD and a Working Group consisting of the Ministry and Waka Kotahi NZTA) staff, with the Study being undertaken from November 2023 to June 2024. The study has consisted of multiple stages, which are demonstrated in Figure 4 below.

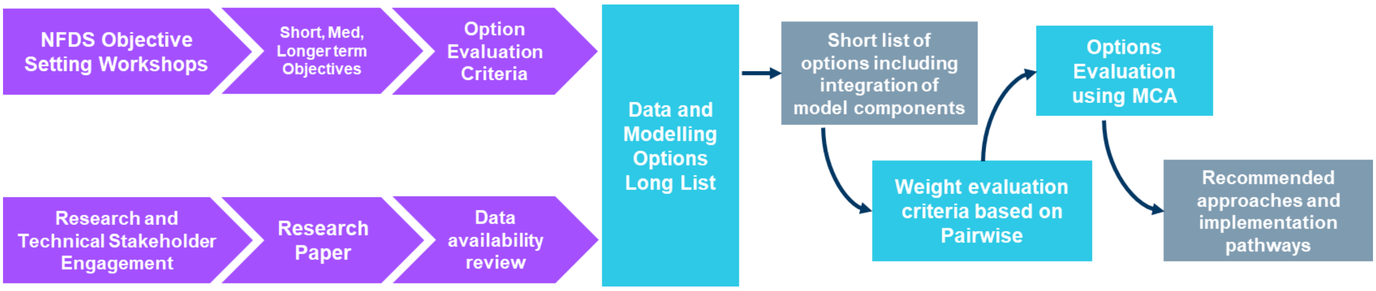


Figure 4: Project stages of the NFDS – Scoping and Methodology Study.

1.2 Establishing NFDS Objectives

An initial step of this NFDS scoping and methodology study was to confirm the objectives and related functions of the proposed NFDS update. This objectives-setting process is described in more detail in the *Objectives-setting Workshop and recommended Objective horizons* report. In summary, objectives for an updated NFDS were established using the following process:

– GHD assembled context-setting documentation which largely covered material that would drive the development of objectives including the *Aotearoa New Zealand Freight and Supply Chain Strategy.*
– Workshops were held to establish draft objectives and categorise these into broad themes that represented the key foci. These were held with the NFDS Scoping Working Group, which included members of The Ministry, relevant contributors from NZTA Waka Kotahi and the GHD project team.
– From this a preliminary table of objectives and requirements was developed. The criticality of each objective was determined by its classification as either core or adjacent/ancillary. Additionally, the focus period of each objective was considered across three-time horizons, representing short-term, medium-term, and long-term timelines. Broadly short term includes the next NFDS iteration and the medium- and long-term subsequent iterations over the course of perhaps 5-10 years.
– Comments were received by the Working Group and the Objectives were confirmed.

These objectives were then used to formulate the evaluation criteria for the assessment of the different modelling approaches. The Ministry held an Industry Steering Group session as part of this scoping study. The session was held in February 2024 as an early discussion relating to the objectives of the NFDS and the availability of data, along with the propensity for industry to contribute data to the study. The Industry Steering Group consisted of the following members:

- Dave Christie, Supply Chain Director - Tainui Group Holdings
- Dom Kalasih, Interim Chief Executive - Transporting NZ
- James Smith, GM policy & strategy – NRC
- Mike Rudge, Chair - ITS New Zealand
- Mike Knowles,*[4] Chair – NZCCO & Shipping Manager – Zespri
- Peter Morris, Executive GM Finance & Commercial - Kiwirail
- Russell Hawkes, TSIG & Lead Transport Planner - Environment Southland
- Veronica Syman, President - Shipping NZ & Manager, Aranui Shipping

The objectives were discussed with the Industry Steering Group and the main outcomes from this conversation included:

- Unrealised value of the NFDS - The previous NFDS study was not seen as practicably usable for industry proposes such as understanding freight flows.
- Acknowledgement of data gathering challenges for future updates – Gaining data from transport operators may be difficult due to the commercial sensitivities and the effort involved.

The second Industry Steering Group session was also proposed and would focus on feedback on NFDS approach options.

This Objectives table is presented in Table 5 below.

[4] Mike Knowles was unable to make the session, but a separate follow-up conversation was held with him the week following.

Table 5: Objectives table with Horizon and core/adjacent allocation.

Objective		Horizon 1	Horizon 2	Horizon 3
01 Inform investment decision making	Improved data reliability and validity	●		
	Assess and understand productivity / service levels		●	
	Understand mode share	●		
	Consideration of supply-chain costs	○	●	
	Consideration of economic value	○	●	
	Network capacity considerations			●
	Bottleneck identification	●		
	More detailed and updatable forecasting		○	
	Extract data for business cases		○	
	Extract data for Project Monty		○	
	System performance monitoring	●		
02 Increase usability and reliability (granular and validated)	Include intra-regional freight movements.	●		
	Include last mile and urban freight movements	●		
	Reliable and more granular commodity data	●		
	Baseline Data validation and calibration processes	●		
	Disaggregate vehicle sizes and types	●		
	Regular validation and calibration	●		
	Identify intermodal opportunities	○	●	
	Enable some form of 'optimisation' (service levels/cost)		○	
03 Enable supply-chain resilience outcomes	Ability to delineate between critical and non-critical freight	●		
	Enable identification of critical freight concentration risk	○	●	
	Enable route and mode concentration risk identification	○	●	
	Non-domestic IMEX supply-chain resilience		○	●
	Generate lead indicators for resilience risks	○	●	
	Scenario modelling to test resilience and response	○		
	Market competition assessment - service provider concentration		○	●
04 Support decarbonisation outcomes	Consider data requirements for decarbonisation objectives.	○		
	Data to produce emissions calculations.	○		
	Data to identify energy infrastructure and fleet transition plans	○		
	Calculate current and forecast emissions	○	●	
	Identify circular economy opportunities		○	
05 Inform policy decisions	Consider data needs for regulatory impact assessments		○	
	Include spatial data to inform regional policy impact	●		
	Forecasting to identify future challenges which may need a policy response		●	
	Potential to support One Network Framework assessments	○		
	Inform economic productivity indicators	○	●	
	Assess policy impact on future freight flows, vehicle types etc		○	●
06 Increase value to private sector and study participation	Transparent and equitable data governance	●		
	Inform private sector investment via useful forecasts	●		
	Foster reciprocal arrangements - trading insight for data	●		
	Consider different data gathering imperatives (mandate/incentivise/voluntary)	●		
	Automate or semi-automate data capture/provision		○	●
	Identify backloading opportunities (identify empty running)		○	●

● *Core requirement* ○ *Adjacent (nice to have)* ○——● *Evolving requirement*

2. National Freight Demand Study Review, Research and Stakeholder Engagement

2.1 Previous NFDS Review

An important step in the Scoping study involved reviewing the 2017/18 NFDS methodology and outputs. This review was performed to gain an understanding of the strengths and limitations of the previous NFDS, including identifying any elements that could be adapted into the updated study. This section discusses these findings. The related technical memo document *Review of the 2017/18 National Freight Demand Study* is available as an attachment to this Report and provides more detail on each of the points discussed in this section.

2.1.1 Methodology and data collection

To establish freight movements for each commodity type, the methodology broadly consisted of three stages:

– Identify the production or import of the commodity by region.

– Identify the movement patterns which link the origin to the destination.

– Identify the region in which the product is consumed or is exported.

Where existing published data was not available (most cases), a range of estimation methods were employed to establish a complete picture of commodity flows. Such methods included:

– Derive a relationship from land-use and/or population statistics.

– Derive a relationship with another commodity (for example, livestock feed with dairy production).

– Industry survey and/or more focussed engagement with industry players.

– Based on the commonly held assumptions such as logs are low-value items and so travel to nearest port or processing facility.

As outlined in Table 6, data was sourced from a range of organisations.

Table 6: Data Providers used for 2017/18 NFDS

Data Providers	Provider type	Commodity type
EROAD	Telematics data provider	Logs, Processed timber
National Animal Identification and Tracing Scheme ("NAIT")	Government Department	Livestock
NZ Petroleum and Minerals (MBIE)	Government Department	Coal, Aggregates, Limestone, Other Minerals
Freight Information Gathering System (FIGS)	Government Department	Petroleum
Agricultural Production Survey by Statistics NZ	Government Department	Wool, Fertiliser
Ministry for Environment (MfE)	Government Department	Waste
Ministry of Primary Industries (MPI)	Government Department	Logs, Processed timber, Livestock
Customs data	Government Department	Multiple
NZ Forest Owners Association	Industry Association	Logs
Inside Resources	Industry Publication	Cement
Balance	Private company	Fertiliser
Bluescope Steel	Private company	Steel
Pacific Steel	Private company	Steel

Data Providers	Provider type	Commodity type
Ravensdown	Private company	Fertiliser
KiwiRail	State-owned enterprise	Logs, Processed Timber
Statistics NZ	Government Department	Multiple

The datasets provided varied in terms of their size, reliability, and quality. These ranged from well-established production surveys with high sample sizes (such as Statistics NZ's Agricultural Production Survey) to more informal engagement with industry players such as Bluescope Steel and Pacific Steel providing specific information about production and movement of the steel products they produced. In most cases, datasets used were specific to a commodity. This review of the datasets used in the study confirms the view that there is a lack of robust and consistent freight movement data in New Zealand.

Forecasts were conducted exclusively for "supply-driven commodities." These are commodities whose "flows are typically based on production capacity and constraints," such as milk, meat, and logs. Forecast techniques included:

- Available published forecast data such as MPI's Wood Availability Forecasts
- The continuation of historical trends
- Trends in overseas demand

2.1.2 Outputs of the Study

The NFDS provides a comprehensive number of outputs. For each commodity type, outputs included:

- Production by region and national level
- Import / export at a national level
- Import / export by port
- Inter-regional origin and destination
- Forecasts of commodity production
- Movement by mode at a national level

2.1.3 Limitations of the Previous NFDS

A series of potential limitations of the Study were identified. These highlighted the gaps which could potentially be filled by an updated NFDS. These included but were not limited to:

- Limited granularity – This was raised by Stakeholders and was previously noted in the Data and Analytical Priorities Deloitte report (2023). Specifically, this relates to a lack of location, vehicle, mode, time, freight format & commodity granularity.
- Lack of clarity on the validation/testing of results – Stakeholders noted that it was hard to trust the NFDS is validation processes were not known.
- Inconsistent disaggregation – as a 'best available data' approach was taken the data is not disaggregated to a similar extent, i.e. general manufactured goods consist 35% of total movements.
- Basis of key assumptions are unclear, so it is difficult to apply own assertions as to reliability.
- Curious results impacted industry's faith in the NFDS – Large volumes of timber from Auckland to Canterbury or a general lack of distribution from Auckland to other parts of the country.
- Repeatability and consistency – Due to the ad hoc nature of the methodology it is difficult to repeat in same fashion as to be able to draw insights regarding trends.
- Limited ability to account for significant structural changes or commodity-specific contract arrangements – when significant events occurred, or are proposed, which re-shape how freight moves in parts of NZ, the NFDS was unable to account for this.

It should be noted that the above observations of the previous NFDS are not a reflection on those who carried out the report. The previous NFDS had a very limited scope and budget and given these circumstances the authors delivered an admirable report.

2.2 Research and stakeholder engagement overview

A comprehensive desktop research task was conducted to determine what procedures are being used for freight movement modelling. This required doing a literature evaluation of publicly available reports and methodologies to establish how well they corresponded with the NFDS's objectives.

The research stage of the NFDS Scoping study was an essential part of this study – providing the foundation of knowledge required to properly assess approaches to freight demand modelling. Desktop research was performed to understand the standards, availability, and requirements of freight movement data and modelling. The outcome of the research is provided in detail in the research Memo *Freight data and modelling practices.*

The provision or access of data required for modelling were also noted to determine any factors that could mean low applicability between the research area and New Zealand.

Research included the review of international literature, reports, and presentations on freight modelling, and importantly, discussions with overseas practitioners, relevant New Zealand Government departments/agencies, and data providers.

2.2.1 Stakeholder engagement

Agencies and transport modelling practitioners were engaged to understand their experience with data collection and modelling. The engagement focused on their experience on the quality of data collection, practicality of data collection, best performing models, and relevant outputs. New Zealand governmental departments and data providers were also approached to understand current data availability and access limitations for potential freight demand modelling usage.

The list of those organisations engaged with is provided in Table 7 below.

Table 7: List of organisations that were engaged with as part of research stage

Organisation	Organisation type	Date
Department of Transport, Western Australia	Government agency	16/01/2024
Department of Infrastructure, Australia	Government agency	16/01/2024
Department of Transport, Victoria	Government agency	17/01/2024
Project Monty team, Ministry of Transport NZ	Government agency	31/01/2024
Transport Administration, Sweden	Government agency	1/02/2024
Transport and Main Roads, Queensland	Government agency	1/02/2024
Bentley, USA	Software provider	13/02/2024
Port Connect	NZ data provider	15/02/2024
Robinsight	NZ data provider	15/02/2024
Transport for NSW, NSW	Government agency	19/02/2024
District Department of Transport, Washington DC, USA	Government agency	23/02/2024
Cambridge Systematics, USA	Consultancy	23/02/2024
Statistics NZ	NZ Government department	4/03/2024
Business Demography team, Statistics NZ	NZ Government department	11/03/2024

2.3 Key Data and Modelling Insights

During the research stage, it was discovered that information on the quality of freight data gathering and viable models existed in various formats but was not comprehensive. Formats included academic literature, guidance documents, government reports and conference papers. There was no holistic document that clearly outlined the multiple approaches to national freight demand models, and when it would be appropriate to use them. The closest document that fits this description, was the Australian Transport Assessment and Planning (ATAP) 2021 guidelines document: *Urban freight demand modelling.* As suggested in the title, the guidance relates to urban freight modelling specifically, but it was found that much of the content could be applied to a national-scale freight model for a country the size of New Zealand.

Drawn from the literature that was available, and from discussions with practitioners, there are a series of key findings, which are set out in this section.

01

There is an inter-connected relationship between data availability and modelling approaches selected.

The availability of data and the modelling approach selected are strongly connected. This is because the development of a model is generally constrained by the data available as inputs (Schaefer et al., 2017). The quality of the results produced by the model hinges on the "the currency, completeness, accuracy, precision, and granularity of the input data." (CSIRO, 2024). For example, the behaviour-based model approach requires more granular data, which can be used to represent decision-making logic. However, this approach would not be a requirement for the aggregate commodity flow models.

In some cases, the model itself is adaptable depending on what level of data is available. For example, in discussions with one of the Australian transport agencies, they revealed their model took a hierarchical approach of ingesting data to represent production of commodities. Selecting the preferential, more detailed input if available. In order of preference, data inputs included:

- Where there is accurate point-of-interest data corresponding to commodity production, production of a specific commodity within that Statistical Area 1 zone can be generated.
- Land-use activities based on cadastral boundaries – identifying industry based on employee and building size.
- In lieu of the more detailed data mentioned above being available a portion of regional production statistics is used to generate production.

02

Although capturing freight data can be costly and challenging, the adoption of telematics and new technologies is reducing reliance on data from industry players. This can help decrease costs and lessen the burden on the industry.

It was widely acknowledged in both the literature and through conversations with practitioners, that freight modelling has consistently posed challenges. These difficulties stem from data scarcity, the confidential nature of the data, and the high costs and intricacies associated with the data gathering and modelling processes (ATAP, 2021; de Jong et al. 2016; McHugh et al., 2021). However, it was also noted that more recent and emerging technologies and methods are reducing this cost and complexity. Shoman et al. (2023) recognise that vast quantities of 'big data' are produced in the freight sector, and they should be leveraged to improve freight modelling. Notably, the use of data from telematics and/or onboard computers from commercial vehicles is recognised to have potential to reduce the cost, time, and resource burden of extensive engagement with industry to collect data.

In discussions with international practitioners, there was a degree of envy regarding the quantity of telematics data available in New Zealand relative to their home countries. This was in reference to the ~40% sample rate of HCV movements that are captured in the EROAD data.

03

A commodity flow survey and baseline commodity flow are critical components of national freight demand model.

The research revealed that the Commodity Flow Survey (CFS) was a critical element of national-scale freight demand models and serves as the foundation of the equally important baseline commodity flow origin-destination matrix. The CFS has been used in each of: France, Norway, Sweden, USA, Australia and South Korea (ATAP, 2021; de Jong et al., 2016; Park & Hahn, 2015, McHugh et al., 2021, Schaefer et al., 2017). In some cases, such as in the United States and Sweden, data collection is mandated.
As recommended by de Jong et al. (2016), in an ideal world, a national freight demand model starts from a complete baseline description of commodity flows demanded by locations for consumption. This then unlocks the ability to consider logistics decisions,

which are the basis for Origin-Destination matrices. They suggest that alongside customs import/export data, the CFS is one of the most valuable ways to achieve this understanding. Similarly, McHugh et al. (2021) suggest that to extrapolate data using destination choice or gravity models, it is necessary to have information on flows between origins and destinations. This can be achieved by dedicated surveys, or from existing commodity flow matrices and economic input-output tables. This sentiment was shared with representatives of Australian transport agencies, who suggested the recent decision to discontinue their CFS was viewed as a major disruption to their ability to accurately model and forecast the flow of goods.

04

The Four-step model is currently the most utilised approach, though limited in its ability to address complex questions.

Another key finding of the research is that the four-step transport model (originally developed for passenger transport and adapted for freight) has traditionally been the most common approach to national freight models. Despite wide usage, many of the policy questions asked by planners and decision makers require more advanced models (ATAP, 2021; de Jong et al., 2016; McHugh et al., 2021). These more advanced models can be broadly referred to as 'behaviour-based models' (including Supply chain models, Tour-based models and Agent-based models, for example), which allow for more advanced and efficient scenario modelling.

McHugh et al. (2021, p.6) state that there are a range of factors that can potentially influence the freight supply chain including "evolutions in the commodity market, political decisions, changes in market conditions and exogeneous developments such as climate change and developments in technology. Freight models should in principle be sensitive to these developments so that they can be used to represent their impact on the system being modelled." In the ATAP guidance document, though focused on urban-settings, it recommends that tour-based models (at a minimum) should be used when developing models for policy guidance.

05

National freight models are often modular with several model types integrated, which of these model types are selected depends on the use-case. Therefore, there is no single approach (beyond the four-step) which is the most commonly used.

It was generally recognised in the literature and through discussions with practitioners that national-scale freight models are most often modular with several integrated model types. There is no single approach, beyond the four-step, which is commonly used. The model types selected are dependent on the use-case. For example, in the ATAP Guidance document (2021) it is recommended that a commodity flow model can be integrated with a tour-based urban freight model - translating commodity flows from the national scale into the urban-context model (influencing number of vehicles, for example).

3. Data Requirements

Our research found that a range of data types and collection methods were currently being used as inputs for freight demand modelling in other jurisdictions. Some datasets were observed to be essential inputs for multiple model types, while others were observed to be emerging (and improving model processes and results) and replacing other more outdated (deficient) data types.

The data evaluation methodology has been carried out as follows:

1. **Research and consultation** - the research stage identified data types and collection methods that were perceived to be of reasonable value and used with relative frequency. These have been incorporated into the data longlist. The assessment was based on discussions with international practitioners, and review of both applied and research-based freight models.
2. **Identification of consistent data compared to the previous NFDS** - to maintain consistency with the NFDS, the data types have been cross-referenced with those used in the previous study. This is to ensure that relevant datasets used in the previous study are also included for consideration in the longlist.
3. **Data type alignment for newly identified datasets** - the longlisted data types have then been assessed in a New Zealand context – performing a check as to whether they exist and to what extent they could be made available for an updated NFDS. This process has included discussions with both public and private data owners. Dimensions added to the data assessment for the New Zealand context include:
   - Data owner and type
   - Data availability
   - Ease and value to make available as an input into NFDS

For the purposes of the NFDS, the most important consideration when assessing each data type is the value in explaining the freight flow system in New Zealand and to individual types of freight demand models.

Data performs multiple roles within a freight demand study as shown in Table 7. The function data plays often has ramifications for how much data may be required, how detailed it needs to be and how often it needs to be gathered. The full long list of data considered is set out in Appendix A.

Table 8: Description of data types/functions

Data Type / Function	Description and Context within NFDS
Baseline Data	Baseline data is used to establish a detailed full picture of commodity movements. A baseline is established when a model is first developed and then there may be periodic re-baselining of the model which is essentially a repeat of the baseline data gathering and analysis process. Baseline data is usually based on a statistically significant sample which is then extrapolated to a population level dataset before being used by the model or within the model itself.
Structural Data	Structural data is data which describes the physical system, i.e. road and rail network spatial data, distance matrix, network performance data and key location data.
Explanatory Demographic and Behavioural Data	These datasets can explain system conditions such as land-use, economic or demographic environment, i.e. population and consumption. This data can also be 'behavioural', i.e. data representing decision-making logic, and can be used to 'train' a model. Behavioural data can be sourced from either 'stated or 'revealed' preference data. Stated preference data is sourced from survey responses, where preference may or may not align with actual behaviour. Revealed preference data is derived from observed data, such as GPS traces used to observe courier vehicles to understand tour logic. Revealed preference data is considered to be more reliable in most cases.
Calibration and Validation Data	Calibration and validation data is used to increase the accuracy and test the accuracy of a model. The data is normally smaller 'point' data which shows as an area of reliable observed movement for example for which wider assumptions and model logic can be built.
Update and Forecast Data	Model update data is generally datasets which are available between baselines which can be used to infer changes in the real world and present those within the model. Update data can also be new forecast data which may include future land use, population or trade datasets.

Data Type / Function	Description and Context within NFDS
Assumption and Parameter	Assumption and parameter data inform the settings of variables and other parameters within the model. For example, these could be parameters regarding the normal distribution of truck weights or the current price of fuel.

In addition to the function of the data, each data type can differ across multiple strata, including, but not limited to:

– Which part of the freight flow system[5] that it represents i.e. the production of commodities, the movement of commodities, their consumption, import/export and mode/vehicle movement.
– The nature of the data i.e. whether it is administrative data, survey data, active tracking data (e.g. telematics).
– The form of the data i.e. whether it is physical (e.g. consignment bills) versus digital (e.g. telematics).

All data types are considered within Appendix A however we take a more detailed approach to the baseline data as this is the most essential.

3.1 Essential baseline data

For any freight demand model to accurately represent freight movements, it is vital to first develop a baseline of commodity production and movement. Our research found that countries with the most well-established a sophisticated demand models had a strong baseline commodity flow dataset.

These baseline commodity flow datasets are largely represented by observed movement data[6] – surveys, such as the Commodity Flow Survey (CFS), administrative records, and some modelling to fill in the gaps. These datasets generally represent domestic commodity production, imports, exports, consumption, vehicle types, mode, and the inter-regional flow between these stages (at a highly aggregated level).

A commodity flow such as this could be considered a pre-requisite for any of the more detailed modelling techniques described below. Without the dataset, modelling techniques cannot be sufficiently validated and/or calibrated to ensure that they represent reality to an appropriate standard. For example, the most common baseline approach across the options assessed uses statistical (regression) relationships between types of businesses, their locations and observed commodity movements to build up (extrapolate) to a dataset of commodity movements which together represents total movements.

In New Zealand, this type of commodity flow dataset does not currently exist but there are components of the observed data available. These are described in the table below.

Table 9: Observed commodity production and movement data available in New Zealand

Dataset	Description	Availability in NZ	Coverage
Industry-specific data	Provides information on the regional distribution of and volume of commodity production through surveys and/or administrative records.	Statistics NZ *Agricultural Production Survey*, MPI's *National Exotic Forest Description (NEFD) Survey* and *Annual Return of Industrial Rocks and Minerals Output Survey* (Quarry Survey).	Given the nature of the industry-specific data, these datasets don't cover all commodity-producing industries, nor do they cover 100% of these industries' production. For example, as was outlined in the 2018 NFDS, the *Quarry Survey* has a 70-80% response rate and covers an estimated 50% of all aggregate production.
Ports data	Details the export and import of commodities through specific ports.	This is available both through public organisations (Customs Services, The Ministry) in the form of the Freight Information Gathering	Ports data covers a large majority of the movement of goods in and out of New Zealand. PortConnect covers ~ 90% of the total tonnage of commodity movement but does

[5] Freight flow system is a catch-all term for freight and freight movement nationally.
[6] Observed movement data is data that describes an actual movement event.

Dataset	Description	Availability in NZ	Coverage
		System (FIGS) or by private organisations, such as PortConnect.	not have full coverage of all ports. There remains some uncertainty about the availability of data from Customs Services.
Telematics data	Heavy commercial vehicle movement data captured from in-cab GPS units. Most often used for fleet management purposes.	As Road User Charges (RUC) for HCVs are based on distance, in-cab GPS units are common and hence there is a wealth of telematics data available in New Zealand. This data is provided by EROAD.	The EROAD data represents ~ 40% of all HCV movements. Some industries are underrepresented such as dairy, as are some vehicle classes such as light commercial vehicles.

As detailed in the table, these datasets can go some way to describe total commodity production and movements but falls short of providing a complete picture.

NFDS Insight:

Truck movement data availability is a source of strength for New Zealand versus other countries. Through stakeholder engagement, it was found that the availability of telematics data was generally low in other countries. The variable Road User Charging (RUC) generates data that is supplied to Government and data aggregators such as EROAD. This data captures approximately 40% of truck movements, hence by simply following overseas and foreign methodologies, the NFDS would miss out on the advantage of domestic context. This emphasises the need for a bespoke and tailored approach which plays to our strengths but also incorporates what is being done well overseas.

3.2 Essential data for forecasting freight demand

In addition to baseline data, other data types are essential for freight demand modelling and forecasting. These datasets are required inputs across most models described in Section 4.

As the datasets are used to explain the variation in production and movement that is observed geographically (and over time) across NZ, they can largely be grouped into *explanatory data*. These are necessary for more detailed modelling and importantly, forecasting. They become useful for forecasting if there are projection data, such as projected employment statistics by region, population and/or land use change.

Table 10 lists the datasets most commonly used as explanatory variables which are available in New Zealand, with varying degrees of suitability in their current form.

Table 10: Explanatory data available in New Zealand

Dataset	Description	Availability in NZ
Land use	A geo-spatial, digital representation of how land is being used. This can be classified as land-cover type such as ‘agriculture’, ‘commercial’ etc. This data is used to inform trip generation and distribution in the four-step model and equivalent steps in some of the more detailed models.	Available in NZ via Land Research Information Systems (LRIS). This dataset has 22 land-use classifications such as 'High Producing Exotic Grassland'. The database is updated every 5 years, with the last update occurring in December 2019.
Point of interest locations	Coordinate-level location data, indicating a type of location such as business and ports. This data can be used as a more detailed version of the land use data or as an input into models that require the actual locations of establishments or freight assets such as the modular supply	Point of Interest data can be pulled together through various sources, from ‘web-scraping addresses’, google API etc. Using openstreetmap places of interest data can provide a good baseline dataset.

Dataset	Description	Availability in NZ
	chain model. Can also be classified as structural data.	
Economic statistics - establishment data	Number of businesses by location/zone, type, and number of employees. This data is sometimes used to infer the production of commodities and the generation of trips.	Available from Statistics New Zealand in the *business demography* dataset. This is updated annually and can be requested in different combinations of variables including: Industry classification Size of business by employees Location (from SA1 and above)
Population Statistics	Census statistics capturing the number of people residing and/or working in a location and their demographic profile. This can be an important data set for understanding the consumption of commodities and the distribution of trips.	Provided at a high resolution for New Zealand (Meshblock and above). Last completed in 2023 and published in May 2024.
Economic indicator statistics	High level economic data demonstrating productivity and other trends across an economy. This is commonly used when building forecasts.	Some statistics are available which relate to general forecasted productivity such as MBIEs *Labour market forecasting* which forecasts short and medium-to-long term trends. There are limited forecast statistics on specific commodities, but some do exist such as MPI's *Wood Availability Forecasts.* International forecasts of the GDP of trade partners are also relevant and available.

In order to confirm the usefulness of these explanatory variables their statistical relationship to commodity production and movement would need to be confirmed. For example, if it was required that the number of 'agriculture' enterprises was used as an explanatory variable for the production of the dairy commodity, then there would need to be a strong statistical relationship between the observed production of milk and the number of agriculture enterprises across different regions and/or years.

3.3 Structural data

Structural data is available in NZ, including but not limited to:

– Statistical zones provided by Statistics NZ, such as Statistical Area 1 (SA1) zones, SA2, SA3, Territorial Authorities and Regions
– Road networks available through openstreetmap.org or data.co.nz
– Rail networks via NZ Road Centrelines (Topo, 1:50k) | LINZ Data Service[7]
– Points of interest data available through openstreetmap.org and google maps API

3.4 Baseline validation and calibration datasets

There are a series of datasets recognised internationally for being useful for the validation and/or calibration of models (in addition to the commodity flow data detailed above). These include HCV traffic volume data, vehicle registrations (including NZTA Safety Inspection reports) and weigh-in-motion data. These are sufficient and available in New Zealand.

3.5 Common data building blocks

Most of the modelling options described in the next section have a need for accurate commodity flow data. The methodology of the options may differ, however, all options at some point need to generate a commodity flow which stems from largely the same datasets.[8]

[7] **NZ Road Centrelines (Topo, 1:50k) | LINZ Data Service**
[8] Specifically, a direct commodity flow survey as discussed in 3.7 and telematics data whereby there is a commodity attribution by transport company as discussed in 3.8.3.

This section describes the most common methods applied to generate commodities and their flows, to prove the point of the similarity of data used. Some methods such as *System Dynamics* use a different approach but could still use these regression analyses for the reconciliation of their results. The most common data aspect among the options is freight generation data. This is how freight materialises - the origin of the freight. Freight generation is quite uniform across the options being evaluated. Freight generation is achieved in a few ways:

– Freight can be imported, for this Customs data can be used to show commodity, volume and port of entry.
– Freight can be produced (harvested, felled, extracted, etc.).
– For produced freight, a method of multi-regression analysis is conducted which establishes the relationship (correlation coefficient) between independent variables (*accessible data sets* such as land-use, production, employment, business classification) and the dependent variable *known commodity origins*[9] (from a commodity flow survey or established industry-specific surveys such as Statistic NZ's *Agricultural Production Survey*). This is shown in Figure 5 below. The reason this is done is that once the relationship between these accessible and frequently updated datasets and commodity origin is known then future changes in the accessible datasets can be used to update or predict changes in commodity flows without constantly repeating the survey exercise.

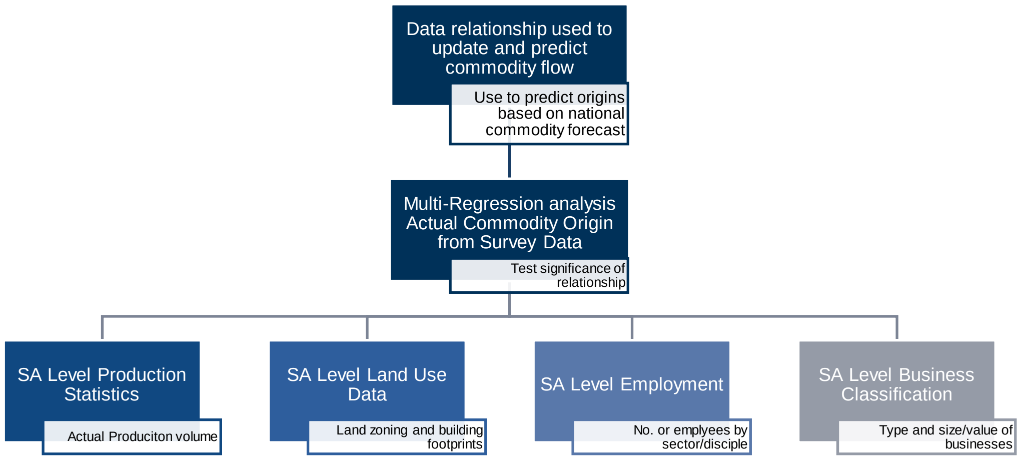


Figure 5: Use of accessible datasets to generate freight origin for domestically produced freight

The methods of formulating a flow by establishing a destination differ and relate to the option selected. However, broadly a flow can be created through:

– Deterministic means, i.e. essentially telling the model where the freight is going based on observed movement of commodity flow survey responses (i.e. actual likely destination).
– Econometric approximation using regression analysis and independent variables such as consumption, production, demographic and land use data to approximate the dependent variable being freight origin or destination.
– Inferred through logic via an attraction or gravity method which essentially uses logic such as 'least cost' to determine a logical flow, that can be based on consumption or production data and known nodes such as ports etc.

As will be discussed briefly in Section 4.3 and in more detail within Appendix D, the best approach may be to have both the 'actual' and the derived.

[9] Known commodity flow data can be gathered via direct survey to gain a sample adequate for understanding the accuracy of the relationship between independent (i.e. land use) and dependent variables (i.e. commodity flow).

3.6 Additional Essential data for behaviour-based models

Behaviour-based models require representation of decision-making logic of actors in the supply chain. Examples of these models include the Tour-based, Supply Chain and Logistics models, and Dynamic Simulation models referenced below. In addition to the datasets listed as essential above, these models also likely require additional surveying to understand behaviours and scheduling data. The most common data capture method for these models is the Establishment-based Freight Survey (EBFS). An EBFS should capture the following characteristics of a business:

– industry type and number of employees
– types of commodities shipped and received
– mode used to transport commodities
– the number and type of commercial vehicles that are at the establishment's disposal
– The average number of stops and distance between stops for truck tours

An EBFS is one of the few techniques identified which connect commodity data with business pack/unpack location, this is particularly useful to understand the relationship between establishment type and commodity flow which can make approximation methods (for forecasting and periods between surveys) more accurate. An EBFS could possibly be implemented as a stand-alone survey or as an extension of the CFS. Scheduling data describes the timetabling and locations of planned freight movements.

Testing with telematics data may reveal that it is capable of representing some decision making in the supply chain (for example, time of day of trips) and may reduce the need for an EBFS. The telematics data is presented as an option in some of the modelling typologies, such as for Four Step Modelling in Section4.3, and is also further discussed in Section 3.8.

3.7 Commodity Flow Survey

3.7.1 The need for commodity flow data

A key finding of research, stakeholder engagement, and analysis is that there is highly likely a need for a Commodity Flow Survey (CFS)[10] in order to close data gaps but also to more accurately predict freight demand. Forecasting is commodity-based and as such good data on commodity flows is important. Commodity flow data is also important to accurately attribute freight consignment to vehicle types and sometimes routes. As was revealed through the research on international practices, the CFS is the key source of information from which a national-scale baseline commodity flow dataset is built upon. Figure 6 below shows an excerpt from an example response to the CFS used in the United States. This survey is considered low-burden on industry, estimated to only take 2.5 hours to complete, once per year.

[10] A direct survey of industry, mostly cargo owners and transport service providers at a company-wide or facility location-based level (enterprise surveys).

Line No. (A)	Shipment ID Number (B)	Shipment Date (MM/DD/YYYY) (C)	Shipment Value (excluding freight charges and excise taxes) in whole dollars, for the entire shipment. Net selling value. Estimates are acceptable. (D)	Net Shipment Weight **in pounds.** Estimates acceptable. (E)	For shipments consisting of more than one commodity, report the description of the commodity that contributed the greatest weight of the shipment in columns (F) through (H). Product or Commodity Description (F)	Is item climate or temperature controlled? (Y/N) (G)	Is item a hazardous material? Enter "UN" or "NA" number (H)	Continue with column (I) on page 5
Ex.1	123-5	02/08/2022	224,235	4,840	Mechanical machinery	Y		→
Ex.2	402H	02/08/2022	1,375	50,125	Sulfuric acid	N	1830	→

U.S. Destination or U.S. Port of Exit (Complete for all shipments.) *For customer pick-ups, see below (I)			Mode(s) of transport to U.S. destination. **Enter all that apply in order used. Use codes at bottom.**	Foreign Destination (for export shipments only) **Note: In column (I) enter the U.S. port, airport, or border crossing of exit.** (K)			Export mode
City	State	ZIP Code	(J)	City	Country	Postal Code	(L)
Los Angeles	CA	90040	24	Beijing	China	065001	6
Newark	NJ	07105	4				

Figure 6: Example response to the CFS used in the United States[11]

3.7.2 Designing a Commodity Flow Survey

There are a range of factors to consider when designing a CFS, such as who the survey should be targeted towards, what are the key pieces of information to request and striking a balance between receiving sufficiently detailed information while not over-burdening participants. This section discusses some of these factors for consideration.

3.7.2.1 Survey Coverage

The target participants of the CFS should be cargo owners (commodity producers) and transport operators (carriers and shippers). The main purpose of surveying the cargo owners is to answer the question of *what moves?* The purpose of surveying the transport operators is to provide a more detailed answer to the question of *how it moves?*

It is recommended that a full census for cargo owners is conducted. As identified in the research, the CFS provides the best opportunity to get a complete view of commodity origin-destinations. It is unrealistic to expect a 100% response rate, so the Ministry should set a target of 65-70% response for cargo owners for each key stratification of the sample. This is similar to response rates for the US and Swedish surveys.

For transport operators, it is not as vital to get as large a sample as there is likely to be less variability in how they operate relative to the commodity-specific cargo owners. I.e., you don't need as much data to gain an understanding of how the sector operates.

Based on feedback from the industry steering group, there was a sense that transport operators were less willing to share data than the cargo owners. It is recommended that there should be further engagement with the peak bodies from both groups prior to surveying, however, there may be more effort required to gain buy-in from the transport operators.

3.7.2.2 Survey Stratification

Stratified sampling is a method of sampling from a population which can be sub-classified into smaller groups based on similar profiles. The US and Swedish CFS, stratify samples based on their geography, industry and size. This is to ensure that there is reasonable coverage of activity across geographic locations, industry type and size of businesses.

[11] **Commodity Flow Survey Questionnaires (census.gov)**

In the stratification process, each of these variables are considered together. For example, if in the Gisborne region, there is a large number of producers of citrus fruits, then there should be representation in the sample from both the high-volume producers and the lower volume producers. If size was not considered and it is left to chance, it might be that only high-volume producers are captured and therefore survey results would not yield an accurate depiction of commodity flows in the region.

The Statistics NZ Business Demography data can be used to aid this stratification process.

3.7.2.3 Industries to target

It should be established which are the key industries to target. This will include, at a minimum, the major commodity producers such as dairy, horticulture and forestry, industries which include critical goods, and industries which include hazardous goods.

The Australian and New Zealand Standard Industrial Classification (ANZSIC) should be used for the classification of industries in the Survey form. The ANZIC system uses a hierarchical structure, with four levels of grouping such as in Table 11 below.

Table 11: ANZIC classifications and example

Level	Number of values	Example
Division	19	C Manufacturing
Subdivision	96	11 Food Product Manufacturing
Group	204	111 Meat and Meat Product Manufacturing
Class	506	1111 Meat Processing

Which of the four levels of granularity is requested from participants will likely depend on the level of commodity detail that is decided upon for the updated NFDS. For example, it may be the case that for some industries it is requested that details on commodity *Group* is requested, and for others, where less detail is required, *Division* classification is requested. Alternatively, it may be decided that all participants respond at the *Subdivision* level, for example.

It should also be determined if there are types of businesses that can be removed from the sample or grouped into a wider miscellaneous group. For example, in the US CFS, *Retail* and *Services* businesses are removed from the Survey as they are unlikely to have significant shipping activities. This reduces cost and requirement of the sample size. Other organisations that are removed include government and military.

In some cases, businesses might already have data that is in a similar shape to that of the outputs of a CFS. In this event, it might be decided that this data can be provided to the Ministry instead of a response to the CFS. This should be reserved for only large organisations, so as to avoid a much greater data processing task.

3.7.2.4 Survey frequency

There are some different options available for survey frequency. Looking abroad, the US conducts a single full survey every five years. In Sweden, a full business census is conducted every five years (businesses >10 employees), with quarterly random sampling stratified by business sector and establishment size.

For the Ministry, it may be the case that frequency can be decided based on the quality of the first survey results. Should budgets and industry buy-in allow, it is recommended that there should at least be some degree of random sampling between the full census surveys. This is an important step to capture any significant shifts in trends.

3.7.2.5 Sample period

The survey period should factor seasonality of movement. The US CFS achieves this by allocating each establishment one of four four-week survey periods, which occur once-per-quarter. Establishments are allocated a period, with consideration of their industry, geography and size, so that there is relatively even distribution across each quarter.

The amount of data requested from businesses should consider a balance between the burden of the request on the participant and the amount of data required to provide a meaningful sample. In the US CFS, the participant is requested to provide all of their shipment activity for each survey week. If the number of shipments exceeds 40, then the participant is asked to provide a systematic sample of their shipments.

3.7.2.6 Survey questions and content

The survey questions and format should be carefully considered. It would be sensible to trial these questions with some industry peak bodies prior to the formal publishing of the survey to gauge the suitability of questions and format. The level of detail (for example, commodity and location) requested should be considered in the context of how much effort is required by the respondent, and in turn, the likelihood of their providing an accurate response. The CFS conducted in the United States has been operating for over twenty years and has a good response rate (74% after weighting for establishment size). The format of this survey could provide a good foundation for a New Zealand survey. The information requested in that Survey and how it translates in the New Zealand context is provided in Table 12.

Table 12: US CFS and commentary on New Zealand context

Information requested	Commentary on New Zealand equivalent (where required)
Shipment ID number.	As is.
Shipment date (month, day).	dd/mm/yyyy format
Shipment value.	In NZD.
Shipment weight in pounds.	Kilograms
Commodity code from Standard Classification of Transported Goods (SCTG) manual.	New Zealand Harmonised System Classification
Commodity description.	As is.
An indication (Yes or No) of whether the shipment was temperature controlled.	As is.
United Nations or North American (UN/NA) number for a HAZMAT shipment.	Globally Harmonised System (GHS 7) hazard classification system.
U.S. destination (city, state, ZIP code)—or gateway for an export shipment.	Minimum of postcode level. It is preferable to use location information that is more familiar to participants. I.e. they are unlikely to be familiar with Statistical Areas.
Domestic modes of transport.	Options provided as list, potentially incorporating RUC vehicle classes.
An indication (Yes or No) of whether the shipment was an export.	As is.
City and country of destination for an export shipment.	As is.
Export mode of transport.	Options provided as list.

The commodities that are being shipped should have alignment with the New Zealand Harmonised System Classification (NZHSC). This is so that there is alignment with the codes used by Customs Services and subsequently the IMEX data that is available.

For transport operators the questions are likely to be different and include more detailed information about the movement of the goods. This survey will have questions including, but not limited to:

- Where are the main hubbing facilities for your operation?
- What is the average time that shipments dwell at the facility for?
- What is the maximum time that shipments dwell at the facility for?

3.7.2.7 Survey publication

It is recommended that, if possible, the survey is carried out online by participants. An online survey format should likely improve the quality of data output, as functionality such as dropdown fields and autocomplete address fields would lessen the chance of human error. Further, this will significantly decrease the time to process the received survey results.

As a secondary option, a bulk upload of data should also be made available, as some participants may find this preferable. This would be a csv/excel upload with mandatory fields and mandatory field types.

Insight for NFDS: Lessons learnt from previous business surveys

While there is currently no CFS undertaken in New Zealand, there is precedent for this type of survey being executed. Up until ten years ago, the Commodity Data Collection (CDC) survey was undertaken and used to inform the national-level Input-Output commodity tables. It was decommissioned as it was too costly to continue (for example, it required a full-time team of 5-6 people and 18 months to complete survey and analysis for four industries). The high costs of the survey were due to various factors, such as: the length of questions that it asked of participants, the manual nature of the response to the survey questions, and the manual analysis it required.

A modern CFS could be far more efficient in comparison to the CDC. Efficiency could be gained through a more streamlined approach, including but not limited to features such as:

- More targeted: Targeted at industries where there is less data available from existing data collection methods.
- Short-form: As can be observed in the US CFS, the time requirements for participants are low (estimated up to 2.5 hours per year).
- Leverage existing administrative data collection: possibly included as part of other administrative data collection such as RUC.

Together, these factors could go some distance to reduce the cost of the data collection and analysis, and the burden on the participant.

It was explored how the CFS could be minimised through modelling. However, to accurately evaluate the effectiveness of these industry minimisation techniques, they would still need to undergo testing against a reliable ‘source of trust.’ This could involve a baseline commodity survey or, at the very least, a tactical survey of a specific region, suitable for assessing the relationship and accuracy of alternative methods.

3.7.3 How a Commodity Flow Survey can improve on the previous NFDS methodology

The use of a CFS would be part of a data and modelling toolkit which diverges from the approach used in the previous NFDS to develop a baseline commodity flow dataset. Figure 7 below demonstrates how the two approaches may differ, with the layers representing a proportional contribution to the development of the baseline.

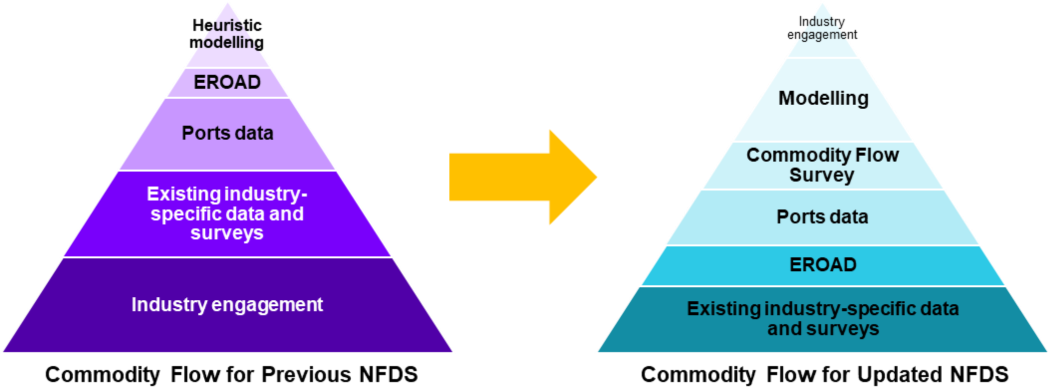


Figure 7: Chart to show example build-up of data and modelling required to construct a commodity flow dataset.

Noted differences with the updated approach include the large reduction of data derived from direct industry engagement with this mostly being replaced by the CFS, and a higher proportional input from the EROAD data and modelling. Existing ports and industry-specific data still play an essential role in building the baseline. This commodity flow baseline approach should yield tangible improvements to the process and outputs of the previous NFDS. These improvements are listed in Table 13.

Table 13: Limitations of previous NFDS and potential improvements with updated approach.

Limitations of previous NFDS	Potential improvements with updated approach
Limited granularity – This was raised by Stakeholders and was previously noted in the Data and Analytical Priorities Deloitte report (2023). Specifically, this relates to a lack of location, vehicle, mode, time, freight format & commodity granularity.	Using a bottom-up survey approach offers improved granularity across all facets of freight movement, as specific questions can be asked of individual organisations and aggregated (as opposed to, in some cases, starting with aggregated data). For example, provided that the CFS will produce outputs at, potentially, a postcode level, there will be opportunity to present origin-destination outputs at a sub-regional level.
Lack of clarity on the validation/testing of results – Stakeholders noted that it was hard to trust the NFDS is validation processes were not known. Basis of key assumptions are unclear, so it is difficult to apply own assertions as to reliability.	It is recommended that a methodology document (potentially a webpage) accompanies the NFDS, so that ongoing updates to the methodology can be documented and made available to users. This document would define these validation results and list key assumptions.
Inconsistent disaggregation – as a 'best available data' approach was taken the data is not disaggregated to a similar extent, i.e. general manufactured goods consist 35% of total movements.	The updated approach should use a recognised commodity classification system such as the New Zealand Harmonised System Classification (NZHSC). This system has been built off international standards and uses consistent aggregation. This provides alignment with the codes used with Customs data, should be familiar to those using the NFDS in the freight sector and should improve opportunities to use the outputs in conjunction with other datasets.
Curious results impacted industry's faith in the NFDS – Large volumes of timber from Auckland to Canterbury or a general lack of distribution from Auckland to other parts of the country.	Using a System Balancing approach means that assumptions can be set and iteratively updated so that the baseline data provides an accurate representation of reality. This should reduce anomalous observations and/or allow for these to be more easily responded to.
Repeatability and consistency – Due to the ad hoc nature of the methodology (where data collection and modelling methods differed across industries and between studies, which made comparison less robust) it is difficult to repeat in same fashion as to be able to draw insights regarding trends.	The proposed formal surveying approach should not change significantly over time nor differ between participants (regardless of their industry). This should improve the repeatability/updatability of the NFDS as the format and quantum of data will not change significantly., i.e. the same processes can be repeated. Further, this consistency in approach will allow for an improved ability to compare insights across time and industry sectors.
Limited ability to account for significant structural changes or commodity-specific contract arrangements – when significant events occurred, or are proposed, which re-shape how freight	The System Balancing approach allows for input data to be updated with relative ease in order to reflect recent significant events that impact freight movements. For example, if port rationalisation occurred and patterns of truck movements altered, EROAD data

Limitations of previous NFDS	Potential improvements with updated approach
moves in parts of NZ, the NFDS was unable to account for this.	could be updated in the model, and with some calibration this would demonstrate the impact of the structural change.

NFDS Insight:

The updated NFDS is likely to be materially different to the previous NFDS in order to achieve the near term and future objectives as defined in previous stages of this project. The need for a more sophisticated delivery methodology and more detailed data largely relates to the need for higher granularity of output. The addition of vehicle types, vehicle trips at a commodity level, route attribution and coverage of intra-regional, last mile and urban freight are significant uplifts in NFDS output.
There is still a question of 'who does what' in terms of allocating functions of the NFDS to different Government departments or agencies however at the options assessment stage we are taking a whole of government view.

3.8 Data considerations and challenges

3.8.1 Data accessibility

There are some residual unknowns with the accessibility of data, in particular data from industry. Non-industry data accessibility concerns mainly relate to NZ Customs data and whether shipping container pack or unpack data is collected and could be made accessible for this study.

Concerns regarding private sector data availability mostly relate to the below issues and concerns and are seen as largely uniform across all NFDS options assessed.

- Data provision impost (the cost and effort associated with providing freight movement data)
- Commercial sensitivity concerns
- Concerns regarding what the data will be used for.

Broadly there are methods to safeguard against commercial sensitivities by aggregating and desensitising data and these processes can be outlines in a Data Governance Plan which should be made accessible to any parties providing data.

Stakeholder engagement has suggested that if there is reciprocal benefit then most entities would be open to providing data, this said there will be commercial sensitivities and data governance assurances needed and this process of accessing data may take multiple months of engagement and agreement.

3.8.2 Industry willingness to share data

Industry stakeholders have shown some willingness to participate in the provision of data. There is a recognition from some industry stakeholders that a) there is a lack of good quality, standardised commodity flow data in NZ, and b) that they will play a major role in providing this data. This has been established through conversations with individual stakeholders, in the Industry Stakeholder Workshop held on 6th March 2024, and as documented in Deloitte's *Freight and Supply Chain System Data and Analytical Priorities* report.

Provided there is this recognition of the need for more data, there may be a willingness to participate in a commodity flow survey. The lower the effort and frequency the CFS is, the higher the good will towards, and subsequent response rates would likely be. For some parts of the freight sector the provision of data is perceived to be more difficult than for others. For example, road freight carriers expressed some concern that their members would find it difficult to report details on their activities due to the incompatibility of how they currently capture their data and concerns around commercial sensitivities.

3.8.3 Opportunity to use EROAD data

EROAD Business Classification data was used during COVID-19 to provide the Government with a better view of up-to-date commodity movements. However, we are classifying it as new opportunity because it is not yet actively updated. If this data was updated and proved to be accurate then it would not replace an initial CFS but could be used to update flows over time and reduce survey repeats and burden on industry participants.

Through discussions with the EROAD data provider – Robinsight, and in discussions with the NZTA Waka Kotahi team who are receiving the data, it was advised that this telematics dataset can include an industry classification for vehicle trips. The industry classification feature of the EROAD data has the potential to make up a large part of the commodity movement picture. This is dependent on three key factors:

1. A mapping between the industry classification of the vehicle and the assumed commodity being moved would need to be developed.
2. The statistical relationship between the assigned industry classification of the vehicle and the assumed commodity it is moving would need to be tested and be determined to be strong.
3. The data sample is determined to be sufficiently representative of the full population of vehicles that it is attempting to represent.

For example, if for the logging sector, trucks are only used to move timber and/or wood products, their industry classification is 'Forestry' and 80% of the timber sector is represented in the EROAD data, then this would reduce the need to request additional details through surveys from the timber industry and reduce the need to fill gaps through modelling.

In another scenario, when determining the movement of aggregates, the related industrial classification of the vehicle might be *construction*. In NZ, construction companies may have many vehicles moving different types of commodities, and so the statistical correlation between the vehicles' industry classification and the commodity could be relatively low and therefore less useful.

In order to understand the overall usefulness of the EROAD data, the relationships between these vehicle industry-classifications and assumed commodities being moved would need further investigation.

3.8.4 Other opportunities with data

Potential new datasets such a e-sim data from trucks, which is separate to telematics as collected as part of road use charging (RUC) obligations in that this is data collected by Original Equipment Manufacturers (OEM's) and then aggregated by a company called Compass IoT. This data includes truck performance, stability and location detail and notably includes a sample of Light Commercial Vehicles (LCV's) which are not included in the RUC data. Details on use of this data are included within this options assessment, however the use of this data has not been tested as part of this project. It is also worth noting that there are concerns with the smaller sample size of this data and potential bias towards new vehicles in the fleet.

4. Modelling Typologies

For the purposes of developing options, we have categorised different freight demand typologies based on their prevailing methodology and function. As not all models are uniform and follow only one methodology or function, we have categorised the models based on their prevailing method/function. For example, some commodity flow and four-step models may use elements of simulation, i.e. a commodity flow model could use some system balancing as opposed to linear extrapolation, and a four-step model could use simulation to conduct truck tour modelling.

There are elements of the NFDS which sit outside of this evaluation process. This is due to them having established processes or there is near-complete data that captures most freight flows and does not require advanced modelling to address data gaps. For example, there is near-perfect freight flow data captured by customs and in port operations systems for imports and exports in and out of New Zealand, hence, international shipping and international airfreight is not a focus of this assessment of modelling approaches.

Rail, domestic airfreight, and coastal shipping is somewhat similar to the near-complete picture described above - whereby trains, aircraft and vessels have consignment level manifests detailing what is moving which need to be produced for legal and safety reasons.

Despite this robust amount of data, there may be barriers to overcome to anonymise information and avoid exposing commercially sensitive data. Some businesses can be highly sensitive about sharing data. Any freight modelling initiative should also contemplate the time and resources needed to process data-sharing agreements and implement anonymisation methods.

4.1 Model typology groups and options

Through research and stakeholder engagement the model typologies and approach options have been identified for assessment. These are set out in Table 14. The full description of each modelling type is detailed in the attached report *NFDS Scoping – Options Paper.*

Table 14: Model Typologies

Model Typology	Sub-Category
Commodity Flow Analysis	Inter-Regional Commodity Flow
	Intra-Regional Commodity Flow
	Intra-Regional Commodity Flow with high level vehicle/mode flows
Four-Step Models	Four-Step Model – Trip-based
	Four-Step Model + Tour Modelling
	Four-Step Model with enhanced route assignment
Supply-Chain Models	Aggregate-Disaggregate-Aggregate Model
	Supply Chain Commodity Flow Models (Modular)
	Supply-Chain Simulation* and System Balancing Models
Dynamic Simulation*	Agent Based Model (ABM) and Discrete Event Simulation (DES)

*Dynamic simulation as opposed to non-dynamic simulation contains an 'internal memory' of temporal events whereby what has occurred would influence what is going to occur. Non-dynamic simulation is static and looks at multiple discrete points in time as opposed to a temporal continuum.

The following section describes the identified approach typologies.

4.1.1 Forecast Methods

Forecasting methods are more universal and generally accepted as compared to the many types of data capture and movement modelling options as described above and so have not been the focus of this research paper.

In the 2017/18 NFDS Report, forecasts of 'supply-driven'[12] commodity production was based on some combination of:

– Available published forecast data such as MPI's Wood Availability Forecasts
– The continuation of historical trends
– Trends in overseas demand
– Future shifts in policy such as those with a purpose to minimise the environmental impact of production
– Discussions with industry

The forecast methodology used in the previous NFDS is more or less adequate for future NFDS's, the key difference is the baseline data and the need for this to be more complete and more granular in future studies to fulfil defined NFDS objectives.

The drivers of freight system growth are supply and demand. Namely, what is the demand and what are the supply-constraints. This is why freight demand forecasts follow established economic methods and use existing forecasts data.

Generally, forecasts are applied to models via the application of growth factors on commodity flows. Growth factors at a commodity level are calculated based on forecasts which largely already exist such as trade forecasts.

Commodity and location-based forecasted growth:

- Exports – often based on overseas trading partner growth.
- Production – based on export demand and domestic consumption (population).
- Imports – driven by domestic production (inputs) and domestic consumption.
- Economic forecasts such as the Economic and Tax Outlook – BPS 2024.[13]
- MPI's Economic Intelligence Unit releases a Situation and Outlook for Primary Industries (SOPI) report twice a year. SOPI reports look at the performance of NZ's main primary sectors and forecast how they will perform over the next 2 to 5 years.

Commodity production forecasts such as those produced by MPI are used to develop commodity growth factors by region which are then applied to the baseline commodity flows by location.

Worth noting is the fact that export volume and production levels should be constrained by potential supply and not just demand driven, for example where demand may outstrip supply due to a lack of arable land or ability to extract resources. Additional guidance on freight demand forecasts is included in the ATAP Guidelines (noting that NZ was a party to their development).[14]

4.1.1.1 The use of stakeholder engagement and a CFS to inform forecast:

Aside from using existing and available economic forecasts to generate commodity and location-based growth factors for use in the NFDS there is an opportunity to incorporate forecast data from a commodity flow survey and/or direct stakeholder engagement if desired. For instance, the CFS could include a question regarding future expected growth and this could be compared to economic data for consistency. If industry sentiment appears to be in conflict with economic data then this should perhaps be addressed with those who are generating economic forecasts. It is not the view of the project team that the Ministry should deviate from existing economic forecast data and create alternative sources of truth which may be inconsistent with more widely accepted economic forecasts.

[12] The authors define "supply-driven commodities" as ones where "flows are typically based on production capacity and constraints".
[13] **Economic and Tax Outlook - BPS 2024 - 27 March 2024 (treasury.govt.nz)**
[14] **4. Step 4: Make demand forecasts | Australian Transport Assessment and Planning (atap.gov.au)**

Insight for NFDS: Role of the NFDS in producing raw forecast data

There is no need for the Ministry as part of the delivery of the NFDS to produce any 'original' forecasting, merely to use existing economic data to produce assumed growth factors at a commodity and location level. This being said, if through the CFS or direct stakeholder engagement there appears to be material inconsistency between established economic growth factors and industry sentiment, then this should be addressed with the entity generating economic forecasts.

4.2 Commodity Flow Model

A commodity flow analysis can be visualised as a matrix with rows as origins and columns as destinations with tonnes of commodities as the value. Generally, origins and destinations are aggregated to regions. The principal reason for selecting a commodity flow approach is to enable others (public or private sector) with a valuable base of data from which further analysis can be conducted and insights derived. A commodity flow approach would not generate a lot of insight, but it serves as an important input into most other models listed below which may be developed by the Ministry or enable development by others. This is similar to the approach taken in the US where the Federal Bureau of Transport Statistics has developed the Freight Analysis Framework. This data is then made available to State Authorities and consultants to derive more granular regional models. Some features of the options within this category are illustrated below.

Option	Commodity Flow Data	Mode, Vehicle and Route Attribution	Last Mile and Urban Freight	Scenario Analysis	Other key functions
Inter Regional Commodity Flow	- Commodity Flow Data - Land Use Data - Business Classification - Production - Consumption - Import / Export - Input/Output National Accounts Econometrics approach which at its core is regression analysis, which assesses the statistical significance of different attributes in explaining a specific outcome or dependent variable (ie commodity).	None	Not granular enough to inform last mile and urban analysis	Production, consumption and land use data inputs could be adjusted to show potential future scenarios and commodity flows could be re-calculated	No additional functionality of note, ie productivity, emissions, future network impact assessment or capacity modelling etc.
Intra Regional Commodity Flow			Not granular enough to inform last mile and urban analysis		
Intra-Regional with high level mode/vehicle flows		Convert commodity volumes into likely mode and intra-regional vehicle flows but no route assignment.	Vehicle numbers could be used to inform additional analysis	In addition to above, different modal shares and vehicle type profiles could be assessed to see impact on vehicle numbers.	

Figure 8: Commodity Flow Model - Options Comparison Diagram

4.3 Four-Step Models

This is the most established and prevalent method for analysing freight movements. Please see the *Research Memo* for further information, however this approach is distinct from the Commodity Flow Models described in Section 4.2 as four-step models include both vehicle and route assignment. Traditionally, a four-step approach is trip-based which only looks at single point-to-point OD movement and truck tour modelling is also not used (which details the multiple load/unloads stops of a journey). This approach is distinct from the simulation category as this is not stochastic, it is deterministic. In Four-step modelling, all outputs are generated in a linear input-output manner, as distinct from simulation which have feedback loops, behavioural characteristics, and temporal discrete event-based approaches. Importantly, it should be noted that elements of simulation could be used in a Four-step model, in particular when it comes to route assignment, mode choice and tour-based modelling.

Option	Commodity Flow Data	Mode, Vehicle and Route Attribution	Last Mile and Urban Freight	Scenario Analysis	Other key functions
Four Step with Trip Modelling	- Commodity Flow Data - Land Use Data - Business Classification - Production - Consumption - Import / Export - Input/Output National Accounts - Econometrics approach which at its core is regression analysis, which assesses the statistical significance of different attributes in explaining a specific outcome or dependent variable (ie commodity).	Commodities are split into consignments by OD and assigned to mode and vehicle types based on known vehicle type profiles from observed movements and vehicle registrations.	Trip Modeling usually over represents the number of trucks involved in last mile and urban movements and is not very accurate.	Production, consumption and land use data inputs could be adjusted to show potential future scenarios and commodity flows could be re-calculated New mode shares and vehicle type profiles could be assessed in scenario analysis.	Emissions and productivity analysis is possible however trip modelling limits accurate and granularity.
Four Step with Tour Modelling		Vehicles are assigned to routes based on cost and time. Ie an assumed logical route not actual route.	Tour modeling is more representative of last mile and urban freight movements. It uses behavioral data from GPS telematics, or e-sim data (compass IoT) to generate tours.		The additional of tour modelling makes productivity and emissions outputs more reliable. Other urban insights are more accurate.
Four Step with tour and enhanced route assignment		Enhanced route assignment enables different route logic ie actual vs lowest cost or routes can be closed or added to observe impact. Background traffic can also influence route choice in this option		Alternative route or network scenarios can be assessed including to understand impact of resilience/disruption scenarios	The addition of enhanced route assignment means 'optimal' routes vs actual can be compared and industry choices better understood.

Figure 9: Four-Step Models – Option Comparison Diagram

Terminology Deep Dive

Econometrics in the context of freight demand modeling:

Econometrics is the application of statistical methods to analyse economic data, estimate relationships between variables, and make predictions. It combines economics, mathematics, and statistics to understand and replicate real world impacts of change, policies, interventions, and economic conditions.

As we will not have access to perfect and ongoing data detailing all freight movements, vehicle types, commodity, mode etc. then the next best thing to do is to understand the relationship between observed freight movements (actuals) and other datasets which are near-complete and/or updated more regularly and/or have reliable forecasts we can use these other datasets as proxies for gathering exhaustive observed movement data.

At the core of econometrics is regression analysis and coefficient which talk to the ability of one or many data sets to predict or approximate an unknown variable (dependent variable).

A detailed description of the econometrics approach is included in Appendix D.

4.4 Supply-Chain and Logistics Models

Supply-Chain and logistics models generally do not look at the entirety of freight movements but rather they are based around particular supply-chains or types of freight. This can enable them to be more bespoke and have more supply-chain specific functionality. This means model logic can be commodity or freight-type specific. However, due to this bespoke nature these models either have a narrower focus or are developed over greater periods of time. This has been the case in Sweden, where the national freight model, SAMGODS, has been in development for almost 20 years.

This class of models may use simulation but is generally non-dynamic, meaning that it is still deterministic and less stochastic. Deterministic in this instance means that data is used to directly inform the model as to how to deal with commodity flows, vehicle and route assignment based on known probabilities / distributions. Non-dynamic models do not feature discrete events (where events occur at distinct points in time triggering changes in the system's state) or feedback loops whereby an event can impact a preceding event (described in more detail in Figure 10 below).

Option	Commodity Flow Data	Mode, Vehicle and Route Attribution	Last Mile and Urban Freight	Scenario Analysis	Other key functions
ADA Model	Starts with total production and consumption then disaggregates to a flow and granular location level based on commodity and enterprise survey. Re-aggregated to represent intra-regional flows	Route is assigned on a **logic-based approach** however this can be done at individual vehicle level and could include consideration of network level of service (network performance)	ADA enables microsimulation at an individual vehicle level and could be conducive to agent-based modeling for tours or urban freight.	The high degree of detail and ADA logic may make it difficult or slow to scenarios. Resilience scenarios should be possible by adapting route assignment logic.	ADA models allow very detailed analysis and can feed data into other microsimulation such as traffic assessment processes
Supply Chain Commodity Flow Models (Modular)	Limited OD survey targeting **specific commodities at a time**. Survey sample is then scaled up to know commodity volumes.	All mode and vehicle choice is parametrized in this model and **selected based on observed movement or user preference**. Route is assigned based on cost.	Vehicle volumes are not aggregated to a total vehicle number as this option is industry-based and iteratively developed.	This approach is capable of running scenarios as it is parametrized and route assignment logic can be changed easily.	These models are largely focussed on observing cost and alternatives routes moves.
Supply-Chain Simulation and System Balancing Models	Similar to ADA where total in/out flows are known and **OD's are assigned based on probabilities** generated from commodity flow survey.	**Mode, vehicles and routes are assigned based on probabilities** developed from sample data from CFS, vehicle profiles, telematics, traffic counts, WIM etc.	Vehicle volumes are detailed at a last mile and urban freight level so this option can include tour modelling for light commercial vehicles.	Highly adaptable due to probability based flows, capable of running many resilience, network performance, and productivity scenarios.	System balancing enables forecasts to be modelling rapidly as in-flows and out-flows can be changed easily.

Figure 10: Supply-Chain & Logistics Model Options

There are alternatives to statistical scaling or extrapolation of a sample to a population. Using a system balancing approach means that samples are scaled to reflect known system characteristics, specifically system inflows, outflows, production and consumption.

In this approach the sample freight movement data gathered as part of a CFS and supplemented with telematics commodity designation is used to inform probability distributions, i.e. the probability of a certain commodity having a certain origin or destination depending on whether it is an import/export or domestically produced or consumed. Once these probability distributions have been established, (likely using a Bayesian Probability approach which can be amended as new data comes to light) then volume is introduced to the system balance model by means of imports & exports (by port), production and consumption volumes (by SA level). Volumes are distributed probabilistically.

For example, if through the sample data we ascertain that if an imported container of paint via Port of Auckland has a 15% likelihood of being destined for Hamilton, then 15% of every container of paint arriving via Port of Auckland moves to Hamilton. Probabilities are also gathered for mode and truck type which can disaggregate this further.

This approach is preferred to linear scaling or extrapolation as it reconciles samples with more system ‘knowns’ and it is highly conducive to forecasting as future volume can be introduced to the system and distributed.

Terminology Deep Dive

What is system balancing?

A system balance model is a type of non-dynamic simulation which balances inflows, dwell (storage) and outflows of nodes and the system overall based on probability distributions. It is aimed at providing the ‘most likely’ flow of freight based on obtained data. Probability distributions become more accurate the more granular data is available, for example, if considering imports and exports flowing in and out of a port then the probability of the freight moving to and from a certain location may be highly dependent on what type of freight it is. If there is a relationship between commodity and OD distribution, then this can be tested via regression analysis. By using a Bayesian Probability method multiple factors which have relationships with OD distributions can be used to build more accurate probabilities based on increased knowledge of real-world movements.

4.5 Dynamic Simulation Models

Dynamic models seek to replicate real-world behaviour as opposed to generating data which looks to reflect outcomes of behaviour. Key to success is to understand and then describe mathematically how people, technologies, the economy, and companies behave. Dynamic models can either be deterministic or stochastic and contain elements of both. In the deterministic case, there is no randomness or uncertainty involved. These models produce the same output for a given set of initial conditions and inputs, making their behaviour predictable and reproducible.

In the stochastic case, randomness is incorporated into the model's inputs, parameters, or processes. This randomness may be owed to variability of data or probabilistic nature of events. These models are most representative of reality if we can interpret and describe that reality accurately. Dynamic simulation is temporal with precedent and dependent relationships based on events. This means that based on an action or event there is a subsequent action based on that precedent. This type of cause and effect is only possible with dynamic simulation. For example, with dynamic simulation a rail mode share of a particular freight corridor can be a product of rail schedules, timing, and alternatives available, it is not prescribed by entering a mode share as would be the case with other options. This approach is very powerful as often insights and potential interventions including policy initiatives depend so much on behaviour and incentives (cause and effect).

Dynamic in this instance means they are non-linear with multiple directions of cause and effect, including feedback loops where outcomes impact preceding inputs. These simulations can accurately model complex systems with many complex precedent and dependent relationships.

Prevailing modelling methods used in dynamic simulation include:

- **Agent-based simulation** – where individual (cognitive) agents are programmed with decision-making rules and hierarchy.
- **Discrete event simulation** – where variables change at discrete times and stages.
- **System Dynamics** – Used to understand how a whole system works based on what we can observe of the system often using machine learning and artificial intelligence.

Within a dynamic simulation all three methods can be used in the same environment to best represent the real word situation they are replicating. For the purposes of evaluation, we have included ABM and DES together as they complement each other and Systems Dynamics separately.

Terminology Deep Dive

Stochastic vs Deterministic:

Deterministic models are based on precise inputs and produce the same output for a given set of inputs. These models assume that the future can be predicted with certainty based on the current state. Stochastic models incorporate randomness and uncertainty into the modeling process. They handle uncertainties in the inputs applied. Deterministic models offer simplicity but lack realism, while stochastic models embrace uncertainty and provide a more nuanced understanding of complex systems.

Deterministic models are easier to understand and to validate whilst models which incorporate stochastic components may be harder to calibrate and validate however once that are accurate, they deliver more realistic and representative outputs.

There are a series of key benefits with dynamic models:

- They are generally better at dealing with data gaps and uncertainty, they also make better use of 'patchy' or anecdotal data. For example, it can use smaller samples to infer wider behavioural characteristics and apply them across the model relatively easily.
- They can uncover emergent behaviours that stem from the collective dynamics of the system, which are challenging to anticipate or predict.
- They are also generally more amenable to running scenarios and sensitivity analysis.

– They are more easily updateable as do not require a full re-baselining as is the case with some other models. This is demonstrated in Figure 11 below.

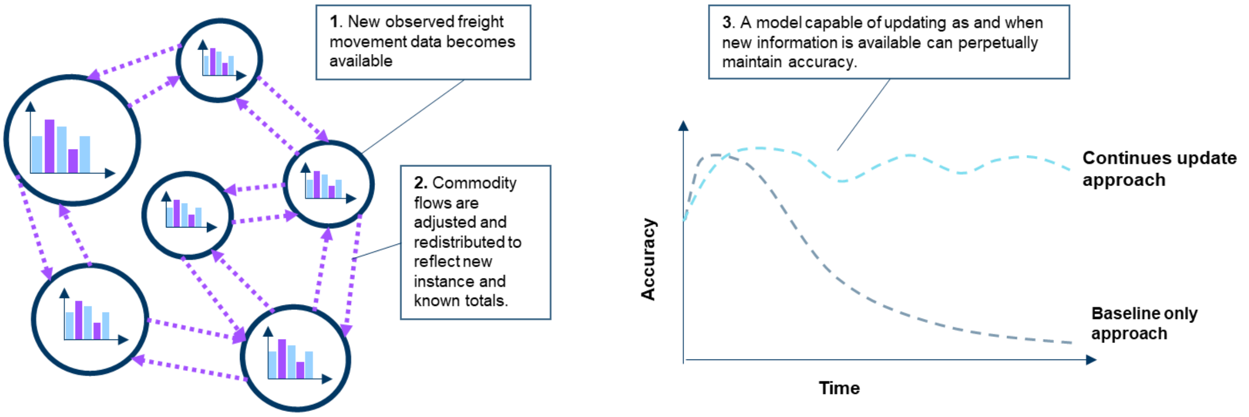


Figure 11: Dynamic simulation and ability to continuously update

Option	Commodity Flow Data	Mode, Vehicle and Route Attribution	Last Mile and Urban Freight	Scenario Analysis	Other key functions
Dynamic Simulation	Dynamic simulation is quite adaptive in terms of the commodity flow data it uses, ie it can be similar to the econometrics baseline data used in Four-Step or it can be similar to the ADA approach or a probability-based system balance approach.	Mode and vehicles can be assigned in multiple methods. Mode, vehicle and route attribution can be a factor of best available option at the point in time given commodity needs or they can be prescribed which is based on actual observed movement data. Road vehicles would likely use Agent Based Modeling (ABM) whereas scheduled services like air, rail and sea would use Discrete Event Simulation	Last Mile and Urban freight can utilise ABM where each truck and LCV can be represented, and logic can be based on realistic behavioral characteristics so impact of congestion and other impediments can more easily be observed.	Scenario analysis is a real strength of dynamic simulation as changes in inputs, variables and assumptions flow easily throughout the model consistently and reliably. Simulation also enables optimisation and goal seeking which is as opposed to 'iterative' scenario analysis where many different iterations are run and the outputs mapped to understand highest performing scenarios. This enables insights to be quickly developed.	Simulation can enable large structural changes to be assessed for their impact relatively quickly, i.e., a port closure or impact of a model shift policy.
Dynamic Simulation with System Dynamics	System dynamics works with aggregate variables and could be used to develop more robust logic connecting freight flows with system inputs such and imports, production, consumption and exports. This logic could use machine learning to change over time.		The use of system dynamics could mean that sub models for urban systems can be developed whereby once system can seamlessly interact with another. Detailed urban models can have feedback loops to the national model.		System Dynamics may enable less industry survey data to be collected over time as system behaviour can be better understood and changes inferred by less and less data.

Figure 12: Dynamic Simulation Options Comparison

4.6 Summary of Model Attributes

The table below is an indicative comparison of the key outputs and function types of the different modelling approaches. The table also highlights the key data sets which are not currently available which may be required to enable each approach.

Table 15: High-level illustrative comparison of relative data, output, and model function aspects to each option.

		Key data required to enable option					Output												Modelling Function						
Model Typology	Sub-Category	Regional Commodity Flow Survey	Regional and Intra-Regional Commodity Flow Survey	Establishment Survey	Detailed Truck Traffic Counts	Urban Freight Movement Data (GPS/Compass IoT/Telematics)	Regional Commodity Flow	Intra-Regional Commodity Flow	Mode (Road/Rail/Air/Sea)	Truck Type	Route	Transport Cost	Truck Utilisation / Backloading	Time of day movements	Urban and Last Mile	Emissions / Energy Use	Disruption Impact & Costs	Forcasts of all outputs	Logic: Deterministic	Logic: Stocastic	Optimisation: Iterations	Optimisation: Dynamic (outcome seeking)	Extraolation: Linear	Extraolation: ADA	Extrapolation: System Balance
Commodity Flow Analysis	Regional Commodity Flow																								
	Intra-regional commodity flow																								
	Intra-Regional Commodity Flow with high level vehicle/mode flows																								
Four-Step Models	Four-step model - trip based																								
	Four-Step Model + Tour Modelling																								
	Four-Step Model with enhanced route assignment																								
Supply-Chain Models	Aggregate-Disagregate-Aggregate Model																								
	Supply Chain Commodity Flow Models (Modular)																								
	Supply-Chain Simulation and System Balancing Models																								
Dynamic Simulation	Agent Based Model (ABM) and Discrete Event Simulation (DES)																								
	System Dynamics																								

Partial

5. Options Evaluation

Following the definition of the range of delivery options for an updated NFDS, a Multi-Criteria Analysis (MCA) process was undertaken to evaluate and compare these options against criteria which align to NFDS objectives.

A required output of this study is to provide a range of potential options for recommendation, covering a spectrum of high-to-low cost and complexity options. To meet this requirement, the higher performing option from each option type category (i.e. Commodity Flow Models, Four-Step Models, Supply-Chain and Logistics Models, and Dynamic Simulation Models) have been further developed and assessed as part of a short list of recommendations.

This section briefly describes the Option Evaluation methodology. A more detailed description is provided in the *Options Paper*, provided as an attachment to this report and in Appendix B. A series of use case scenarios was also used as a supplementary exercise to assess the value of each option and is available in Appendix C. The MCA spreadsheet tool, which contains the workings, has also been provided as an attachment with this report.

Prior to the final evaluation a series of steps were taken. These were as follows:

- Drawing from the objectives determined as part of the objectives-setting stage, an initial set of evaluation criteria were identified which attempted to encompass the objectives.
- Following on from the confirmation of the evaluation criteria, it was requested that the Working Group undertake a pairwise assessment as a method to provide a weighting value to each of the criteria. A pairwise assessment requires the assessor to compare the relative importance of each criteria against each other criteria.

As a separate exercise from the criteria weighting, scoring of each delivery option against the evaluation criteria was undertaken by GHD. Ten options were scored using a 10-point scale (from 'Significantly negative' to 'Significantly positive').

The 'System Dynamics' delivery option was dropped as it was determined to be an unrealistic option due to the high delivery risk associated, as there is very little research that has been done in using this modelling concept for freight demand. The results are demonstrated in Figure 13 below which shows each option's score by the criteria category (Cost and Complexity, Improved Policy and Investment Decision Making, Dependability) and grouped into the option typology.

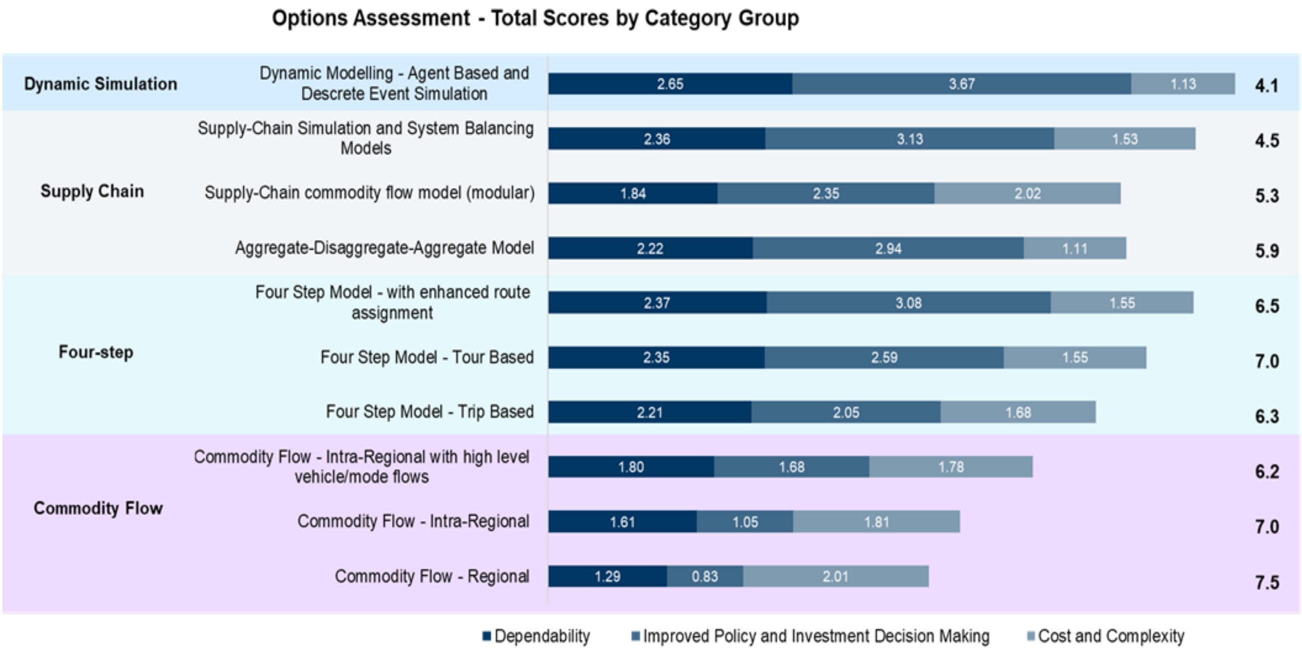


Figure 13: Total scores for the Options Assessment (including weighting)

Based on the highest-scoring option from each modelling typology approach, the following options have been selected as potential approaches to update the NFDS:

- Commodity Flow - Intra-Regional with high level vehicle/mode flows
- Four Step Model – with enhanced route assignment
- Supply-Chain Simulation and System Balancing Models
- Dynamic Simulation – Agent Based and Discrete Event Simulation

A summary of the strengths and limitations of each of these high-performing options is outlined in the MCA Scoring table in Appendix B.

A pairwise sensitivity analysis was also undertaken to understand if there was any significant influence of criteria weighting on the final evaluation scoring. As is discussed in Appendix B, the final evaluation score is not sensitive to changes in weighting.

To further aid in understanding the strengths/limitation of each high-ranking approach, these were tested in their ability to perform in different hypothetical freight-movement-impacting scenarios. The results of these tests are provided as part of Appendix B.

6. Implementation Pathways

In the context of implementing the NFDS, various adaptive pathways have been devised to address uncertainties related to data and to accommodate different 'approach philosophies.' These approaches range from striving for the best possible outcome to a more expedited forge-ahead approach. Alongside adaptive pathways, the recommendations section of this report also proposes a recommended pathway.

6.1 Adaptive development pathways

In any complex data, analytics and modelling project there are unknowns at the outset which mean there needs to be a degree of adaptability in the pathway taken. This is primarily due to the below:

- Prior to new data being gathered the true nature of the data is not known.
- Data can only truly be tested for appropriateness once it is gathered, this is especially true for the econometrics approach which relies on gaining valid regression outputs.
- Data gaps, once identified may take time to fill, there are likely gaps which may favour some modelling methodologies over others therefore having an adaptive approach regarding modelling choice may be beneficial.

However, aside from inherent need for adaptability there is also a need based on exogenous factors such as budget and time constraints and social/economic factors. Over the course of any program these factors can change and may influence approach options and preferences.

To reflect the need for adaptability, GHD has provided a set of adaptive pathways for implementing an updated NFDS, as outlined in Table 1. Below is commentary related to the pathway diagrams illustrated in Section 6.2

Table 16: Overview of adaptive pathways for implanting the revised NFDS

Pathway	Overview
Pathway 1: Best possible outcome approach	This approach seeks to maximise the value of available data by deferring the model methodology decision until most knowns are removed. This deferral of the model approach methodology means that there is very limited parallel development, i.e. developing the NFDS model alongside data collection and therefore there is a longer delivery timeline associated with this pathway. Additionally, as this approach has a few additional avenues which are exhausted prior to delivery there would be additional cost associated with this pathway as compared to others.
Pathway 2: Forge to the end	This development pathway prioritises delivery timelines by enabling parallel delivery of modelling and data capture. This option requires that a decision is made early regarding the approach method and the most adaptable method is chosen. This option has limited avenues of exploration and will do the best with what is available in terms of data.
Pathway 3: No Commodity Flow Survey	This approach is relevant if it is determined that a CFS is not possible, practical, or preferred for myriad reasons. This pathway also defers the method decision until there are less unknowns, largely the decision regarding approach depends on the efficacy of the use of telematics (i.e. EROAD) to also gather accompanying commodity designation by transport operator type.
Pathway 4: Enable and delegate	This pathway is offered if it is decided that the role of the Ministry is largely as an enabler or value to ultimately be derived by others. This approach is similar to that of the Federal US Government whereby they collect data and make it available for others but do not generate insight beyond general commodity flows themselves. This approach works were there are sufficient counterparties to undertake such value-additive work and that there is not a concern regarding potential duplication of effort and a lack of interoperability i.e. Councils all doing their own thing.

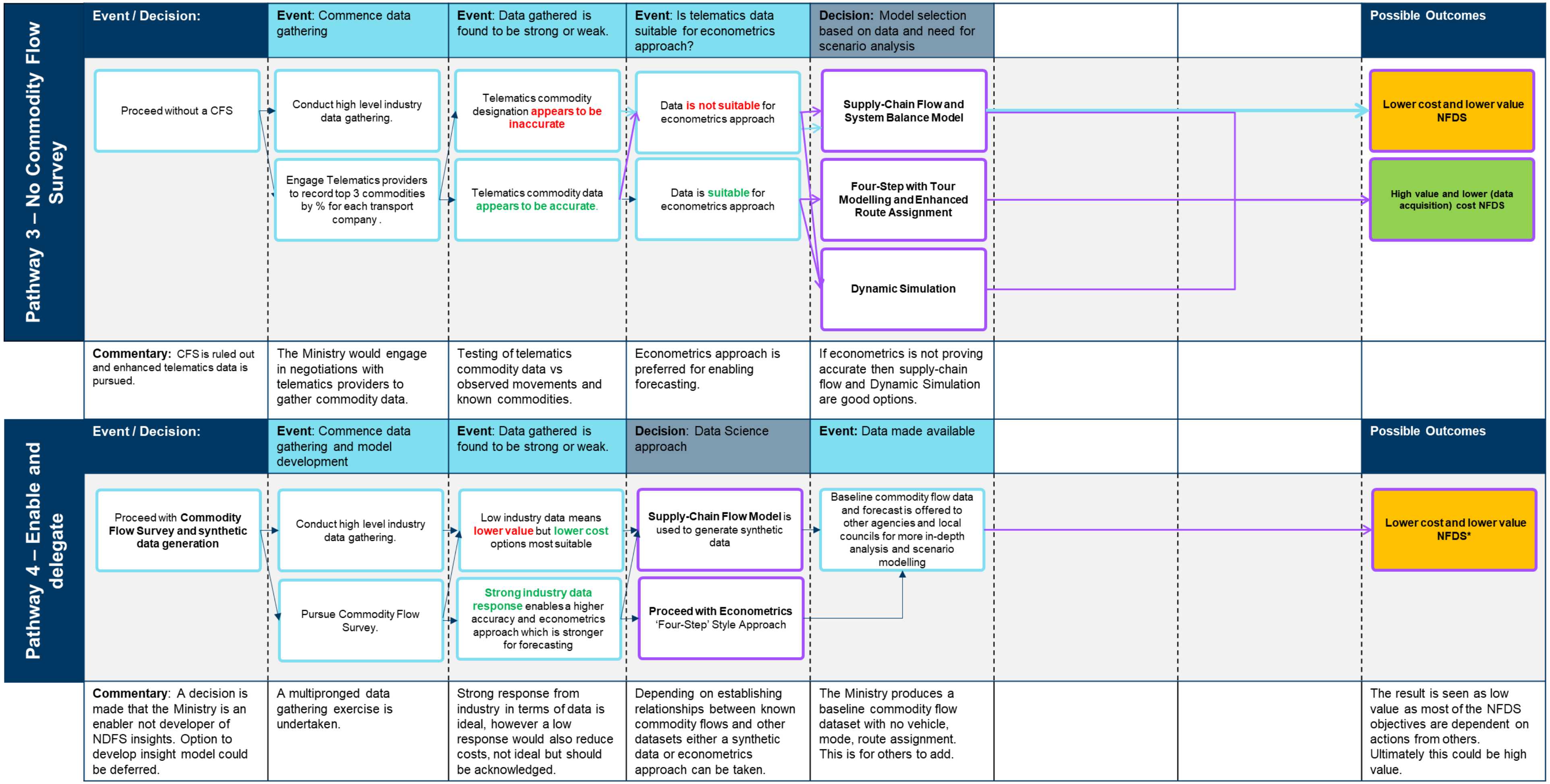
6.2 Adaptive Development Pathway Diagrams

Pathway 1 – Best Possible Outcome Approach

Event / Decision:	Event: Industry Response	Decision: How to proceed	Event: Establish ongoing reliance on industry data.	Decision: Reliability / Dependability = Value	Event: Cost & Benefit Hold Point	Decision: NFDS Delivery Options	Possible Outcomes
Proceed with **Commodity Flow Survey**	Industry **response rate low** and sample data not statistically significant	A **lack of industry data** means results may be **less reliable** and validity compromised	NFDS **proceeds without any reliance on data individual businesses** other than industry data which already exists, ie from industry associations.	Low industry data means **lower value** but **lower cost** options most suitable	Prospect of low-cost **lower value** NFDS	**Supply-Chain Flow With System Balancing** Model includes high level movements on certain commodities	**Lower cost and lower value NFDS**
	Industry **response satisfactory** and sample data is statistically significant	**Sufficient** industry data means that **commodity and intra-regional movements** can be assessed	**No strong correlation between industry supplied** data and other more accessible datasets is found so **reliance on industry data remains high**	Reliability and dependability are more fragile due to industry dependence plus **costs are higher** due to need for ongoing industry survey	Prospect of a potentially **higher cost**, **high value** (less updatable) NFDS	**Dynamic Simulation** Commodity flow, truck numbers, routes, urban freight and last mile plus scenario and optimisation capability	**High value and lower (data acquisition) cost NFDS**
			A strong correlation between industry commodity data and other data sets is established meaning **less industry data is needed in future**	Strong correlation means all modelling options available, and **results will be high value**	Ability to achieve **higher value and lower cost** (data) NFDS	**Four Step Model** Commodity flows, truck numbers, routes, urban freight and last mile minimal scenario analysis	**Highest value and higher cost NFDS**
Commentary: A 'best possible outcome' based approach is taken and timelines are not seen as very urgent, 3-year budget is available.	A CFS is progressed, and response rates tested. Tests relate to stratified statistical significance in terms of commodity and location coverage.	The NFDS can continue even if industry response is poor however this will dictate which delivery options are available/suitable.	Low levels of granular commodity movement data means the options which rely on strong regression relationships like four-step are not viable.	Faced with potentially lower-value outcomes due to a lack of data a decision to proceed or how to proceed is made.	The relationship between data availability and modelling options is complex, however Supply-Chain Flow models work well under any data situation, Four-Step models rely on strong commodity flow data and econometrics whereas Dynamic Simulation also works well with limited data however it is a more expensive option the more unknowns there are.		This proceed with caution approach will result in a good match between data and modelling option but it may take more time and have a few wrong turns along the way.

Pathway 2 – Forge ahead

Event / Decision:	Decision: Decide on most versatile modelling approach	Event: Commence data gathering and model development	Event: Establish ongoing reliance on industry data.	Event: Quality of input data dictates value of output			Possible Outcomes
Choose least risk delivery method given knowns at outset	**Supply-Chain Flow and System Balancing**	Pilot Commodity Flow Survey.	Synthetic dataset is generated with the model using best available data and depending on quality of industry supplied data could be moderately or highly accurate	Low industry data means **lower value** but **lower cost** options most suitable			**Lower cost and lower value NFDS**
		Conduct high level industry data gathering.		**Strong industry data** response enables a higher accuracy			**High value and medium cost NFDS**
		Commence model development.					
Commentary: Delivery time is prioritised and unknows aren't to lead to delays, results wanted in 18 months.	The supply-chain flow model is the most adaptable in any data availability situation so in a 'forge ahead; scenario this may be the best option.	A multipronged data gathering exercise is undertaken. CFS is referred to as a Pilot as an outcome does not rely on it being successful in an econometric/regression sense.	Using the supply-chain and system balancing model all 'knowns' are entered into the model to build the best possible probability based synthetic data set.	Strong response from industry in terms of data is ideal, however a low response would also reduce costs, not ideal but should be acknowledged.			Depending on the quality of input data this scenario could result in a lower value lower cost NFDS or a high value medium cost. Medium as still a CFS but no extensive econometrics approach


Pathway 3 – No Commodity Flow Survey
Event / Decision:
Event: Commence data gathering
Event: Data gathered is found to be strong or weak.
Event: Is telematics data suitable for econometrics approach?
Decision: Model selection based on data and need for scenario analysis
Possible Outcomes
Proceed without a CFS
Conduct high level industry data gathering.
Engage Telematics providers to record top 3 commodities by % for each transport company.
Telematics commodity designation appears to be inaccurate
Telematics commodity data appears to be accurate.
Data is not suitable for econometrics approach
Data is suitable for econometrics approach
Supply-Chain Flow and System Balance Model
Four-Step with Tour Modelling and Enhanced Route Assignment
Dynamic Simulation
Lower cost and lower value NFDS
High value and lower (data acquisition) cost NFDS
Commentary: CFS is ruled out and enhanced telematics data is pursued.
The Ministry would engage in negotiations with telematics providers to gather commodity data.
Testing of telematics commodity data vs observed movements and known commodities.
Econometrics approach is preferred for enabling forecasting.
If econometrics is not proving accurate then supply-chain flow and Dynamic Simulation are good options.
Pathway 4 – Enable and delegate
Event / Decision:
Event: Commence data gathering and model development
Event: Data gathered is found to be strong or weak.
Decision: Data Science approach
Event: Data made available
Possible Outcomes
Proceed with Commodity Flow Survey and synthetic data generation
Conduct high level industry data gathering.
Pursue Commodity Flow Survey.
Low industry data means lower value but lower cost options most suitable
Strong industry data response enables a higher accuracy and econometrics approach which is stronger for forecasting
Supply-Chain Flow Model is used to generate synthetic data
Proceed with Econometrics 'Four-Step' Style Approach
Baseline commodity flow data and forecast is offered to other agencies and local councils for more in-depth analysis and scenario modelling
Lower cost and lower value NFDS*
Commentary: A decision is made that the Ministry is an enabler not developer of NDFS insights. Option to develop insight model could be deferred.
A multipronged data gathering exercise is undertaken.
Strong response from industry in terms of data is ideal, however a low response would also reduce costs, not ideal but should be acknowledged.
Depending on establishing relationships between known commodity flows and other datasets either a synthetic data or econometrics approach can be taken.
The Ministry produces a baseline commodity flow dataset with no vehicle, mode, route assignment. This is for others to add.
The result is seen as low value as most of the NFDS objectives are dependent on actions from others. Ultimately this could be high value.

6.2.1 Pathway optimisation

Based on assessing these approach pathways and their higher performing attributes an option 'optimisation' process was undertaken which resulted in two distinct approach options being developed and recommended. These pathways are hybrid variants of pathway 1 and 3, and 2 and 4 respectively.

6.2.1.1 Pathway 1A: Best outcome & minimise CFS (Hybrid of 1 & 3)

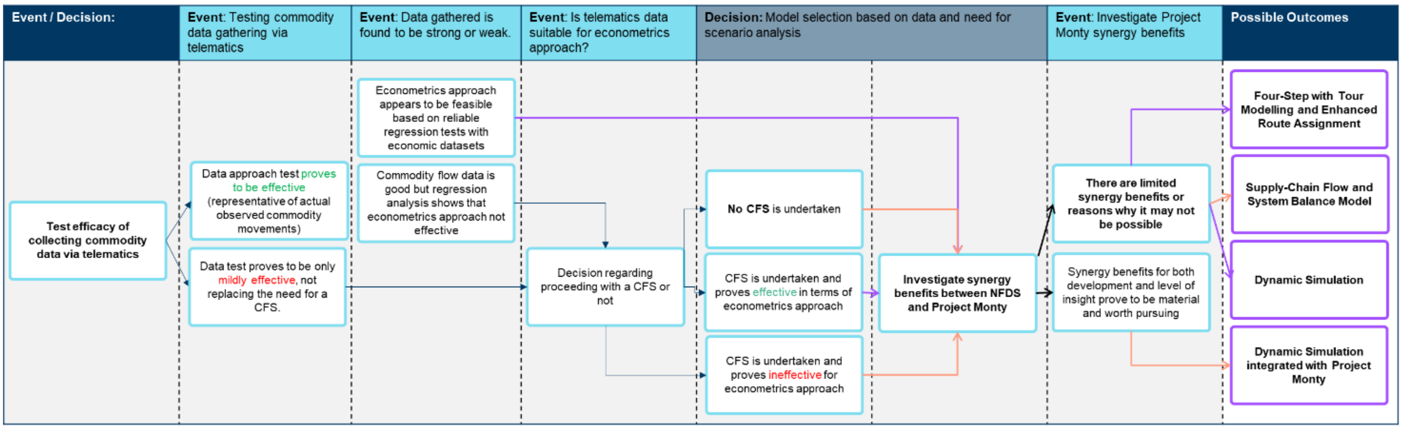


Figure 14: Recommended adaptive delivery pathway 1A

This option balances the prudent approach of pathway 1 where the decision regarding approach method is deferred until there are minimal unknowns and also the risk mitigating benefits of pathway 3 which strives ahead without a total reliance on the CFS. In this pathway the EROAD commodity attribution is tested and the CFS minimised to reflect residual data gaps.

6.2.1.2 Pathway 4A: Truncated enable and delegate (Hybrid of 2 & 4)

This pathway is a balance between the expediency of the forge ahead pathway and the practicality of the enable and delegate pathway. This pathway commits early to System Balancing as the most adaptive[15] modelling methodology and then makes data available for others to generate insight.

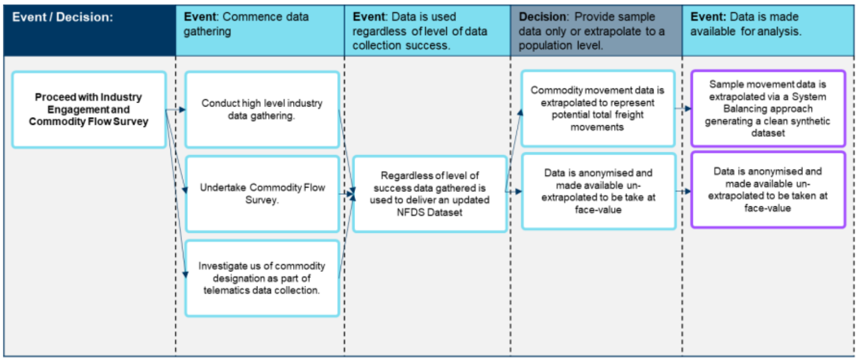


Figure 15: Expedited adaptive pathway recommendation 4A[16]

[15] Adaptive in the sense that System Balancing can be reflective of full system macro level flows early on and improve in accuracy and granularity as more data becomes available.
[16] Appendix D under 'System balancing as a means of CFS sample extrapolation' outlines how system balancing can be used as an effective means of scaling or extrapolating a CFS sample data into usable synthetic data more representative of system-wide movements.

6.3 Delivery approach for high-ranking options

6.3.1 High Level Scope Summary

For each of the high-ranking options a Scope of Works (SoW) has been developed which is of sufficient detail to describe the approach for the purposes of tendering the delivery or as a basis for approach design for internal delivery.

Below are scope summary diagrams to provide a high-level overview of the approach option and a detailed SoW for each option is included in Appendix D.

Through the options definition process it was identified that most options have the same foundation in terms of a commodity flow survey and an econometrics approach, similarly there is no variation in the options assessed with regard to forecasting methodology.

6.3.1.1 SoW: Commodity Flow Model with high level vehicle/mode flows

The commodity flow model option focusses on producing a commodity flow dataset and has limited modelling and scenario analysis capability.

Commodity Flow Survey (CFS)	Econometric Analysis	Extrapolate Commodity Sample to Population*	Forecasting	High level mode and vehicle flow	Results and Scenario Builder
The commodity flow survey gathers a sample of real freight movements, mode and vehicle type.	Econometrics uses regression analysis to establish mathematical relationships between the known movements gathered in the CFS. These relationships with land use data, production, consumption and import/export data are then used to extrapolate the CFS to a population* (next step) and are also used to be able to generate a proxy commodity flow data set in the future through changes in datasets for where there is an established statistical relationship.	Based on the previous step a nation-wide commodity flow can now be established. These flows are converted into probabilities which are used in the synthetic data generation phase. This sample is then extrapolated to an annual population sample using known seasonality profiles (such as export, import and production /consumption seasonality).	Forecasting uses economic and demographic data to inform commodity growth factors over time.	This stage would take the commodity flows and assigned high level OD pair related mode and vehicle numbers based on an average payload per vehicle and known rail volumes. Vehicle flows would be proportional high -level estimates and not route specific as no network assignment. Any detailed vehicle route assessments would have to occur outside of this option.	Scenario analysis is limited and would largely relate to changes in commodities and to changes in payload per vehicle and mode shares.

Figure 16: High Level Scope Diagram for Commodity Flow with High Level Mode and Vehicle Flows

*Population in this instance means statistical population.

6.3.1.2 SoW: Four-Step with Truck Tour Modelling and Enhanced Route Assignment

The enhanced four-step model is more granular in detail and is an established method. However, it is quite cumbersome with regard to scenario analysis as it can often require changes in base data and potentially time-consuming model re-runs.

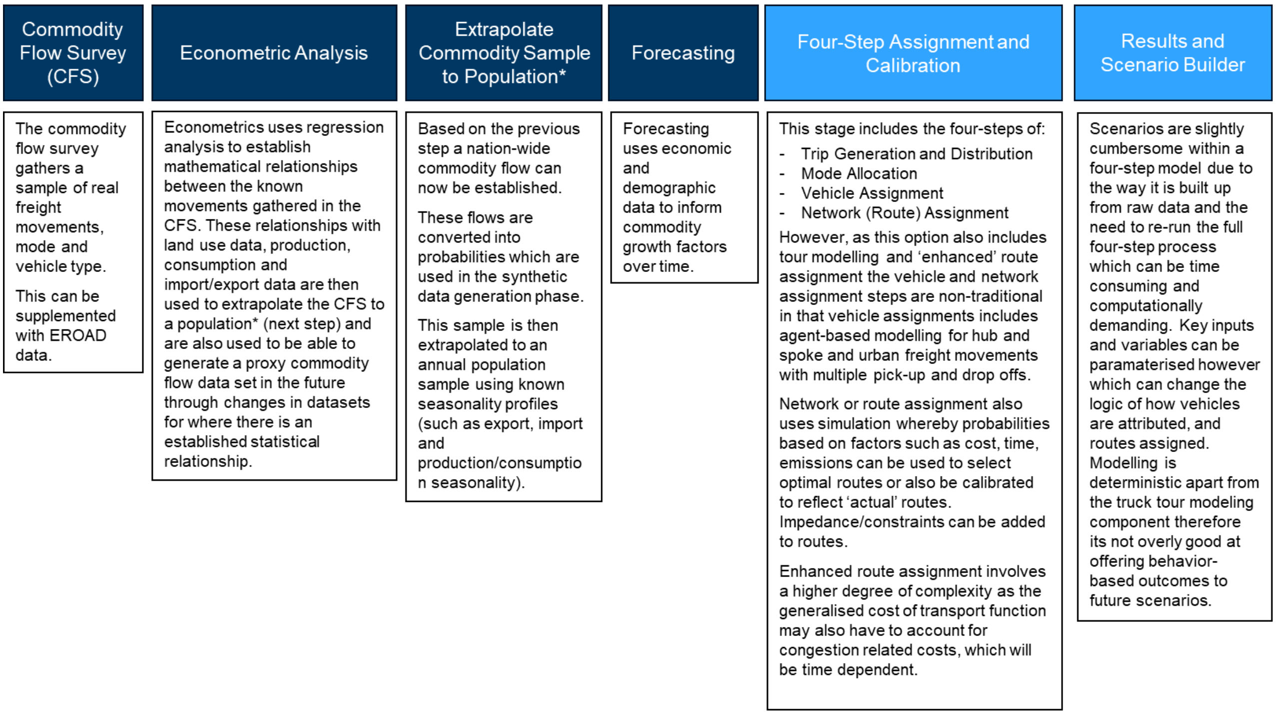


Figure 17: High Level Scope Diagram Four-Step with Truck Tour Modelling and Enhanced Route Assignment

6.3.1.3 SoW: Supply-Chain Model with System Balancing

This approach uses simulation in terms of stock and flow modelling and produces probability-based synthetic data which creates a very clean data set and is more conducive to scenario analysis.

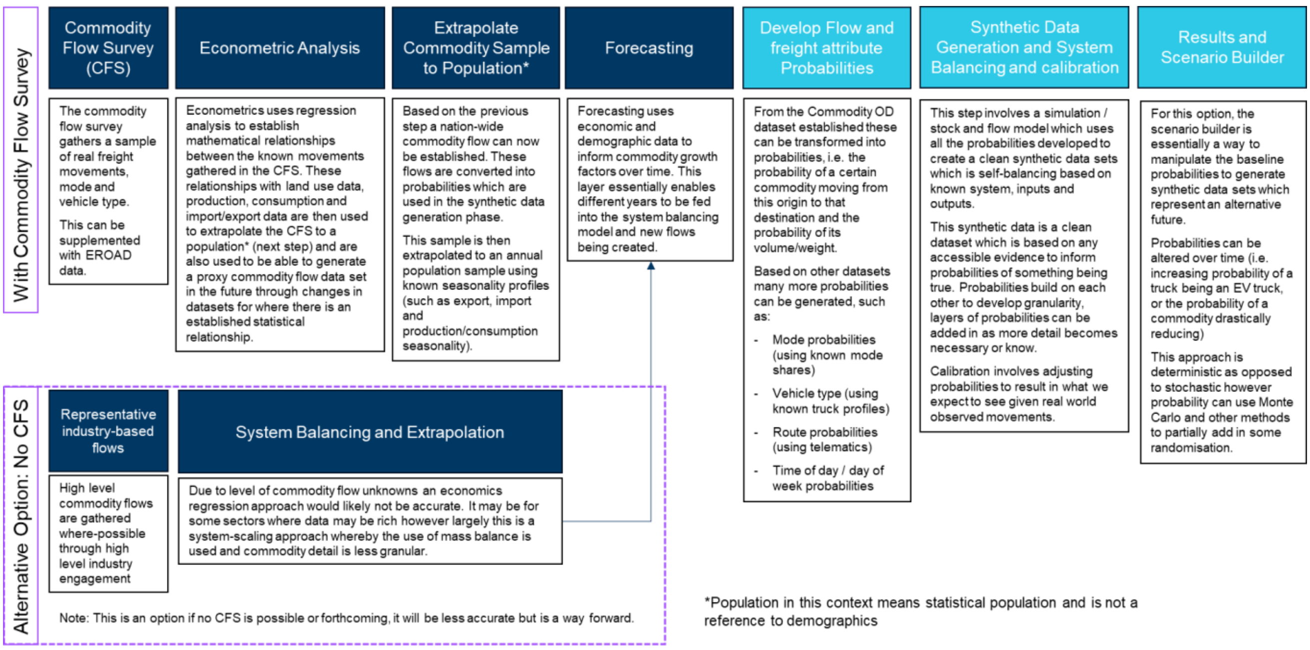


Figure 18: High Level Scope for Supply-Chain Model with System Balancing

6.3.1.4 SoW: Dynamic Simulation

Dynamic simulation is the most representative of the real world and is valuable in looking at how the system may behave in the future or with policy and economic changes however it takes more time to calibrate in order to reflect the current state. This method uses Discrete Event Simulation (DES) and Agent-based Modelling (ABM). This option could be developed in the Project Monty modelling environment and integrate with people movements creating a holistic movement model.

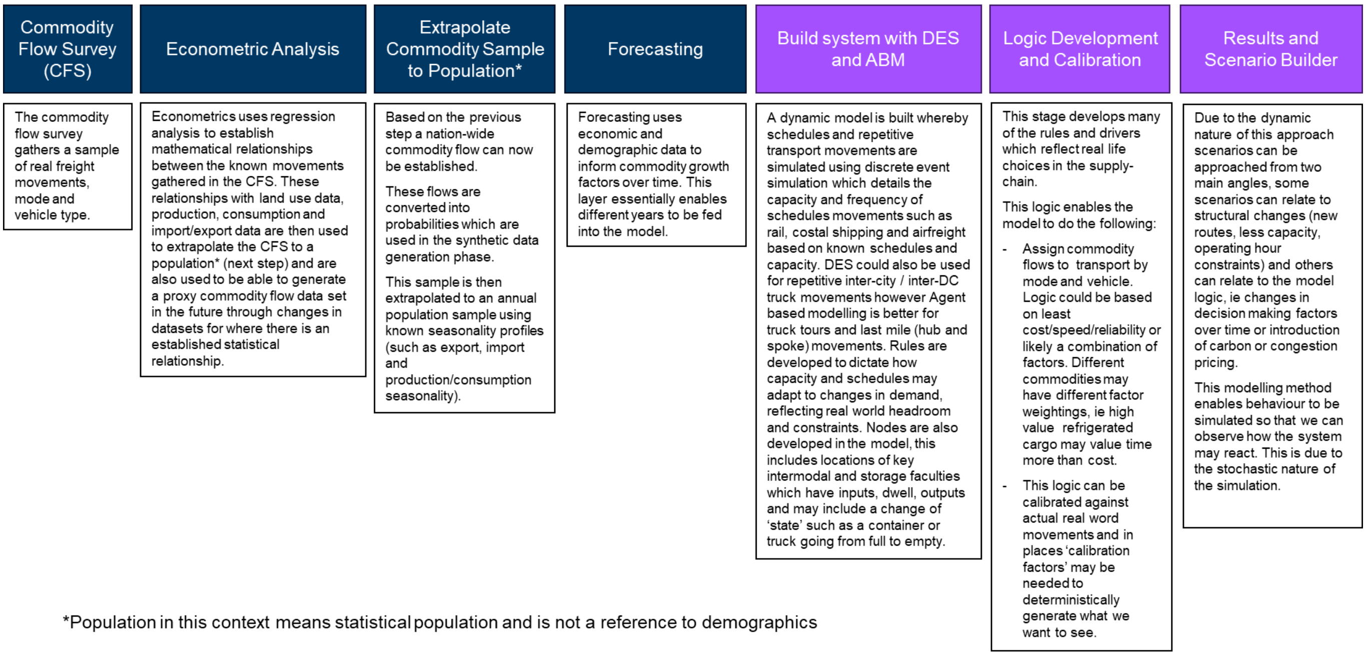


Figure 19: High level scope for Dynamic Simulation

6.4 Additional Delivery Considerations

6.4.1 Consideration of NFDS interoperability with Project Monty

An extensive agent-based model has been developed by the Ministry to understand the movement of people in New Zealand. At the time of writing this report limited information regarding Project Monty is known to the GHD team however it does appear that there may be a potentially co-beneficial relationship between the NFDS and Project Monty.

Currently, Project Monty uses EROAD data to represent HCV movements, which make up a small percentage of movements on the road network in the model. However, these movements are currently 'static', whereas agents making personal transport decisions in the model are autonomous.

If the NFDS were to be integrated into Project Monty, then this would need to be done in consideration of the Dynamic Simulation option. This option utilises both discrete event simulation and agent-based modelling and would be conducive with Project Monty for this reason. This is reflected in the Executive Summary.

Essentially the Dynamic Simulation option as outlined in this report would be built within the Project Monty modelling architecture. This would be a very powerful approach as a single model would represent all people and freight movements and the interrelationship between them. The challenge may be that the model may become slow and more complex, however good design can account for this. The approach would be particularly powerful with regard to road usage as both passenger and truck movements will be stochastically simulated and will be able to show observers the impact of impediments, policy changes and infrastructure improvements on both people and freight movement.

6.4.2 Evolution of approach over time

It is acknowledged that the scoping of the NFDS is not a single step, this is why we have identified objectives by horizon where possible. There are logical development pathways which avoid wholesale shifts in methodology and minimise and lost value or effort. Some development pathways are detailed below:

1. Evolution of a Commodity Flow Approach:
    a. Regional commodity flow
    b. Regional and intra-regional commodity flow
    c. Regional and intra-regional commodity flow with high level route and vehicle assignment
2. Evolution of Four-Step Model
    a. Traditional Four-Step Model
    b. Four-Step Model with Tour Modelling
    c. Four-Step Model with Tour Modelling and Dynamic Route Assignment
3. Evolution of Supply-Chain Models
    a. Supply-chain system balance.
    b. Supply-Chain Simulation
    c. Dynamic Simulation with DES and ABM
    d. Addition of System Dynamics
4. Evolution of Dynamic Simulation
    a. Dynamic Simulation with DES and ABM
    b. Addition of System Dynamics

6.4.2.1 Model growth over time

Not only can models evolve over time to incorporate added functionality but they can also grow over time. This is exemplified by the CSIRO TraNSIT Tool which started as a means of understanding the movement of live cattle and has been periodically expanded to include other commodities.

6.4.3 Procurement Methods

The way the NFDS is delivered, including what is procured vs what is completed by Government agencies does have a bearing on the cost.

6.4.3.1 Trade-off between delivering in-house and outsourcing

Through the technical stakeholder engagement, it is clear that most public sector participants prefer to develop their own data analytics and modelling functions within open-source platforms and not be beholden to subscription based software solutions. Generally, this is to do with developing institutional knowledge, potentially keeping costs down, and not being dependent on any external parties. However, there is anecdotal evidence that suggests that a model being exposed to only two of three individuals within a Government agency may represent greater risk exposure to relying on an external software provider. This is evidenced by the instances of models and approaches being abandoned or moth balled as key individuals have moved on.[17]

NFDS Insight:

Inhouse vs out-sourced delivery

It is true that institutional knowledge should be developed and maintained internally however when considering NFDS implementation options there is an element of risk related to both in-house and outsourced delivery. Outsources delivery risk relates to being contractually dependent on an external party to undertake services or make available software, however this risk is not necessarily more than internal individual subject-matter-expert risks.

[17] Specific instances were mentioned in confidence as part of technical stakeholder engagement.

Recommendations

Summary

7. Recommendations

The purpose of the Ministry seeking scope options to deliver an enhanced NFDS were not strictly to gain a third-party view on how the NFDS should proceed, therefore a recommended approach is offered only as a point of reference if useful.

1. GHD recommends that the need for a CFS is properly tested by progressing the only identified alternative which is gaining a transport operator-specific commodity designation via telematics aggregator EROAD. It is currently unknown whether this would be accurate or indeed possible, however an informed decision on how to proceed is not possible until this is investigated further. If this approach proves effective, then the 'No CFS' adaptive pathway could be followed. However, the project team believes that even if this method is effective, it likely would not replace the need for at least a highly tactical CFS.
2. If needed, a CFS can be administered by the Ministry and/or Statistics NZ. This may need to be a fully representative survey every 3 or so years, or it can be continuous via small randomised stratified samples or a combination thereof.
3. The top three ranked options are all high performing options which represent a significant step up in understanding current and future freight movements in New Zealand. It does appear that there is potential synergy between the NFDS and a major people movement model being developed under the name 'Project Monty'. Project Monty is a nationwide Agent-Based Model which may have a suitable modelling environment for the inclusion of the Dynamic Simulation option as defined in this report. The GHD team have no knowledge of the workings of Project Monty however it is suggested this option is assessed further.
4. If the commodity designation via telematics approach proves to be effective but not to the extent that a reliable econometrics approach is possible then this leaves either the Supply-Chain Simulation and System Balance approach or the Dynamic Simulation approach. If there are synergy benefits in terms of development and level of insight, then this would then preference the Dynamic Simulation approach. This recommended approach is detailed below.

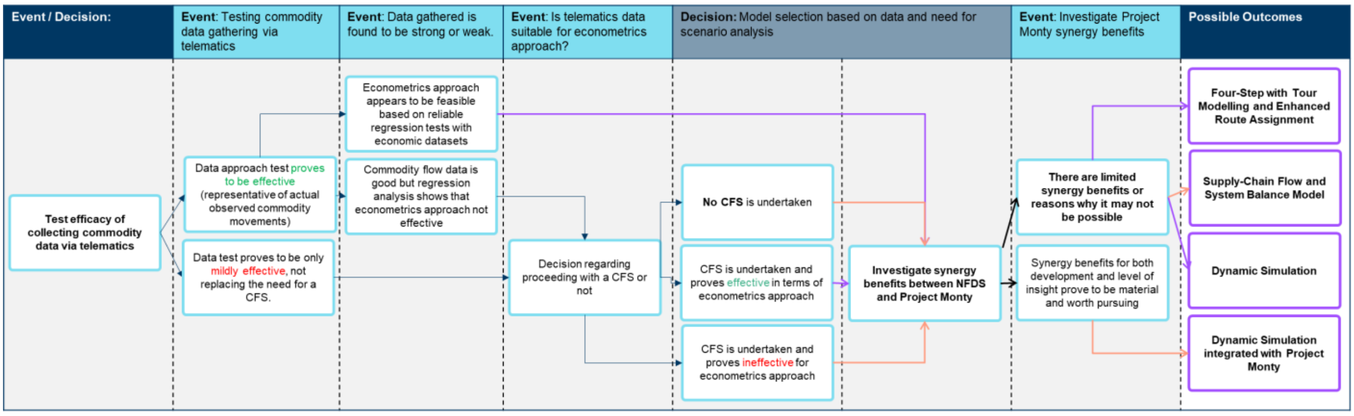


Figure 20: Recommended adaptive delivery pathway 1A

5. In developing recommended options based on pathways assessed it is recognised that there may also be a need to expedite results under an '*Enable and Delegate*' variant which would accelerate the delivery of up-to-date commodity flow data to inform more urgent needs. The below variant is also recommended by GHD if time is of the essence.
6. The role of delegates within the enable and delegate delivery model is important and the presence of these 'counterparties' needs to be considered in selecting this option.

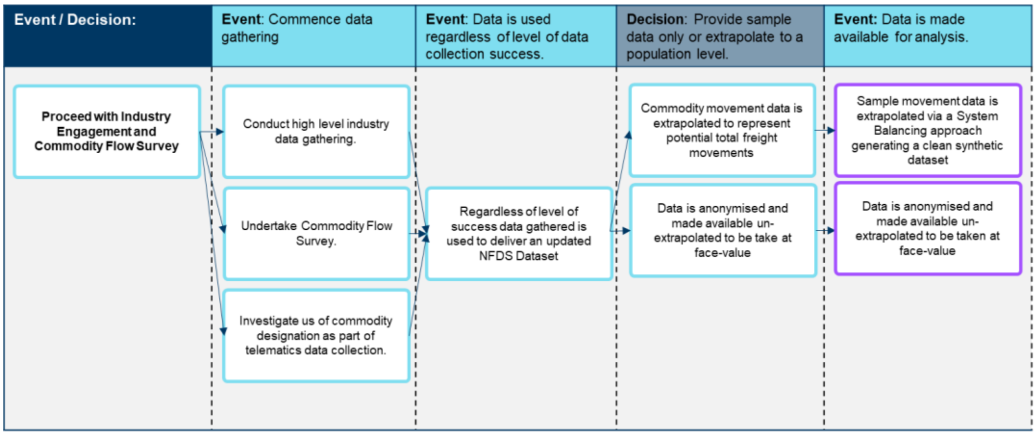


Figure 21: Expedited adaptive pathway recommendation 4A [18]

7. The above alternative does not preclude the ultimate delivery of the recommended option in Figure 20. In addition, it enables interoperability with Project Monty to be assessed in parallel to progressing with data gathering which is essential under any NFDS option.

[18] Appendix D under 'System balancing as a means of CFS sample extrapolation' outlines how system balancing can be used as an effective means of scaling or extrapolating a CFS sample data into usable synthetic data more representative of system-wide movements.

8. References

Note that references largely centred around the research paper and hence only key references have been repeated here

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Appendix A

Data Longlist

ID	Dataset	Description	Nature of data	Main function / part of system captured	New Zealand-context commentary	Exists in NZ?	Availability confirmed?	Owner	Owner Type	Short-listed
1	Road vehicle telematics	Data captured from in-cab GPS units. Most often used for fleet management purposes.	Active location data	Vehicle movement	As Road User Charges (RUC) for HCVs are based on distance, in-cab GPS units are common, sothere is a wealth of telematics data available. This data is provided by EROAD and captures ~ 40% of all HCV movements.	Yes	Yes	EROAD	Private	Yes
2	Connected vehicle / On-board computer data	On-board computers are becoming more prevalent in both passenger and commercial vehicles, this big data now generates billions of data points per day. Companies such as Compass IOT purchase this data from the vehicle manufacturers, and through the use of machine learning techniques, are able to process this data into meaningful insights for heavy commercial vehicles.	Passive location data	Vehicle movement	This is an emerging data set in NZ and is provided by Compass IOT. Compass data is being used as a data input for freight models currently being developed in Australia.	Yes	No	Compass IOT	Private	Yes
3	App-based GPS data	An anonymised, aggregated data set capturing the Location-Based Services data from mobile device users. Data aggregators purchase this data from app publishers and on-sell. The data has a high-level resolution but lower sample size. Commercial vehicles can be imputed from the data based on the profile of their movements, in terms of speeds and distance of travel, and types of locations visited.	Passive location data	Vehicle movement	Most GPS data providers operate globally and hence data is available in NZ. The data is very cheap but requires processing and there is inherent uncertainty around the accuracy of capturing freight vehicles given it is a device connected to a person not a vehicle.	Yes	Yes	Various	Private	No
4	Mobile network data (MND)	MND provides the movement of a person based on the triangulation of their position as they move and connect to cell towers. Details of movement is less granular than the coordinate level GPS data. However, sample size can be much greater, provided it reflects the market-share of the mobile network operator providing the data (can represent up to 35% of a population in some cases). There is precedent for using MND to build a freight model through observing known freight movement characteristics in the data.	Passive location data	Vehicle movement	This type of data is provided by Qrious in NZ, a data science arm of Spark. The data is relatively expensive. It has been used by Highways England to capture freight vehicle movements with some success.	Yes	Yes	Qrious	Private	No
5	Land-use classification data	Spatial data layer, which is a digital representation of how land is being used.	GIS	Commodity production	Available in NZ via Land Research Information Systems (LRIS). This dataset has 22 land-use classifications such as 'High Producing Exotic Grassland'. The database is updated every 5 years, with the last update occurring in December 2019.	Yes	Yes	LRIS	Public	Yes
6	Structures data	Spatial data layer representing building footprints. Can be used to approximate the volume of production of a business.	GIS	Commodity production, Commodity consumption	This data was last updated by LINZ in 2019. The data has an incomplete 'use' field so would need to be combined with other data sets to understand whether building is part of freight system. This could be complex.	Yes	Yes	LINZ	Public	No
7	Points-of-Interest (POI) data	Coordinate-level location data, indicating a type of location.	GIS	Network elements	The Openstreetmap data set (open source) does include some freight asset locations - such as ports, processing facilities, intermodal hubs etc. However, this cannot be relied upon to be complete. Google Places API can also be used here.	Yes	Yes	Openstreetmap	Open-source	Yes
8	Road network	A spatial data layer representing the road network. A necessary component of any freight model that strives to show volumes of movement on a road network level.	GIS	Network elements	Openstreetmap data is available in NZ. May require some fixes to be fit-for-purpose for a network routing tool such as would be required for a freight model.	Yes	Yes	Openstreetmap	Open-source	Yes
	Overweight and over-dimension routes	A spatial data layer representing the parts of the network that are designated for overweight and overdimension routes.	GIS	Network elements	Available via Waka Kotahi NZTA	Yes	Yes	NZTA	Public	Yes
9	Zoning System	A zoning system is used to geographically divide up parts of a country or region. These can vary in size depending on the use case and compatibility with other data sets.	GIS	Zone System	In New Zealand, the Statistical Area 2 (SA2) is a commonly used geography for higher resolution data analysis and modelling.	Yes	Yes	Statistics New Zealand / LINZ	Public	Yes
10	Weigh-in-Motion	These are on-road sites that capture the weights of vehicles as they are moving alongside their license plate. They are designed to monitor overloaded vehicles.	Administrative data	Validation	Weigh-in-Motion sites are currently limited in NZ. There are plans to roll out more but this has an uncertain timeframe.	Yes	No	NZTA	Public	Yes

ID	Dataset	Description	Nature of data	Main function / part of system captured	New Zealand-context commentary	Exists in NZ?	Availability confirmed?	Owner	Owner Type	Short-listed
11	Traffic counts (at location)	Data derived from physical counting technologies placed on or beside the road such as loop counts or bluetooth counters. These are most often used to calibrate and/or validate freight models.	Administrative data	Validation	In New Zealand, these are provided by Waka Kotahi as Annual Average Daily Trips (AADT) which has a split between passenger and freight vehicles. There is a comprehensive network of counters throughout the country.	Yes	Yes	NZTA	Public	Yes
12	Vehicle registration data	Administrative data capturing vehicle registration data.	Administrative data	Vehicle movement	This can also be referred to as Safety Inspection Data, it is available, but requires the signature of an agreement. It is currently used by the Vehicle Emissions Prediction Model (VEPM) Vehicle emissions prediction model | NZ Transport Agency Waka Kotahi (nzta.govt.nz).	Yes	No	NZTA	Public	No
13	Private container tracking data	Data provided by private companies with access to ports scheduling, booking and operations systems. Data is used in operations and/or aggregated and on-sold.	Active location data	Import/Export, Commodity movement	In New Zealand, PortConnect provides aggregated data capturing > 85% of all commodity movements in and out of ports (by tonnage). This data does not have pack/unpack locations, and currently does not have some ports such as Wellington's Centreport.	Yes	Yes	PortConnect / Swire	Private	Yes
14	Public container tracking data	Administrative data provided to government relating to the import and export of goods at the container level.	Active location data	Import/Export, Commodity movement	In NZ, this data is published by the Ministry of Transport. It does not include pack/unpack locations. There is an outstanding question if pack/unpack location is available via Customs Services.	Yes	Yes	FIGS	Public	Yes
15	Population statistics - residential	Census statistics capturing the number of people residing in a location and their demographic profile. This can be an important data set for understanding the consumption of commodities and the distribution of trips.	Statistics	Commodity consumption	Provided at a high resolution for New Zealand. Most recent version published in May 2024.	Yes	Yes	Statistics New Zealand	Public	Yes
16	Population statistics - employment	Census statistics capturing the number of people working in a location and their type of employment. This data is sometimes used to infer the production of commodities and the generation of trips.	Statistics	Commodity production	As above.	Yes	Yes	Statistics New Zealand	Public	Yes
17	Economic statistics - establishment data	Number of businesses by location/zone, type and number of employees. This data is sometimes used to infer the production of commodities and the generation of trips.	Statistics	Commodity production	This is known as the 'Business Demographics' and is provided by Statistics NZ. Data is available down to the SA2 level (and possibly lower for certain purposes).	Yes	Yes	Statistics New Zealand	Public	Yes
18	Economic indicator statistics	High level economic data demonstrating productivity and other trends across an economy. This is commonly used when building forecasts.	Statistics	Forecasting	There is a wealth of statistics published by Statistics New Zealand and private organisations such as banks and economics consultancies.	Yes	Yes	Statistics New Zealand, banks and private consultancies	Public	Yes
19	Customs data	Detailed administrative data capturing the entry/exit of goods across national borders.	Administrative data	Import/Export	Awaiting response from Customs on availability of pack/unpack locations data.	Yes	No	Customs Service	Public	Yes
20	Industry-specific business administrative data	Data that is captured via administrative processes that are specific to an industry. Such as catch size for fisheries or animal-tracing for livestock.	Administrative data	Commodity production	There are some datasets that were used in the previous NFDS such as National Animal Identification and Tracing Scheme (NAIT) data.	Yes	No	Various	Private	Yes
21	Commodity Flow Survey	A survey undertaken to capture information relating to the production and movement of commodities to, from and within a country or state. CFS data is a critical input to a majority of freight models.	Survey	Commodity movement	A CFS has never been published in NZ. Stats NZ has previously undertaken the Commodity Data Collection Survey, which was far more detailed than the CFSs used in other jurisdictions and did not capture information relating to the movement of goods.	No	-	-	-	Yes
25	Trip diary	A trip diary survey develops a profile of trip types generated by the business – distance travelled, routes taken, number of stops, activity (loading, unloading), time of day etc. It often requires cumbersome manual data entry by participants, and could largely be replaced by GPS trace data from telematics or other means.	Survey	Vehicle movement, Commodity movement	Reasonably expensive to execute and unprecedented in NZ.	No	-	-	-	No

ID	Dataset	Description	Nature of data	Main function / part of system captured	New Zealand-context commentary	Exists in NZ?	Availability confirmed?	Owner	Owner Type	Short-listed
26	Establishment-based Freight Survey	The purpose of an establishment-based freight survey (EBFS) is to provide a profile of a business that generates commodity flows and commercial vehicle movements in the urban context. The EBFS can be viewed as the business counterpart to the residential-focussed Household Travel Survey – requesting detailed information relating to urban freight activities - types of commodities shipped, fleet size etc.	Survey	Vehicle movement, Commodity movement	Reasonably expensive to execute and unprecedented in NZ. Data from one establishment can be applied to others of the same industry but would need multiple to capture different sectors. Should largely focus on distribution centres.	No	-	-	-	Yes
27	Roadside Survey	These surveys are in-person interviews with truck drivers.	Survey	Vehicle movement, Commodity movement	Reasonably expensive to execute and unprecedented in NZ. Outdated with the introduction of other emerging data such as telematics and GPS traces.	No	-	-	-	No
28	Business Survey	Large-scale surveys to capture business data.	Survey	Commodity production	The Agricultural Survey and Business Register Update survey are available in NZ. These both hold valuable information about the value, size and location of businesses.	Yes	Yes - granularity is not known.	Statistics New Zealand	Public	Yes
29	Rail movement	Administrative data from rail operators.	Administrative data	Commodity movement	Forms a key part of the freight flow system in NZ. The scale and availability of data is yet to be confirmed.	Yes	Yes - granularity is not known.	KiwiRail[19]	Public/Private	Yes
30	Air movement	Administrative data from air-freight operators.	Administrative data	Commodity movement	Forms only a small part of freight flow system but can represent items of high value.	?	No	Air NZ, air freight companies such as NZ Post and DHL.	Private	Yes
31	Coastal shipping movement	Administrative data from domestic shipping operators.	Administrative data	Commodity movement	Forms only a small part of freight flow system.	?	No	?	Private	Yes

[19] KiwiRail (arcgis.com)

Appendix B

Evaluation of Options – Additional Detail

Determining evaluation criteria

Drawing from the objectives determined as part of the objectives-setting stage, an initial set of evaluation criteria were identified which attempted to encompass the objectives. Table 17 below demonstrates how the evaluation criteria were mapped across from and relate to the Objectives. Broadly the short-term horizon (1) includes the next NFDS iteration and the medium- and long-term subsequent iterations over the course of perhaps 5-10 years (2 and 3).

These initial evaluation criteria were then discussed with the Working Group, with a separate memo '*NFDS Evaluation Criteria – Additional Detail*' also provided at the time.

Table 17: Aligning objectives with option evaluation measures / criteria

Objective		Horizon 1	Horizon 2	Horizon 3	Measure/Criteria
01 Inform investment decision making	Improved data reliability and validity	●			Accuracy and Reliability
	Assess and understand productivity / service levels		●		Ability to identify increased efficiency opportunities
	Understand mode share	●			Value of sector-based productivity insights
	Consideration of supply-chain costs	○—	—●		Ability to identify increased efficiency opportunities
	Consideration of economic value	○—	—●		Value of Sector Productivity Insights
	Network capacity considerations			●	Network performance and capacity
	Bottleneck identification	●			Network performance and capacity
	More detailed and updatable forecasting		○		Repeatable and up-to-date
	Extract data for business cases		○		Interoperable with other processes and functions
	Extract data for Project Monty		○		Interoperable with other processes and functions
	System performance monitoring	●			Network performance and capacity
02 Increase usability and reliability (granular and validated)	Include intra-regional freight movements.	●			Enable urban freight insights
	Include last mile and urban freight movements	●			Enable urban freight insights
	Reliable and more granular commodity data	●			Accuracy and Reliability
	Baseline Data validation and calibration processes	●			Accuracy and Reliability
	Disaggregate vehicle sizes and types	●			Value of sector-based productivity insights
	Regular validation and calibration	●			Accuracy and Reliability
	Identify intermodal opportunities	○—	—●		Ability to identify increased efficiency opportunities
	Enable some form of 'optimisation' (service levels/cost)		○		Network performance and capacity
03 Enable supply-chain resilience outcomes	Ability to delineate between critical and non-critical freight	●			Enable Resilience insights / outcomes
	Enable identification of critical freight concentration risk	○—	—●		
	Enable route and mode concentration risk identification	○—	—●		
	Non-domestic IMEX supply-chain resilience		○—	—●	
	Generate lead indicators for resilience risks	○—	—●		
	Scenario modelling to test resilience and response	○			
	Market competition assessment - service provider concentration		○—	—●	
04 Support decarbonisation outcomes	Consider data requirements for decarbonisation objectives.	○			Enable decarbonisation insights / outcomes
	Data to produce emissions calculations.	○			
	Data to identify energy infrastructure and fleet transition plans	○			
	Calculate current and forecast emissions	○—	—●		
	Identify circular economy opportunities		○		
05 Inform policy decisions	Consider data needs for regulatory impact assessments		○		Interoperable with other processes and functions
	Include spatial data to inform regional policy impact	●			Ability to identify increased efficiency opportunities
	Forecasting to identify future challenges which may need a policy response		●		Network performance and capacity
	Potential to support One Network Framework assessments	○			Interoperable with other processes and functions
	Inform economic productivity indicators	○—	—●		Network performance and capacity
	Assess policy impact on future freight flows, vehicle types etc		○—	—●	Ability to identify increased efficiency opportunities
06 Increase value to private sector and study participation	Transparent and equitable data governance	●			Minimise impost on industry
	Inform private sector investment via useful forecasts	●			Value of sector-based productivity insights
	Foster reciprocal arrangements - trading insight for data	●			Minimise impost on industry
	Consider different data gathering imperatives (mandate/incentivise/voluntary)	●			Delivery Risk
	Automate or semi-automate data capture/provision		○—	—●	Minimise impost on industry
	Identify backloading opportunities (identify empty running)		○—	—●	Ability to identify increased efficiency opportunities

● Core requirement ○ Adjacent (nice to have) ○——● Evolving requirement

Based on the aligning of objectives with evaluation categories, and as confirmed with the Ministry Working Group, the criteria and groupings outlined in Table 18 were finalised.

Table 18: Evaluation Criteria and description

Criteria Grouping		
Dependability	Accuracy and Reliability	The extent to which the outputs are accurate and reliable, with consideration of how much observed data is incorporated.
	Repeatable and up to date	The extent to which the model can be updated with relative ease, with consideration of how this impacts the ability to update more frequently.
	Future-proof approach / scalable and adaptable	The extent to which the option can be adapted in the future, should there be a change in direction or a need for significant improvement.
	Interoperable with other processes and functions	The extent to which the model and its outputs are able to operate with or alongside existing processes and functions, such as Project Monty.
Improved Policy and Investment Decision Making (Public and Private Sector)	Value of sector-based productivity insights	The extent to which the selected option delivers the detail required to provide meaningful productivity insights across different sectors. This is largely a function of the level of granularity provided for different commodities and modes.
	Network performance and capacity	The extent to which the option provides insights into the performance of transport infrastructure such as road network and ports. Those options that consider travel time and costs would score higher.
	Enable urban freight insights	Consideration of whether the option can show intra-regional/urban movements or is future-proofed to do so.
	Enable Resilience insights / outcomes	The extent to which the option can show resilience-related insights such as bottlenecks, alternative routing options etc.
	Enable decarbonisation insights / outcomes	The extent to which the model can produce direct or indirect outputs which can be used to demonstrate decarbonisation opportunities such as an EV fleet scenario or optimisation scenario.
	Ability to identify increased efficiency opportunities	The extent to which the option provides direct or indirect opportunities for supply-chain efficiency gains.
Cost & Complexity	Establishment Costs	The up-front cost to establish the NFDS including the initial design and implementation of data collection.
	Ongoing Costs	The costs associated with the up keep of delivery including addition of new data, running scenarios and re-baselining (if required).

Criteria Grouping		
	Delivery Risk	The risk of an unsuccessful delivery process. This largely relates to the complexity of the option and the available capacity to deliver in the NZ context.
	Minimise impost on industry	The extent to which the option requires input from industry and whether this impost can be minimised for the establishment period and/or over time.

Pairwise Assessment

Following on from the confirmation of the evaluation criteria, it was requested that the Working Group undertake a pairwise assessment as a method to provide a weighting value to each of the criteria. A pairwise assessment requires the assessor to compare the relative importance of each criteria against each other criteria. The assessor determines a score from 1-5 of relative importance (from 'Much Less Important' to 'Much More Important' using a matrix table, an example of which is provided in Figure 22 below. In this example, 'Accuracy and Reliability' is considered by the assessor to be 'More Important' (score=4) than the 'Repeatable and up-to-date' criteria, and 'Repeatable and up-to-date' was considered to be equally important (score=3) to 'Interoperable with other processes and functions'

Criteria	Accuracy and Reliability	Repeatable and up-to-date	Future-proof approach / scalable and adaptable	Interoperable with other processes and functions	Value of sector based productivity insights
Accuracy and Reliability	0	4	4	4	4
Repeatable and up-to-date	2	0	4	3	3
Future-proof approach / scalable and adaptable	2	2	0	2	3

Figure 22: Excerpt from a Pairwise Assessment matrix

Pairwise assessment results

The pairwise assessment results are shown in Figure 23 and Figure 24. These charts demonstrate that, for the most part, the extent to which the assessors valued the different criteria was relatively consistent, and that when averaged, the weighting across the criteria is relatively consistent with a few highly rated and lower rated criteria.

Each of the lines in Figure 23 represent an assessor and the weighted value of each criteria resulting from their pairwise assessment. The chart shows that the upper and lower bounds of weighting do not demonstrate a great deal of variability, i.e. there was not a great deal of divergent opinions among the assessors. Exceptions to this include the categories: 'Repeatable and up-to-date', 'Network performance and capacity' and 'Ability to identify increased efficiency opportunities'.

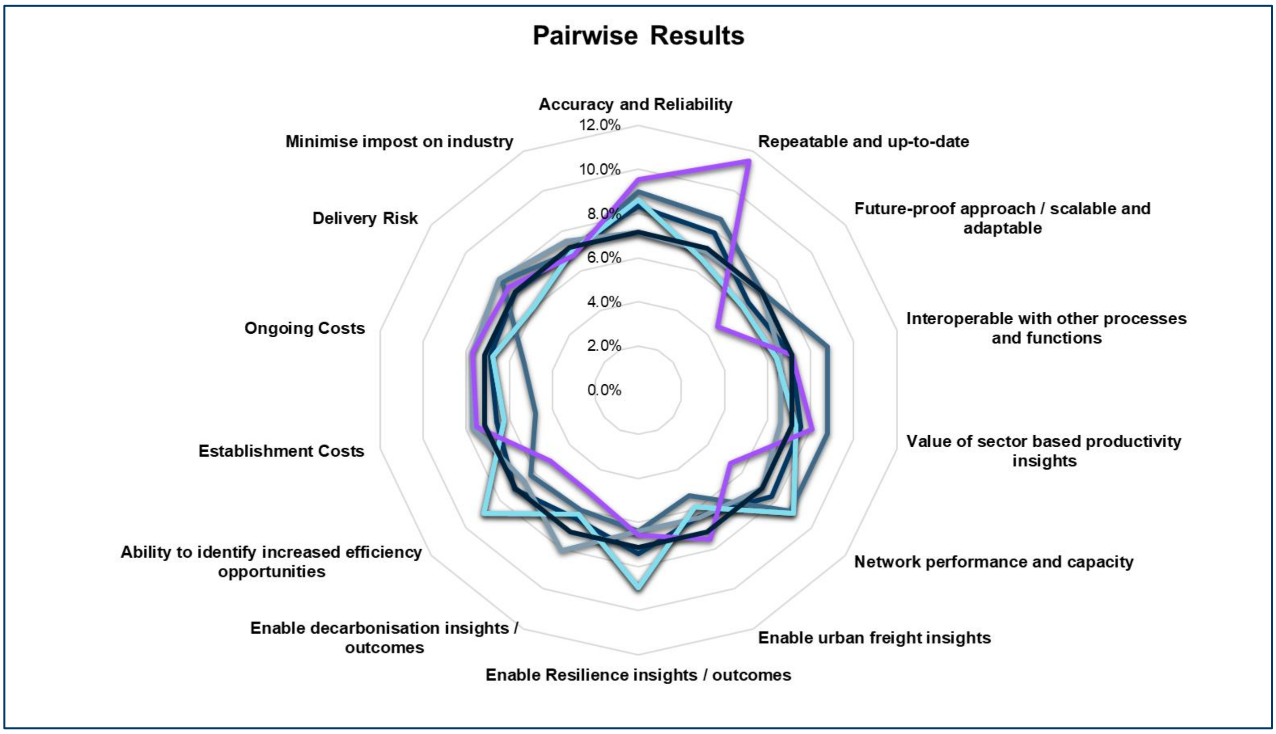


Figure 23: Pairwise assessment results

Figure 24 below demonstrates that, when averaged, the weightings were largely consistent across the criteria. Criteria that were considered the most important by the assessors were ‘Accuracy and Reliability’ and ‘Repeatable and up-to-date’. Criteria that were considered the least important were ‘Future-proof approach / scalable and adaptable’, ‘Enable decarbonisation insights / outcomes’ and ‘Enable urban freight insights’.

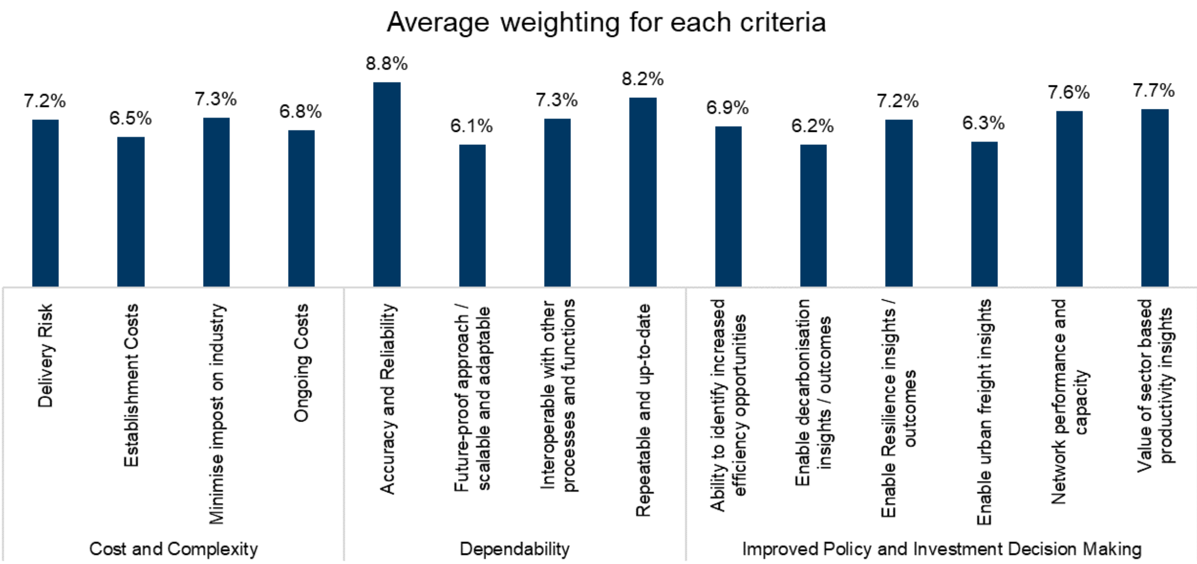


Figure 24: Average weighting across each participant for each assessment criteria

Option evaluation scoring

As a separate exercise from the weighting, scoring of each delivery option against the evaluation criteria was undertaken. Ten options were scored using a 10-point scale (from ‘Significantly negative’ to ‘Significantly positive’).

The ‘System Dynamics’ delivery option was dropped as it was determined to be an unrealistic option due to the high delivery risk associated, as there is very little research that has been done in using this modelling concept for freight demand.

The MCA spreadsheet has been provided as an attachment with this report. The results of the MCA are discussed in the following section.

Options evaluation results

Following the Pairwise assessment each of the updated NFDS options were scored against the evaluation criteria. The results are demonstrated in Figure 13 below, and the workings to develop these scores are available in the MCA spreadsheet provided as an attachment to this report. Figure 13 shows each option’s score by the criteria category (Cost and Complexity, Improved Policy and Investment Decision Making, Dependability) and grouped into the option typology.

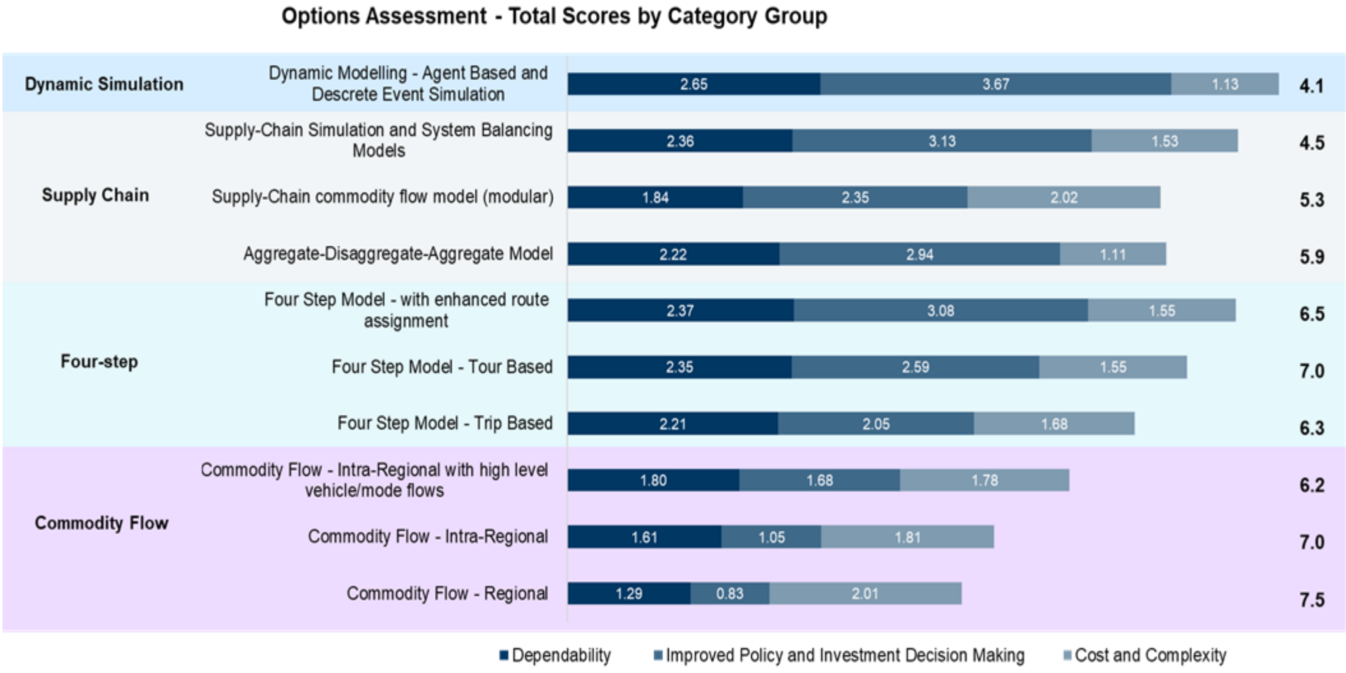


Figure 25: Total scores for the Options Assessment (including weighting)

Based on the highest-scoring option from each modelling typology approach, the following options have been selected as potential approaches to update the NFDS:

– Commodity Flow - Intra-Regional with high level vehicle/mode flows
– Four Step Model – with enhanced route assignment
– Supply-Chain Simulation and System Balancing Models
– Dynamic Simulation – Agent Based and Discrete Event Simulation

A summary of the strengths and limitations of each of these high-performing options is outlined in the MCA Scoring table below.

Table 19: Detailed MCA Scoring Table: Strengths and limitations of each of these high-performing options

Group	Criteria	Meaning / Interpretation of Options
NFDS Dependability	Accuracy and Reliability	-Does the option offer ways to test and provide evidence of accuracy? -Does the option incorporate observed movement data? -Does the method include outputs which are representative of total freight movements?
	Repeatable and up-to-date	-Does the option allow for updates with relative ease? -Does the option allow for consistency in re-baselining? -Is there potential for frequent or incremental updates? I.e. annually.
	Future-proof approach/scalable and adaptable	-Is it possible for the option to increase in functionality, accuracy and depth over time? -Does the option scale without significant shifts in approach? -Does the option allow for changes in emphasis in the future?
	Interoperable with other processes and functions	-Is there evidence that this option would provide useful input to other processes and functions? Such as business cases, de-bottlenecking exercises, options analysis, traffic impact assessment, congestion reduction assessments etc. -This also speaks to the detail/granularity available. Options which are able to offer urban freight and last mile visibility, or capable of running scenario analysis.
Improved Policy and Investment Decision Making (Public and Private Sector)	Value of sector based productivity insights	-Does the option appear to have good coverage of commodity classes? I.e. is there a clear path to obtaining commodity flow information and updating it over time?-Does the option cover all modes: air, sea, road and rail? -In terms of productivity insights, does the option provide vehicle movement information? I.e. beyond tonnage or volume of commodities. Is it possible to see how full trucks are, does it utilise weight-in-motion (WIM) data or road user charging (RUC) and/or telematics (ie EROAD) data to provide vehicle utilisation insights. -Is there any evidence that suggests the option would be able to utilise courier delivery data for small parcels?
	Network performance and capacity	-Does the option appear to provide insights into how transport infrastructure is performing? I.e. road, rail and ports. -Is the route assignment logic based on actuals or is it theoretical based on 'best route'? -Is there a trip or tour time component? where different travel times are based on time of day and network performance (level of service). -Would the option allow for the quantification of costs related to congestion? -Would the option allow for identifying more productive or less impactful (emitting) modes or routes?
	Enable urban freight insights	-Does the option include intra-regional movements? -Does the option include methods to capture data on urban freight movements? -Does the option include tour modelling, or agent-based modelling? This would enable a more accurate picture of urban freight movements. -If the option does not include urban movements, is there the possibility that it could in the future, or would this represent a wholesale shift in the approach?
	Enable Resilience insights / outcomes	- Does this option enable the segmentation of different commodity types and - Is the option capable of identifying bottlenecks, whether they be a lack of routes, modes, or service providers? -Does the option appear capable of running disruption scenarios? Ie close routes or modes and observe what happens? -Is the option capable of providing outputs which could enable the calculation of disruption costs and impacts? -Is the option capable of assessing intervention measures, ie enable cargo re-routing and provide capacity-based insights? -Is the option capable of considering resilience factors unique to New Zealand such as the Cook Strait crossing?
	Enable decarbonisation insights / outcomes	-Would the option enable the running of fleet transition scenarios? I.e. would it enable ICE vehicles to be supplanted with EV's and for reductions to be quantified? -Does the option enable specific vehicle and route attribution based on actual vehicle and route used or is it theoretical of and abstraction (hybrid of actual and theoretical)? -Does the option enable movement 'optimisation' ie it may be capable of generating insights which may enable the movement of the same or more freight with less emissions? -Does the option represent all freight movements nationally or is it modular (sector specific and non-exhaustive) or flow based?
	Ability to identify increased efficiency opportunities	-Does the option either directly or indirectly create the opportunity for supply-chain efficiency options to be generated? Specifically, this would mean that in addition to productivity KPI's there is able ability to run scenarios which would look at alternative supply-chains, i.e. the impact of new intermodal terminals, mode shift or new freight corridors. -This may also include the ability to look at the impact of using higher-productivity freight vehicles or moving more freight at off-peak times.

Criteria	Commodity Flow - Regional		Commodity Flow - Intra-Regional		Commodity Flow - Intra-Regional with high level vehicle/mode flows	
Accuracy and Reliability	• Commodity flows between regions could be produced quite accurately. • High accuracy for commodity flows between regions. Reliable when at a high-level and aggregated but may lose accuracy when disaggregated	7	•High accuracy for commodity flows between regions. Reliable when at a high-level and aggregated but may lose accuracy when disaggregated • Reliable flows when at a high-level and aggregated but may lose accuracy when disaggregated	7	• Introducing a high level vehicle and mode flow within regional and intra-regional commodity flows may be inaccurate e or reliable without route assignment.	5
Repeatable and up-to-date	• Regional commodity flows would still rely on industry data gathering and therefore not seen as easier than other options to update. • A simple flow model would be less up-to-date as it does not use econometrics and other input data sets (production,consumption,land-use etc). These data sets can provide a proxy for updates between commodity flow surveys	4	• Intra-regional commodity flows would still rely on industry data gathering and therefore not seen as easier than other options to update. • A simple flow model would be less up-to-date as it does not use econometrics and other input data sets (production,consumption,land-use etc). These data sets can provide a proxy for updates between commodity flow surveys	4	• Similar to commodity flow options but mode and vehicle estimates could be recalibrated more often than by using traffic counts and telematics versus commodity flow updates	6
Future-proof approach/scalable and adaptable	• This approach is minimal and likely would not be delivered in a way which Is scalable. • Data is not granular so not a lot of expansion options without increased data.	2	• This option can have common aspects to 4-step modelling • This option could be delivered in a way which is scalable . It has a good basis in terms of data from which to extend,	6	• This option can have common aspects to 4-step modelling and also basic simulation. • This option could be delivered in a way which is scalable and it has a good basis in terms of data from which to extend,	7
Interoperable with other processes and functions	• This approach would not provide much value in its own right, additional analysis and disaggregation would be needed	3	• This approach would be more valuable for regional business cases and infrastructure improvements, additional analysis and disaggregation would be needed.	4	• Only minor improvement compared to more basic commodity flow. •Having the addition of intra regional vehicle flows may help better inform investment decisions compared to the lack of truck or mode movement data.	6
Value of sector based productivity insights	• Commodities could enable sectoral insights but not when it comes to productivity	2	• Commodities could enable sectoral insights but not when it comes to productivity	3	• This option does not include much usable detail to assess or understand productivity.	4
Network performance and capacity	Flows alone would not enable this	2	Flows alone would not enable this but a slight improvement on regional only	3	Flows alone would not enable this but a slight improvement on regional only	4
Enable urban freight insights	Limited	2	Intra-regional would assist in understand ing urban freight but the insights would need to be generated elsewhere	3	Intra-regional would assist in understand ing urban freight but the insights would need to be generated elsewhere	3
Enable Resilience insights / outcomes	Flows not at a vehicle or PCU level so not within significant additional data and effort	2	- Flows are not at a vehicle or passenger car level, so resilience insights cannot be known without significant additional data	2	- Flows are not at a vehicle or passenger car level, so resilience insights cannot be known without significant additional data	4
Enable decarbonisation insights / outcomes	Flows not at a vehicle or PCU level so not within significant additional data and effort	2	Flows not at a vehicle or PCU level so not within significant additional data and effort	2	Vehicle numbers may be suitable for calculating total emissions and emissions at a regional level.	5
Ability to identify increased efficiency opportunities	Not enough information to assess efficiency	2	Not enough information to assess efficiency	2	Flows are not granular enough to speak to efficiency as only high level vehicle numbers, ie no backloading insights, time of day or utilisation.	4

Criteria	Four Step Model - Trip Based		Four Step Model - Tour Based		Four Step Model - with enhanced route assignment	
Accuracy and Reliability	• Four step models are an established industry standard and there are ways to test accuracy and also guidelines regarding model validation • Trip modelling is known to lack accuracy in comparison to tour modelling, as it can overstate the number of trucks on the road, due to the assumption that each OD pair is a truck trip instead of one truck completing a tour or many trips	7	• Four step models are an established industry standard and there are ways to test accuracy and also guidelines regarding model validation • Accuracy can be improved if accurate tour modelling data is added properly to understand truck behaviour. The methodology is good, but there is the potential for inaccuracies.	8	•Because this model allows different route assignments, it could enable more reliable output, since routes are not just assigned on a lowest cost basis.	8.5
Repeatable and up-to-date	• Four-step models require significant baselining which isn't overly easy to repeat. • Four-step models can however use more accessible and up to date data to update the model, ie update land use, production and consumption data as an indicator of commodity flow changes. This means it can be updated relatively easily but not re-baselines easily (baselining re-calculates regression analysis).	8	• This is like other 4-step options' update process. Tour logic can be updated based on telematics and GPS and truck e-sim data. This data is available soon after actual truck movements so it can be relatively up to date.	8.5	• This is similar to other 4-step options in terms of repeatability and being up to date	8.5
Future-proof approach/scalable and adaptable	• From a 4-step model with trip modelling it could be enhanced with tour modelling and then more accurate and adaptive route assignment however it not a minor undertaking to move to dynamic simulation based approaches.	7	• A 4-step model with tour modelling can be further enhanced to improve route assignment and also this enables resilience scenario running.	6	• This option is at the higher end of 4-step functionality and without moving to a more dynamic simulation it may have hit its limits of scalability.	5
Interoperable with other processes and functions	• 4-step models use datasets which are also used in other forecasting and analysis processes so there is a high degree of consistency and interoperability.	7	• The addition of tour modelling will increase usefulness with urban freight related assessments, including informing policy changes.	8	• Enhanced route assignment may enable assessing different network configuration scenarios which may increase usefulness and interoperability in informing investment decisions and assessing impacts.	8.5
Value of sector based productivity insights	• 4-Step can include many commodities and sectors, • As this modelling is more linear it is not setup to goal-seek or optimise therefor 4-Step models can vary with regard to productivity insights. Without tour modelling the productivity insights are less in an urban setting.	6	• 4-Step can include many commodities and sectors, • This modelling is more linear and is not setup to goal-seek or optimise therefore 4-Step models can vary for productivity insights. Tour modelling enables productivity insights in an urban setting.	7	• The addition of enhanced route assignment can enable more productivity insight as different route logic can be compared, ie actual route vs least-emissions route/mode etc.	7.5
Network performance and capacity	• Four step modelling usually does not enable network capacity assessments. Route allocations are normally all-or-nothing assignments, and there is no feedback loop between network performance and route assignment causing level-of-service impacts to be excluded.	5	• The addition of tour modelling will increase usefulness with urban freight related system performance however the data would need to be fed into another model or process for capacity and other insights	6	• The addition of enhanced route assignment can include capacity calculations, ie background traffic and travel times could influence route assignment therefore showing impact of network performance	8
Enable urban freight insights	• Trip modelling not ideal for urban environments	3	• Tour modelling enhances urban freight insights.	7	• Enhanced route assignment may enable some urban freight insights such as looking at mode shift impacts and bypasses/alternative routes etc.	7.5
Enable Resilience insights / outcomes	• 4-step models can be used to identify or assess resilience risks, impacts and response scenarios however as its not a simulation it needs to be done via iteration and may take time and be complex	5	• Including tour modelling does not in itself enable resilience insights and outcomes.	5	• Enhanced route assignment would improve resilience insights and make sunning scenarios and understanding responses easier than without this enhancement.	7
Enable decarbonisation insights / outcomes	4-step modelling would be able to calculate emissions at quite a granular level but not very functional in terms of assessing lower carbon options or understanding impacts on efficiency.	5	• The addition of tour modelling would improve decarbonisation insights as it more realistically interprets actual vehicle movements. This would be useful when looking at back to base charging vs enroute charging etc.	6	• Being able to look at different modes and routes will assist with identifying and assessing decarb options.	7
Ability to identify increased efficiency opportunities	• As this modelling is more linear it is not setup to goal-seek or optimise therefore ability to identify efficiency opportunities is limited.	5	• Adding tour modelling will enable more urban freight related productivity insights	6	Enhanced route assignment means that alternative operations, routes, times of day etc can be assessed relatively easily.	7

Criteria	Aggregate-Disaggregate-Aggregate Model		Supply-Chain commodity flow model (modular)		Supply-Chain Simulation and System Balancing Models		Dynamic Modelling - Agent Based and Discrete Event Simulation	
Accuracy and Reliability	• The ADA model relies on accurate enterprise-level data as opposed to the four-step models which uses commodity flow information. ADA models can be reliable if there is a high response rate from enterprises (by location). • ADA is not overly sophisticated in terms of closing data gaps as compared to simulation methods therefore reliability is very much dependent on data completeness.	7	• This type of modular commodity based model is literately developed over time sector by sector. • It may be accurate but only for the sectors it covers so it does not include total freight flows.	5	• Simulation and system balancing models take time to calibrate and validate but once they are reflective of the real world they can tend to stay more accurate for longer. System balancing is inherently easier to validate and trust as system flows like the economy needs to balance.	8	• As with simulation and system balancing more advanced models with DES and ABM are better at maintaining accuracy over time and benefit from a more constant calibrating and validation process as opposed to lumpy baseline establishment activities.	9
Repeatable and up-to-date	• Similar to 4-step modelling an ADA model can be updated with production, consumption and land use data.	8	• As the model is literately developed there are disparate levels of up-to-date data. • As this model relies on the best available data at the time and more ad-hoc industry engagement it is less consistent between updates.	5	These models are parameterised meaning many input variables can be changed easily as opposed to needing major baselining activities. Small samples of data can be used to update input parameters.	8	These models are parameterised meaning many input variables can be changed easily as opposed to needing major baselining activities. Small samples of data can be used to update input parameters.	9
Future-proof approach/scalable and adaptable	•As ADA has enterprise based data it could enable tour modelling for more accurate urban freight insights.	6	• This model is by definition scalable and adaptable over time. It could morph over time to include system balancing or and ADA approach.	9	Simulation models are scalable and adaptable built in code and on platforms which can be replaced over time	8	Simulation models are scalable and adaptable built in code and on platforms which can be replaced over time	9
Interoperable with other processes and functions	• This approach uses datasets which are used for other processes and forecasts, it also produces quite detailed movement data so can offer valuable input into investment decisions and policy assessments	8	This approach has proven to be less interoperable with other tasks and processes as it used dissimilar datasets and has inconsistent levels of detail between sectors. Due to the lack of consistency and transparency there is less trust in this method in terms of its use becoming normal practice.	6	• Similar econometrics methods can be used to develop and forecast commodity flows enhancing transparency and interoperability. Outputs can be granular in terms of different vehicle types etc.	7	• Similar econometrics methods can be used to develop and forecast commodity flows enhancing transparency and interoperability. Outputs can be granular in terms of different vehicle types etc.	8
Value of sector based productivity insights	• This approach produces quite detailed movement data and utilises detailed commodity data gathered from enterprise surveys.	8	• The modular sector by sector approach means that sectors can be prioritised and deeper dives can be made. However insights will be restricted to certain sectors.	5	• Commodity coverage can be quite detailed in this method and so to can vehicle types, modes, time of day movements etc.	7	• Commodity coverage can be quite detailed in this method and so to can vehicle types, modes, time of day movements etc. The more advanced modelling enables more productivity related insight including capacity, utilisation and resilience.	8
Network performance and capacity	• ADA does not specifically include capacity modelling but it does have route assignment and therefore could either accept impacts of background traffic or feed PCU's into a transport model which can measure capacity impacts.	7	This approach does not enable good network level insight as it is not representative of total freight flows.	3	• Network performance may largely come for connecting the system balance model with a strategic transport model by exporting an OD matrix.	7	• Network performance and capacity insights could be generated within this more advanced model. Background traffic could be imported from another strategic passenger movement model.	9
Enable urban freight insights	•ADA has enterprise based data so it could enable tour modelling for more accurate urban freight insights.	7	• This approach can be used with tour modelling for urban freight insights however it may not be representative of all freight movements due to the sector based incremental development.	6	This approach could generate granular urban freight data however it will not be as accurate without agent based modelling whigh techically this option does not include.	7	The options can generate detailed urban freight movements including use of ABM for tour modelling and model individual rail.	9
Enable Resilience insights / outcomes	•Commodity data needs to be quite detailed for ADA modelling therefore segmentation of critical and non-critical freight may be possible • ADA does not specifically include capacity modelling but it does have route assignment and therefore could feed into another process or iterate scenarios related it understanding resilience	7	This apporach has proven effective at identifying sector based resileance insights including focussing on critical freight, however not at a system level.	7	Similar to the modular approach but this can show system wise resiliance insights including testing response scenarios.	8	Similar to the modular approach but this can show system wide resiliance insights including testing response scenarios. More stochastic apporach means response scenarios are more accurate due to the use of behavioural characteristics	9
Enable decarbonisation insights / outcomes	• ADA is quite detailed and as such should be useful in both calculating emissions and looking at emission reduction scenarios however there is no inherent optimisation capability within ADA.	7	Yes, but again only for sectors covered by the model	7	Good level of decarbonisation insight however not as accurate as use of ABM in terms of understanding impact of alternative fuels of level of service or productivity impact.	8	Highest level of insight due to behavioural characteristics inclusion and the capability to understand level of service and productivity impacts related to future fules. Also better suited to optimisation of re-charging locations and types etc.	9
Ability to identify increased efficiency opportunities	• ADA does not have an inherent optimisation capability and would there for have some parameterised variables (changeable input assumptions) but other than that opportunities to increase efficiency would be needed progressed outside of the model.	6	Yes, but again only for sectors covered by the model	6	Good level of insight, able to optimise flows and vehicle type and time of day movements vs actual.	8	High degree of insight, limited by data availability and model developers.	9

Pairwise sensitivity analysis results

Sensitivity Analysis of Assessor Scores

A pairwise sensitivity analysis was undertaken to understand if there was any significant influence of criteria weighting on the final evaluation scoring. As is demonstrated in Figure 26 below the final evaluation score is not sensitive to changes in weighting. There is one exception to this, where, viewed in isolation, one assessor's weighting would rank the Aggregate-Disaggregate-Aggregate model higher than the Supply Chain commodity flow model.

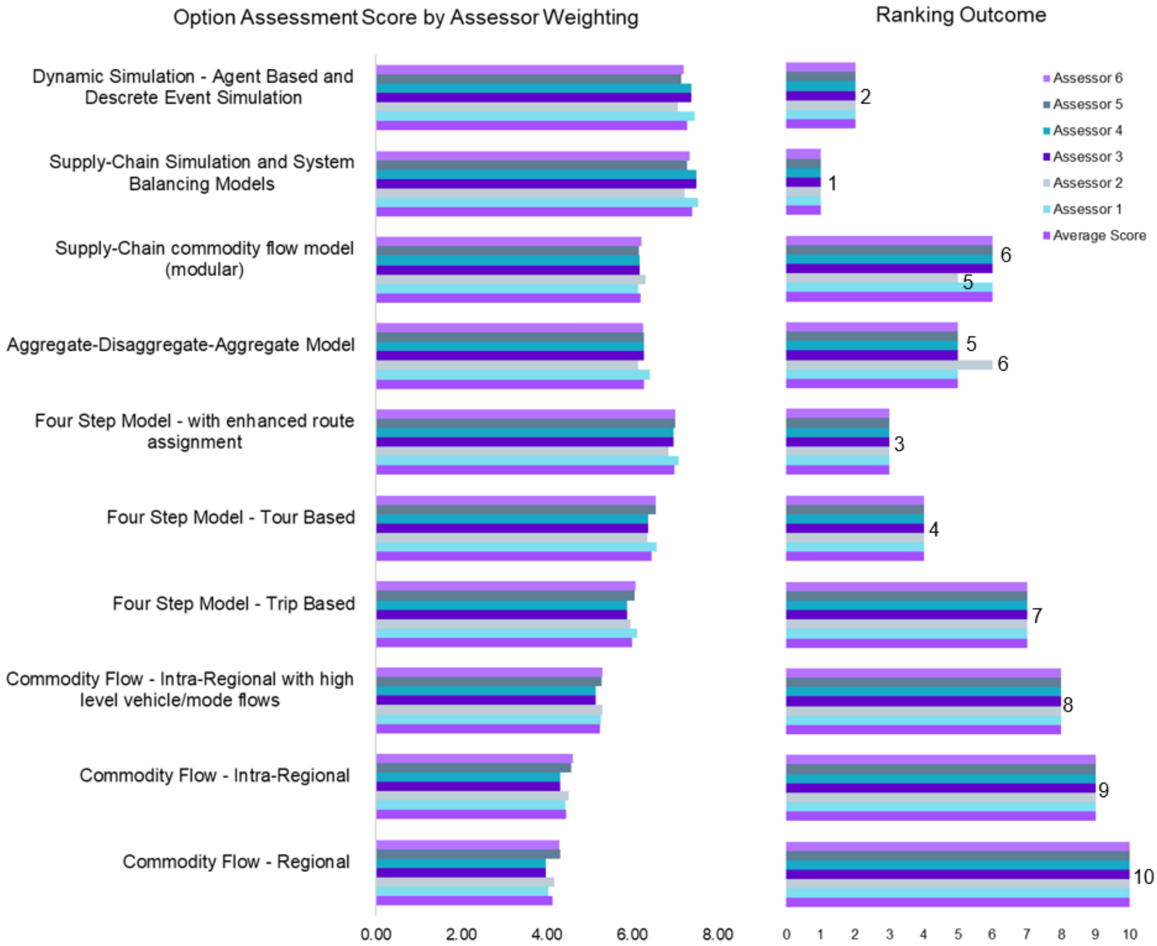


Figure 26: Option Assessment Score by Assessor Weighting

Sensitivity Analysis of Adjusted Criteria Weighting

The pairwise assessment also provides an opportunity to understand the influence of different weighting scenarios. Three scenarios were developed, in each case the relevant evaluation criteria weightings were doubled (relative to the final average weightings, scenarios included:

– Value-for-money scenario - doubled the weighting of 'Establishment Costs' and 'Ongoing Costs'
– Emphasis on risk scenario - doubled the weighting of 'Delivery Risk' and 'Accuracy and Reliability'
– Productivity and Efficiency Scenario – doubled the weighting of both 'Value of sector based productivity insights' and 'Ability to identify increased efficiency opportunities'

The result of these scenario analyses is demonstrated in Figure 27 below.

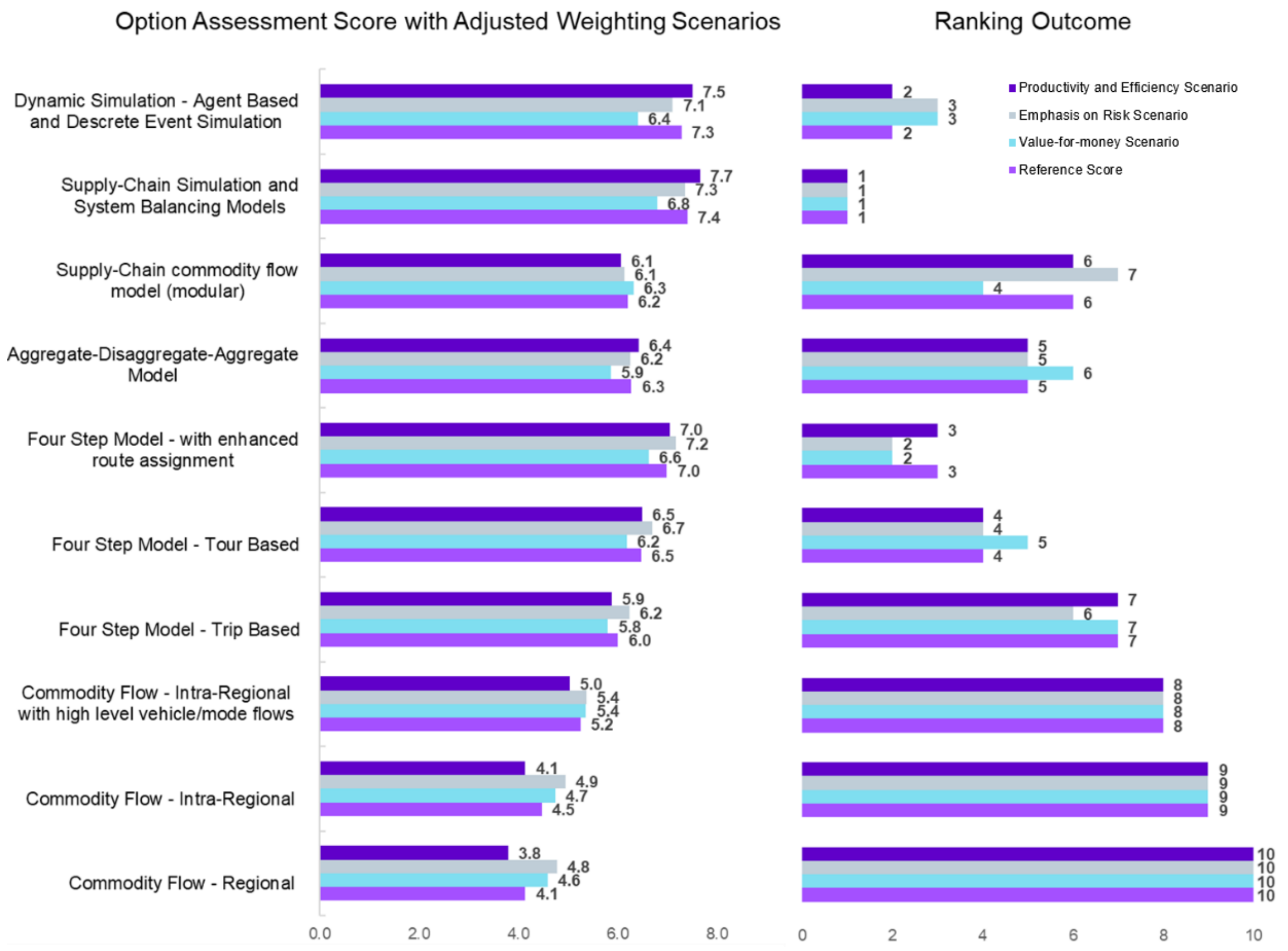


Figure 27: Option assessment score and rank with adjusted weighting scenarios

Under each of these scenarios, the *Supply-Chain Simulation and System Balancing Model* remains the highest ranked option, and the *Dynamic Modelling – Agent Based and Discrete Event Simulation* and *Four Step Model – with enhanced route assignment* options either second or third option. Under the Value-for-money and risk scenarios, the Dynamic Modelling option drops from second to third ranking, reflective of its higher cost and higher-risk delivery scoring. In contrast to this movement, the *Four Step Model – with enhanced route assignment* ranking improves to second-placed ranking under these scenarios as it has a lower cost and risk profile (as reflected in the scoring).

For the Productivity and Efficiency Scenario there was no movement in rankings with the reference score. This result demonstrates that the options were scored relatively consistently across the 'Value of sector-based productivity insights' and 'Ability to identify increased efficiency opportunities' criteria.

For the other short-listed option – *Commodity Flow – Intra-Regional with high level vehicle/mode flows*, under no scenario was there a shift in rankings.

Appendix C

Demonstrative use cases for high-ranking options

Demonstrative use cases of the high-ranking options

This section provides additional detail on the higher-ranking options and for comparison purposes the Intra-Regional Commodity Flow with high level vehicle/mode flows option is included as a base case, as this option is the most closely aligned to the 2017/18 version of the NFDS. The short-listed options were more adaptive and include Dynamic Simulation and Supply-Chain Simulation with System Balancing. The enhanced Four-Step approach scored highly in the MCA since it has the ability to do scenario testing, but it is crucial to highlight that it is more complicated to run with these added capabilities.

To assist in characterising the high-ranking options, some specific hypothetical use-case scenarios for the NFDS were developed by the Ministry. Five use cases were developed along with commentary regarding the ability of each short-listed option to address the use case challenge. Generally, an ability to run scenarios and look at alternative interventions or generate output which can be used to assess policy or investment options was a requirement to address the use-case challenge.

Each shortlisted option was scored for its ability to meet the use case requirements. The ratings include:

– Red: Not useful beyond being able to supply data into another process/analysis
– Orange: Moderately useful in addressing use case need
– Light Green: Useful in addressing the use case need
– Dark Green: Highly useful and may deliver additional insight into informing/testing solutions

Use Case Scenario 1: Impact of Port Constraints

Overview

A particular key port is becoming constrained and is increasing prices in reaction to increased demand, these increased prices have an impact on the cost of living and are set to increase further in the future. Options to increase capacity exist elsewhere, however the true economic social and environmental cost of these options is not known, separate studies have been undertaken but none are a fair comparison of options based on a 'single point of truth' in terms of freight movement data and analytics.

Example questions the Ministry could ask:

– *What are the additional supply-chain costs to exporters and importers if other port locations are used?*
– *What export commodities and regions are most affected?*
– *What is the change in emissions if other ports are used?*
– *What are resilience issues related to other port locations?*

Example questions NZTA could ask:

– *What land transport investments would be needed if other port locations are used?*
– *What routes would freight travel over under different port locations?*
– *How would the mix of vehicle types over key routes change under different port locations?*
– *What would be the road vs rail share under different forecasts and/or port locations?*

Table 20: Use case 1 considerations based on the shortlisted options

Shortlisted option	Use Case 1 Performance	Rating
Intra-Regional Commodity Flow with high level vehicle/mode flows	This approach would provide high level data related to vehicle tonne kilometres (VTK) and commodity data could then be fed into separate analysis to inform impact of port constraints. Most analysis would likely need to occur outside of the model and would be high level and relative (for purposes of option comparison). Routes are not assigned nor is capacity calculated.	

Shortlisted option	Use Case 1 Performance	Rating
Four-Step Model with enhanced route assignment	Enhanced route assignment makes this Four-Step approach more useful in running scenarios. Port volumes could be changed in the back end (likely not parametrised) and alternative OD scenarios could be run with cost and route impacts being compared. Resilience issues could be identified, and impacts assessed elsewhere. Impacted commodities could be identified. Mode shift scenarios could be investigated by altering assignment logic. Largely this approach would be valuable however running this analysis may be slow, have challenges and require data science expertise. Capacity outputs may only be gained through interacting with other models which include non-freight movements.	
Supply-Chain Simulation and System Balancing Models	This approach enables scenario analysis to take place more easily and quickly without having to adjust input data. This model is built from probabilities dictating most outputs therefore probabilities are adjusted to reflect scenarios. In this instance the probability of certain exports or imports going to one port vs another could be changed and outputs such as VTK, mode share, emissions, cost can be mapped. Calculating the need for new infrastructure could be done via impacting travel times (average speed) on certain corridors and then lifting restrictions to see impact. A proxy for congestion can be used here via probabilities of travel speeds by time of day.	
Dynamic Modelling - Agent Based and Discrete Event Simulation	This is the most adaptable in terms of scenario analysis. Rather than dictating what exports and imports may do, this approach is not prescriptive, the stochastic qualities mean that port (or any keep node) could be constrained, and the model will essentially generate the scenario.	

Use Case Scenario 2: Optimal Crown role in key freight connection

Overview

The Cook Strait connection has two operators, one Crown owned and providing road and rail connections and the other privately owned and providing road connections only. The Government is considering the optimal Crown response for the future of this connection.

- *What commodities are transported over the Cook Strait, and what is the origin and destination of those commodities?*
- *What is forecast demand for freight transport over the Cook Strait?*
- *How might mode and route choices change under different scenarios?*
- *How might freight transport prices change under different scenarios?*

Table 21: Use case 2 considerations based on the shortlisted options

Option	Use Case 2 Performance	Rating
Intra-Regional Commodity Flow with high level vehicle/mode flows	Commodities would be able to be identified, along with interisland forecasts however mode-change scenarios would not be accurate/meaningful under this option. Pricing impacts will also not be assessable in this option.	
Four-Step Model with enhanced route assignment	This option will be able to answer most of the questions posed under this scenario however scenario development may be a bit cumbersome given the reliance of this mode on manipulating raw/aggregated data.	
Supply-Chain Simulation and System Balancing Models	This option will be able to answer most of the questions posed under this scenario. This option would allow the ability to restrict or stop a conduit (such as inter-island sea-freight) and observe the likely alternative local flows and resulting cost changes.	
Dynamic Modelling – Agent Based and	This option will be able to answer most of the questions posed under this scenario. This option would also allow the ability to restrict or stop a conduit (such as inter-island sea-freight) and observe the likely alternative local flows and resulting cost changes, however it	

Option	Use Case 2 Performance	Rating
Discrete Event Simulation	would also enable the introduction of a coastal shipping solution and other alternatives for option assessments.	

Use Case Scenario 3: Service provision at seaports

Overview

Crown entities provide services at ports and need to plan ahead for future staffing and facility's needs.

– *What are the forecasts for vessel types and sizes and for international vs coastal shipping port visits?*
– *What commodities are transported via seaports, what are the seasonal patterns for volume and types of freight?*
– *What are the land transport volumes/patterns on ports (for understanding health and safety risks)?*
– *What is the forecast demand for seaport visits?*

Table 22: Use case 3 considerations based on the shortlisted options

Option	Use Case 3 Performance	Rating
Intra-Regional Commodity Flow with high level vehicle/mode flows	Supplying forecast demand for import and exports and domestic cargo at a port and commodity level will be possible however vessel numbers, port visits, vessel types and landside patterns (assumed truck numbers at a port level) will not be possible in this option.	
Four-Step Model with enhanced route assignment	This approach will be able to provide answers to these questions as this data will be outputs of the commodity flow and econometrics approach. Freight generation models based on regression-based methods could be used to forecast the tonnes of freight produced and attracted in different zones.	
Supply-Chain Simulation and System Balancing Models	This approach will be able to provide answers to these questions as this data will be an output of system balancing. Service levels can be investigated through the application of supply chain analysis based on operations research methods. The combination of optimisation and simulation approaches could allow to inform the capacity constraints of seaports.	
Dynamic Modelling – Agent Based and Discrete Event Simulation	This approach will be able to provide answers to these questions as this data will be outputs of the baseline data within the simulation and show how freight agents respond to different levels of service at seaports (i.e. move to use other ports).	

Use Case Scenario 4: Heavy Vehicle Rules

Overview

The Ministry and NZTA advise on and administer rules relating to heavy vehicles which require consideration of objectives related to safety, asset condition and productivity.

- *What routes do different vehicle types/weight currently use and how might that change under different rules/scenarios?*
- *Will the scale of change vary for different vehicle types/weights?*
- *What types of commodities would be most affected by changes to rules?*
- *What would be the emissions impacts of changes to rules?*

Table 23: Use case 4 considerations based on the shortlisted options

Option	Use Case 4 Performance	Rating
Intra-Regional Commodity Flow with high level vehicle/mode flows	Vehicle movements in this option are not route-specific but rather are representative of the actual profile (types of vehicles and flows between statistical areas). This will help inform understating of the link between commodities and types of vehicles and enable emissions calculations (not overly accurate) however it will not be able to inform any insights regarding restricting certain routes or vehicle types and what impact that may have.	
Four-Step Model with enhanced route assignment	This option would enable these questions to be answered however as methodology is only stochastic for route assignment the impact of policy changes will be quite restricted and not provide insight on unintended consequences (for example the impact of changing truck types on rail mode share).	
Supply-Chain Simulation and System Balancing Models	This option would answer these questions and also be able to provide insight into impacts of policy decisions, trends or restrictions on mode share, emissions, and supply-chain service levels.	
Dynamic Modelling – Agent Based and Discrete Event Simulation	This option would answer these questions and also be able to provide insight into impacts of policy decisions, trends or restrictions on mode share, emissions supply-chain service levels. This option also may enable the optimisation of vehicle policies i.e. be able to calculate optimal vehicle type profiles or mode uses.	

Use Case Scenario 5: Support for heavy vehicle decarbonisation

Overview

The Ministry would like to support to heavy vehicle operators to decarbonise their vehicle fleet.

- *What are the main barriers to road freight operators using electric vehicles?*
- *What routes or freight specific issues exist which would affect the support needed (i.e. depot charging, mid-trip charging, capital cost of vehicles)*
- *On which routes is public charging or refuelling infrastructure most needed to supplement depot charging and give fleet operators the confidence to decarbonise?*

Table 24: Use case 5 considerations based on the shortlisted options

Option	Use Case 5 Performance	Rating
Intra-Regional Commodity Flow with high level vehicle/mode flows	This option would not assist directly with any of these questions as the modelling method does not consider vehicle movements or generate outputs such as VKT across the road network. It only considers commodity flows and locations.	

Option	Use Case 5 Performance	Rating
Four-Step Model with enhanced route assignment	This option would be able to include Zero Emissions Vehicles (ZEV) in the vehicle assignment logic and show why these trucks may be cost prohibitive and how this varies with different route and commodity types. This option includes tour modelling which will be beneficial in identifying where truck charging could be positioned to decrease impact on service levels.	
Supply-Chain Simulation and System Balancing Models	This option will deliver everything as per the previous option, with the addition of it being more easily achieved and with different fleet transition uptake scenarios being more easily tested. This option will enable better understanding of trip stops and extent of trip legs, allowing a better understanding of energy use considerations.	
Dynamic Modelling – Agent Based and Discrete Event Simulation	This option will enable all the previous options but as it uses agents it would be a lot more accurate at being able to interpret actual real-world behaviour and incorporate charging times in terms of impact, demand profiles for charging infrastructure and therefore more accurately inform the required charging capacity.	

Insight for NFDS:

Broadly deterministic methods (such as Four-Step econometrics and commodity flow models) are well suited to telling us things we already know to be true given data inputs. They are suited to allowing us to paint a picture of what has happened or what is happening, however they are less useful in terms of filling gaps in our understanding or being able to provide insight on how a system may behave in the future or when the environment changes. This is when the stochastic approaches are most useful whereby there is a degree of interaction between various causes and effects though the use of modeling behavioral characteristics. These methods are particularly good at identifying potential unintended consequences or counter-intuitive outputs which without the stochastic approach we may not have been able to predict. Stochastic approaches are also helpful in providing some degree of uncertainty (i.e. confidence intervals) around the implications or impacts related to different interventions.

Appendix D

Scope of Works for high-ranking options

The NFDS delivery scopes below have been developed from the context of a Request for Proposal being issued to the market or to form the basis of internal delivery.

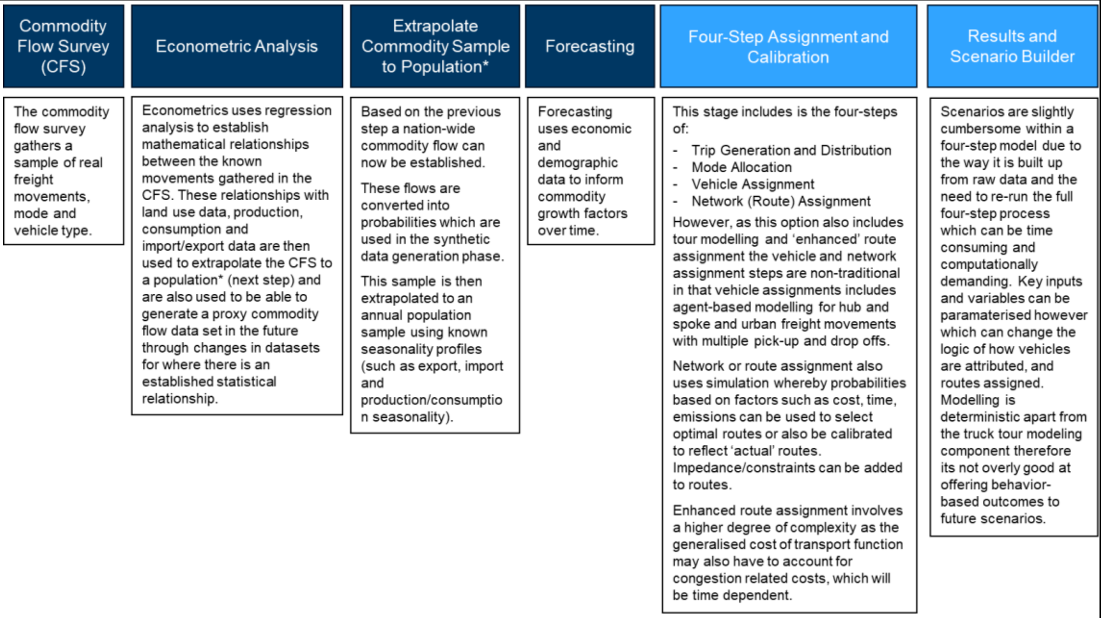
Scope Component	Approach Description
Develop Data Collection and Stakeholder Engagement Plan	A data collection and stakeholder engagement plan should be developed. A stakeholder engagement plan would consist of: 1) Purpose of engagement 2) Key project messaging 3) Means of engagement 4) List of stakeholders 5) Timing of engagement activities A Data Collection Plan would consist of: 1) Data gap analysis 2) Approach to close data gaps 3) Data validation plan including definition of statistics significance thresholds 4) Risk Management Plan including risk mitigation measures and alternative approaches if primary approach is unsuccessful 5) Data Governance Plan including how data will be handled, and license or NDA agreements and cyber security measures
Build Model Basis Document	A Model Basis Document (or a Basis of Design) should be developed which would be signed off by the Ministry prior to model build commencing. A model basis document locks in certain model functionality but does still have some degree of adaptability as information comes to light during development. A Model Basis Document would consist of: 1) Definition of Model Purpose and Objectives 2) Definition of overall model function including a model schematic showing main data flows, inputs, processes, and outputs. 3) Model Functional Specification, including: a. Key parameters b. Model form/schematic c. Key variables d. Outputs 4) Technical data analytics description, including: a. Description of the datasets being used b. Definition of sample sizes and extrapolation methods c. Definition of validation and testing processes including regressions and required correlation coefficients in generation of dependent variables d. Description of data sanitisation including any data joining and/or synthetic creation e. Description of forecast methodology 5) Technical model description, including: a. Description of the model logic used at each step b. Definition of any current unknowns which will require resolving during the model development c. Definition of code management and version control processes 6) Data and Modelling Platforms a. Identification of any software being used and coding language used. Note preference is for open-source code such as R Python, JavaScript and SQL. 7) Model Calibration Process

	a. Definition of how the model will be calibrated to reflect historical and current freight movements, including use of calibration factors and how these will be applied. 8) Model Validation process a. Definition of how the model will be tested and what constitutes a valid model. Description of how non-valid test outcomes will be handled. 9) Model documentation and handover process
Data Gathering and Analysis	This scope section will focus on obtaining currently unavailable data and will follow the approach defined in stage 1.
Commodity Movement Data	Commodity flow data extrapolation: Extrapolation of this sample data gathered from telematics providers and business locations can be completed in various ways. It is suggested that both a bottom up and top-down method is used and then are reconciled to each other. - Top-down method: Total commodity volumes are known (production, consumption, import, export) so each commodity instance (OD pair) is scaled up until the total commodity flow is reached. - Bottom-up method: Sample sizes for each SA are estimated based on responses. Based on sample size estimates, these are extrapolated up to a population size and then reconciled to total known volumes.
System balancing as a means of CFS sample extrapolation (as in alternative recommended enable and delegate option)	There are alternatives to statistical scaling or extrapolation of a sample to a population. Using a system balancing approach means that samples are scaled to reflect known system characteristics, specifically system inflows, outflows, production and consumption. In this approach the sample freight movement data gathered as part of a CFS and supplemented with telematics commodity designation is used to inform probability distributions, i.e. the probability of a certain commodity having a certain origin or destination depending on whether it is an import/export or domestically produced or consumed. Once these probability distributions have been established, (likely using a Bayesian Probability approach which can be amended as new data comes to light) then volume is introduced to the system balance model by means of imports & exports (by port), production and consumption volumes (by SA level). Volumes are distributed probabilistically. For example, if through the sample data we ascertain that if an imported container of paint via Port of Auckland has a 15% likelihood of being destined for Hamilton, then 15% of every container of paint arriving via Port of Auckland moves to Hamilton. Probabilities are also gathered for mode and truck type which can disaggregate this further. This approach is preferred to linear scaling or extrapolation as it reconciles samples with more system 'knowns' and it is highly conducive to forecasting as future volume can be introduced to the system and distributed.
Forecast Data	Forecasting methods are more universal and generally accepted as compared to the many types of data capture and movement modelling options as described above and so have not been the focus of this research paper. In the 2017/18 NFDS Report, forecasts of 'supply-driven'[20] commodity production was based on some combination of: – Available published forecast data such as MPI's Wood Availability Forecasts – The continuation of historical trends – Trends in overseas demand – Future shifts in policy such as those with a purpose to minimise the environmental impact of production – Discussions with industry

[20] The authors define "supply-driven commodities" as ones where "flows are typically based on production capacity and constraints".

	The forecast methodology used in the previous NFDS is more or less adequate for future NFDS's, the key difference is the baseline data and the need for this to be more complete and more granular in future studies to fulfil defined NFDS objectives. The drivers of freight system growth are supply and demand. Namely, what is the demand and what are the supply-constraints. This is why freight demand forecasts follow established economic methods and use existing forecasts data. Generally, forecasts are applied to models via the application of growth factors on commodity flows. Growth factors at a commodity level are calculated based on forecasts which largely already exist such as trade forecasts. Commodity and location-based forecasted growth: - Exports - often based on overseas trading partner growth. - Production – based on export demand and domestic consumption (population). - Imports – driven by domestic production (inputs) and domestic consumption. - Economic forecasts such as the Economic and Tax Outlook – BPS 2024.[21] - MPI's Economic Intelligence Unit releases a Situation and Outlook for Primary Industries (SOPI) report twice a year. SOPI reports look at the performance of NZ's main primary sectors and forecast how they will perform over the next 2 to 5 years. Commodity production forecasts such as those produced by MPI are used to develop commodity growth factors by region which are then applied to the baseline commodity flows by location. Worth noting is the fact that export volume and production levels should be constrained by potential supply and not just demand driven, for example where demand may outstrip supply due to a lack of arable land or ability to extract resources. Additional guidance on freight demand forecast is included in the ATAP Guidelines (noting that NZ was a party to their development).[22] **The use of stakeholder engagement and a CFS to inform forecast:** Aside from using existing and available economic forecasts to generate commodity and location-based growth factors for use in the NFDS there is an opportunity to incorporate forecast data from a commodity flow survey and/or direct stakeholder engagement if desired. For instance, the CFS could include a question regarding future expected growth and this could be compared to economic data for consistency. If industry sentiment appears to be in conflict with economic data then this should perhaps be addressed with those who are generating economic forecasts. It is not the view of the project team that the Ministry should deviate from existing economic forecast data and create alternative sources of truth which may be inconsistent with more widely accepted economic forecasts.
Model Development	
Four Step Model – Econometrics Approach	NOTE: The econometrics approach can be common to all modelling methodologies recommended however, its efficacy is heavily dependent on being able to predict dependent variables with independent variables. This is tested via regression analysis. A linear regression calculates the accuracy of the approach. If the approach proves to be inaccurate then it either should not be used or must be heavily calibrated (forced through manual intervention). Therefore, these acceptable thresholds need to be defined upfront and options for progressing if these thresholds are not met need to be presented. **Four Step Model Development** Overview of approach:

[21] https://www.treasury.govt.nz/sites/default/files/2024-03/economic-tax-outlook-bps24.pdf
[22] https://www.atap.gov.au/tools-techniques/cost-benefit-analysis/5-step-4-make-demand-forecasts



Steps 1 and 2 of a four-step model are Trip Generation and Trip Distribution which cover the origin and destination of freight movements. How these are calculated using the econometrics approach is detailed below.

The econometrics approach:

Prior to progressing with a Four Step Model the reliability of an econometrics approach needs to be ascertained.
This is achieved by using regression analysis and 'actuals' as obtained in the data collection phase.

Econometrics estimation analysis is to be performed:

A multi linear regression model[23] is to be built where the natural logarithm of independent variables and the natural logarithm of the dependent variable commodity is ascertained.

Independent variables:

- Land use data, for example, land-use type, floorspace or footprint by industry type
- Employment data by location and employment type
- Production data by location
- Consumption data by population / location
- National Accounts Input Output Tables[24]

The analysis performs a series of econometric tests to ensure that the assumptions of linear regression are satisfied and to isolate the appropriate independent variables of interest. These tests include:

Linearity: It is assumed in this test that there is a linear relationship between independent variables and the dependent variable; and this relationship is tested. This test is completed by applying a logarithmic function to the dependent variables and removing categories within independent datasets which remain non-linear.

[23] Some models are non-linear. For example, gravity models, which aside the multiplication of production and attraction attributes, can have power or exponential function in denominators.

[24] National accounts input-output tables: Year ended March 2020 | Stats NZ

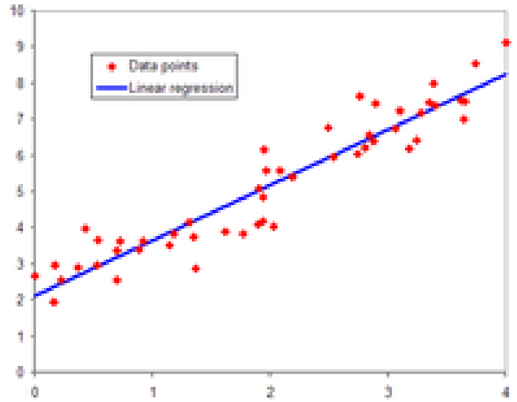
Multicollinearity: For those independent variable categories which have shown to be highly correlated with the dependent variable (commodity flows), the correlation factors can be combined to improve the accuracy of the predicted dependent variable.

Homoscedasticity: When a regression model exhibits homoscedasticity, it means that the spread or scatter of the residuals (the differences between the predicted and observed values) is roughly the same across all values of the predictor variables. A plot of residuals against fitted values is created and assessed, ideally residuals are evenly spread.

Normality of errors: This plot compares the observed residuals to the expected values under a normal distribution. If the points closely follow a straight line, it suggests normality. This tests the validity of the analysis.

Based on the above analysis a formula is created which estimates the generation and attraction of commodity movements based on the categories within the independent variable data sets which provide to have the most reliable ability to estimate commodity flows.

Below is an example of the logarithmic relationship between dependent variables and the independent variable (the variable we are seeking to estimate/predict).



Econometrics Calibration and Validation:

Calibration and validation should be completed in accordance with established guidelines such as ATAP Guidelines per below.

3.6 Model Calibration and Validation Criteria

Table 3-3 shows criteria for freight model calibration acceptance and validation that should be considered by the modeller. The criteria apply to all three model types, except where noted. Note that some of the criteria reflect 'desirable' situations, meaning that judgement also must be applied.

Table 3-3: Recommended calibration and validation criteria for urban freight modelling

Survey Type	Definition
Calibration	• Any linear regression component of a freight model (e.g. a trip generation equation or a formulation that estimates commodity flows from economic inputs) should desirably be able to demonstrate an r^2 value comparator greater than 0.85; and • Any logit model (e.g. applied as part of a mode share formulation in a commodity flow model or as part of a tour decision chain in a tour-based model; logit formulations are not common in trip-based models) should desirably be able to demonstrate a pseudo-r^2 greater than 0.45 (Hensher et al., 2005).
Validation	• Screenline sum comparisons against observed flows should have a r^2 greater than 0.85 and individual freight flows on primary distributor roads (Highways and Freeways, including ramps) should have a GEH < 5 for 85% of count locations. This applies to the assignment of matrices developed in commodity flow models, trip-based models and tour-based models; and • Assigned link volumes in and out of special freight generators (e.g. Ports and Airports) specific to the freight movement should meet the GEH < 5 criteria in all instances. This applies to the assignment of matrices developed in commodity flow models, trip-based models and tour-based models.

Source: Wonnacott and Wonnacott (1990), Hensher et al. (2005), UK Highways Agency (1987).

Risks with econometrics method: This approach may require manual calibrations to account for non-uniform Statistical Areas (SA's). For example, where there are locations which have more unique attributes such as an SA which is heavily dominated by one commodity, or there is infrastructure such as an intermodal terminal which is the only industrial land in the SA so it attracts and generates high freight volumes but does not have commensurate attributes reflected in dependent variables, ie employment, land use, production and consumption. This is one of the downsides of an econometrics approach, it is better in more uniform instances.

Econometrics for forecasting:

Econometrics is particularly useful for forecasting as future dependent variables can be used to predict future independent variables. Therefore, future land use plans, populations growth, consumption, trade forecasts etc can all be used to estimate commodity flows once the relationships between these variables and commodity flows are known.

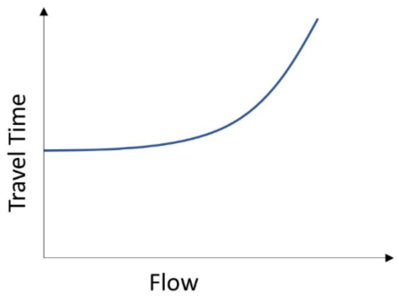
<u>Steps 3 and 4 Mode and Network Assignment</u>

Both mode choice and network assignment should be completed two ways and have these methods parameterised so they can be toggled between in the model.

Two methods for both mode choice and network assignment:
1) Actual mode and routes based on known movements.
2) Mode and route assignment based on choice factors, i.e., time, cost, reliability (minimal congestion and route closures).

If both of the options above are possible, then its preferable that both options are used and can be toggled between to test impact of changing route choice parameters vs actual routes taken, i.e. what if time was favoured more than cost (especially in the case of direct toll charges)?

Mode choice will be a known input based on available rail, shipping and airfreight datasets and preferences revealed via the CFS. The balance of which is moved by road and due to the precise steps, there is now a clear understanding of model distribution.

	Network assignment can be based on telematics data which is good in New Zealand so this should be heavily relied on to assign trucks to routes. Assignment could be further improved when combined with information from traffic counts, weight-in-motion equipment, and other datasets such as e-sim data (i.e. Compass IoT) and GPS data. This data can be used to assign vehicles to the actual routes used based on probability. IE each possible route between each OD pair is defined and a probabilistic assignment is made based on actual data. With regard to mode and route assignment based on choice factors many models use the "equilibrium assignment" technique. This process allocates traffic to links so as to minimise the generalised cost of the vehicle trip between origin and destination. These relationships are quantified as volume-delay functions (VDFs), which determine a link's traffic volume, typically expressed in vehicles per hour, as a function of travel time and cost. The way congestion impedance is accounted for should be by time of day and day of week and this should reflect real traffic flows. Example of a generalised cost equation: *Generalised cost = distance × costVKT + travel time × costVHT + net calibration factor* Where: - Cost VKT is: cost of Vehicle Tonne Kilometres - Cost VHT is: cost per Vehicle Hours Travelled. - Travel time is: *freeflow.time × (1 + a ((vehicle volume + background traffic volume)/ route capacity)^b) + intersection delays.* o Parameters A and B are used to adjust the impact of an additional truck and background traffic on travel time, A determines how sensitive time travel is to changes in volume and B controls the shape of the relationship, ie linear or exponential. These should be calculated in traffic models. o Intersection delays represent extra time spent at intersections for that route. - Net calibration factor is an adjustment factor which may or may not be needed to calibrate the formular result to better reflect reality or future changes. An illustration of the basic confluence between travel time and rate and volume is below:  Enhanced route assignment: We suggest an 'enhanced route assignment' approach as per the options assessment. This enhancement includes the use of multiple assignment algorithms and in particular the inclusion of feedback loops so that each assignment decision is made in respect of previous decisions. GIS-based network analysis tools can facilitate route assignment, by allowing to systematically assign costs throughout the networks, and can also include other external costs like energy use and emissions. Multiple route assignment algorithms should be available to use within the model, including but not necessarily limited to: 1) The 'All-or-Nothing' Assignment Algorithm 2) The Method of Successive Averages 3) The Frank-Wolfe Assignment Algorithm 1) All-or-Nothing Assignment Algorithm: Also known as shortest path assignment. In this approach, all traffic from an origin to a destination is assigned to a single shortest path (route). Each traffic zone is connected to

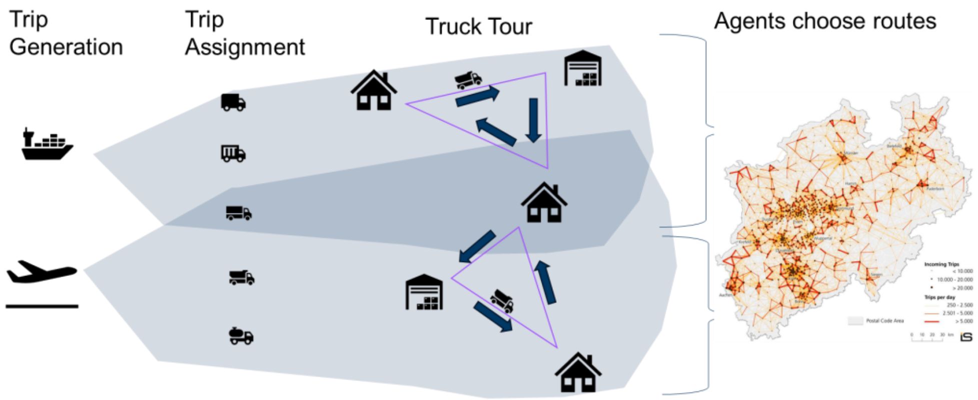
	other zones, and the algorithm determines the shortest path for each zone pair. A limitation is that it Ignores feedback effects (congestion) caused by the assigned traffic. This is often used in early planning studies to estimate traffic patterns. 2) Method of Successive Averages: Also called the user equilibrium assignment. This method accounts for feedback by iteratively adjusting route choices until equilibrium is reached. Initially, trucks choose routes based on perceived travel costs. The algorithm redistributes traffic based on travel time differences between alternative routes. Iterations continue until no truck can reduce their travel cost by switching routes. 3) Frank-Wolfe Assignment Algorithm: Also known as the linear programming-based assignment which is an optimisation technique for traffic assignment and formulates the assignment problem as a linear program. It balances the cost-minimisation objective with network constraints and iteratively adjusts traffic flows toward an equilibrium solution. This approach handles feedback effects and congestion more accurately. It is commonly used in large-scale transportation networks. **Dynamic network (route) assignment (Optional):** Dynamic network assignment (DNA) is an optional additional function which mimics some of the stochastic qualities of dynamic simulation. The Frank-Wolfe assignment algorithm gets close to a DNA approach however it does not use live or near-live data to understand current or live instances. Importantly this function also includes the ability to optimise, or goal seek optimal outcomes at a network level, i.e. minimise emissions, minimise cost. Constraints can be lifted to see what optimal outcomes may emerge, i.e. what if all freight moved at the most ‘optimal time’? Optimal in this instance being best travel time and lowest cost. The methodology should include the below aspects: 1) Time-Dependent: DNA considers time-varying factors such as traffic congestion, road closures, and varying travel times. 2) Real-Time Adaptation: It adapts to changing conditions by re-routing trucks as needed. 3) Complex Modelling: DNA models estimate future travel times and incorporate dynamic changes in traffic demand, roadway capacities, and traffic control settings. Network assignment should also be able to consider planned developments of the transport network as well as being able to add in links or increase capacity of links to test impact in terms of productivity, emissions and the like.
Tour Modelling (Agent Based)	Tour modelling is a suggested enhancement to the four-step approach. One of the reasons being that it accounts for the artificially high truck numbers produced by trip modelling which has a 1 for 1 relationship between an OD pair and a truck. In reality, a truck may make multiple pick-up and drop-off stops, this is called a milk run or a ‘tour’. Optimising backloads and triangulating movements are a continuous focus of transport operators and these techniques allows for this to be captured and/or optimised. Importantly tour modelling allows for the generation of empty truck trips whereby there may be no backload. Data requirements for truck tour modelling: **Truck behavioural data**: GPS data, truck e-sim data, telematics. This data is used to understand what trucks do. In particular, identify those in urban areas who appear to perform tours, i.e. frequent stops for periods representative of unload/load periods, and how often they return to the same place. Based on behaviour major depots and stores can be identified. Data should be considerate of the below: - Correlate with truck types, if possible, to understand potential payload - Truck performance data (such as from e-sim data i.e. Compass IoT) to understand if truck is likely full or empty.

- Identify routes and road types, travel times.
- Temporal aspect, does behaviour differ during different times of day?

Tour Model Development:

- Identify geographic areas for which tour modelling is to be used based on need/areas of interest, these are likely urban areas.
- Within these areas use above data and possible enterprise level (location) survey data to identify key destinations, such as:
    - Depots
    - Major stops (loading unloading) linked to these depots
    - Truck type and load if available
    - Tours, sequence of trips and stops over the course of a day varying by day of week.
- Develop tour logic, based on the data above logic needs to be developed to describe the behaviour of the agent (truck). I.e. how many stops might it do and when might it return to the depot and for how long? This might utilise a Multiple Discrete-Continuous Extreme Value (MDCEV) approach.
- Key components of MDCEV:
    - Discrete Choice Component: Represents the choice among different alternatives (e.g., truck tours).
    - Continuous Choice Component: Captures the continuous aspect (e.g., tour duration, distance travelled) associated with each alternative.
- An alternative to MDCEV is using a Multinomial Logit (MNL) model. The MNL uses probabilities to inform whether a tour continues, and more stops are added based on probabilities calculated from behavioural data.
- The number of agents in the system should never exceed the number of trucks on the roads unless this is an experiment, indeed the number of trucks should ideally reflect data gathered from depot operators so that the truck numbers are realistically constrained meaning that the number of stops they need to complete will reflect the challenge of catering for a particular delivery schedule with the number of trucks available.
- Agents choose network pathways based on observed behaviour. Agents route logic is to be changeable.

The below is a basic illustration showing how commodity inputs lead to truck trips (linehaul) and then to truck tours (last mile) and are then assigned to the network in the form of agents.



Source: GHD

The figure below illustrates the linear tour logic.

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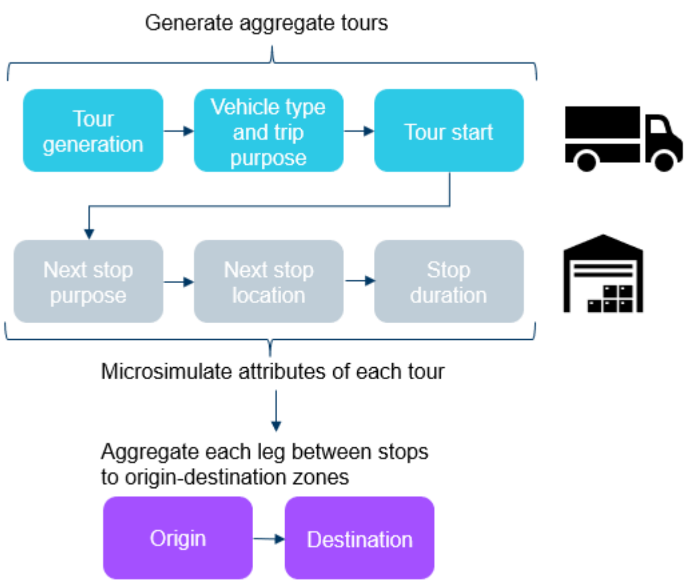

</td></tr>
<tr><td>Model Calibration and Validation</td><td>
Given some data validation and calibration has taken place as described in the process above, these tests relate to accuracy of model outputs.

A complete validation test should be included within the BoD and a record of how the model performed in these tests should be produced before the model is accepted by the Ministry.

Examples of validation tests and calibration activities include:

Data Validation and Cleaning:

Data Consistency: Check for inconsistencies, missing values, and outliers in the input data (commodity flow survey, land use data, demographics, etc.).
Data Completeness: Ensure that all necessary data fields are available and properly recorded.
Data Transformation: Normalize or transform data as needed (e.g., log transformations) to improve model performance.

Model Calibration:

Adjust model parameters to fit observed data. Calibration involves fine-tuning the model to match historical freight movements.
Use statistical techniques (e.g., least squares regression) to estimate model parameters.

Validation Metrics:

Calculate relevant metrics to assess model performance:

Root Mean Squared Error (RMSE): Measures the average prediction error.
Mean Absolute Percentage Error (MAPE): Evaluates the relative error.
R-squared (R^2): Indicates the proportion of variance explained by the model.

Compare model predictions with actual observed data.

Scenario Testing:

Apply the model to different scenarios (e.g., policy changes, economic fluctuations) and compare predicted results with actual outcomes.
Validate the model’s ability to handle various conditions.

Sensitivity Analysis:

Vary input parameters (e.g., population growth rates, production capacity) and observe the impact on model predictions.
Identify sensitive parameters and assess their influence on the overall results.

Peer Review and Expert Judgment:

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<tr><td></td><td>
Engage domain experts (transport planners, economists) to review the model structure, assumptions, and results.
Seek feedback on model validity and potential improvements.
7. Comparative Studies:
Compare the results of the developed model with existing studies or historical data.
If available, refer to previous National Freight Demand Studies in New Zealand.
8. Documentation and Transparency:
Document all validation procedures, assumptions, and limitations.
Make the validation process transparent for stakeholders and decision-makers.
</td></tr>
<tr><td>Paramaterised Variables and Develop Outputs Dashboards and Report Extract Process</td><td>
1. Parametrised assumptions and variables as defined at the Basis of Design Stage
2. Output dashboards to be generated including but not limited to:
OD heatmaps by commodity and volume
Sankey Diagrams by OD, mode, volume and commodity
Commodity forecast outputs
Key output metrics by highlighted SA (via interactive map). For example:
Truck trips by number and VKT
Emissions
Commodity
Major routes
3. Data report filtering and extract process: Any generated data should be able to be extracted in CSV form or via SQL to other databases.
</td></tr>
<tr><td>Data and Model update process</td><td>The data update and model update (refreshing based on new data) process should be streamlined, defined, and documented.</td></tr>
<tr><td>Model handover and user guides</td><td>Training in model use and logic should take place as well as developing model use guides and the ‘As Built’ Model Basis Document which has all the same sections of the initial BoD but it reflects exactly what was built.</td></tr>
<tr><td>Post Model Development</td><td></td></tr>
<tr><td>Production of NFDS Report</td><td>The data and model are only a part of the NFDS. The NFDS requires an accessible report the structure of which is to be decided by the Ministry however likely sections would include:
1) High-level overview of freight flows by commodity
2) Overview of forecast growth
3) High-level overview by mode, road, rail, sea, air.
4) Regional flows
5) Intra-regional flows
6) Urban flows
7) Transport emissions
8) Key productivity statistics
9) Resilience analysis and key constraints, identify vulnerable commodities, routes.
10) Economic benefit of freight and freight movement
11) Detailed datasets, including OD tables by commodity</td></tr>
</table>

Supply-chain simulation Model with System Balancing
The table below only replaces the **Model Development** Section above.

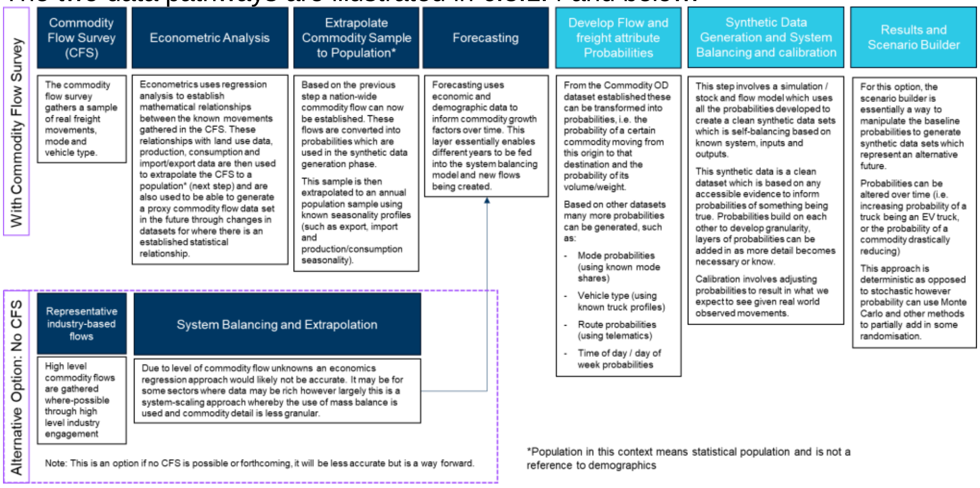
Model Development	
Supply-chain simulation Model with System Balancing	Note that upon development of a commodity flow dataset via telematics providers and direct survey ***the effectiveness of the econometrics approach should still be tested. If econometrics is effective, then it is useful for all modelling options recommended in this report.***

Data inputs

If econometrics is effective, then this will lessen the need for ongoing commodity flow data as the ability to predict commodity flow has been ascertained. In addition, econometrics is a preferred way to inform forecasting given changes in dependent variables i.e. land use.

If econometrics does not prove to be effective and pass validation tests, then commodity flows need to be created through other means.

The two data pathways are illustrated in 6.3.1.4 and below.

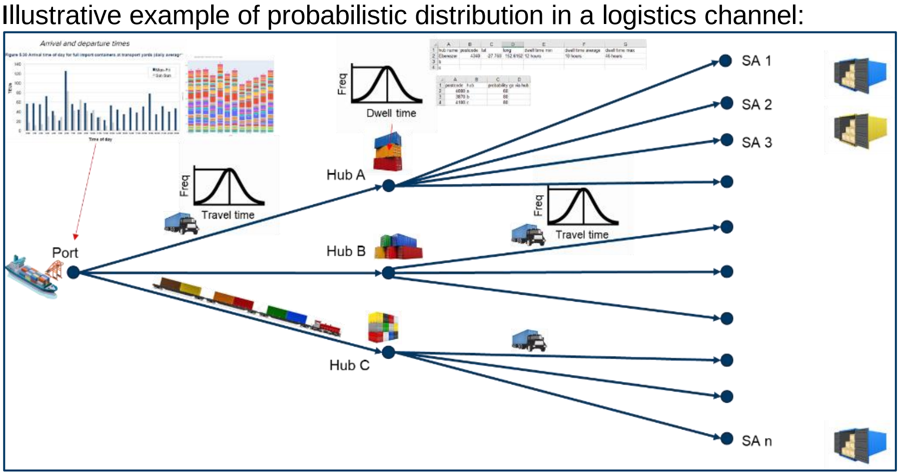


Distribution Channels

In contrast to a trip-based model, the same origin-destination flow can change modes along the way. In this way, the linked trips across transfer points are similar to vehicle tour-based models, with the intermodal transfer points corresponding to the intermediate stops.

The distribution channel model component selects the distribution channel for the shipment, a key element of the framework that represents a business decision made by shippers. A distribution channel refers to the supply chain a shipment follows from the supplier to the consumer/buyer, which is critical to freight-related business operations. The distribution channel might affect the cost, shipment size, and frequency of shipments between a buyer-supplier firm pair. In this framework, the transfer facilities are represented in the supply chain rather than including all establishments that goods move through as they travel from the producer to the consumer; this is because of limited data for these detailed supply chains. The distribution channel model uses discrete choice methods to identify the unique aspects of the supply chain.

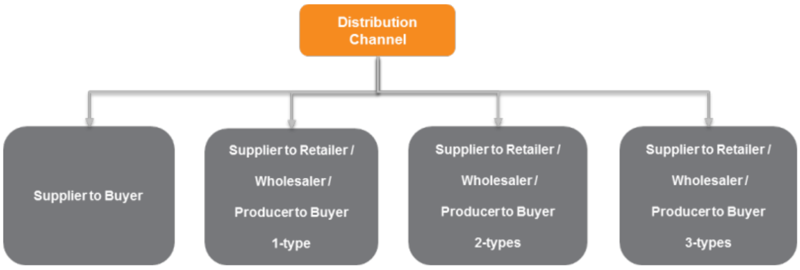
Illustrative example of probabilistic distribution in a logistics channel:



Source: GHD

The distribution channel model uses discrete choice methods to identify the unique aspects of the supply chain. The concept of distribution channel can be simplified to obtain a reasonable sample for model estimation, as shown in the figure below. Four alternatives for distribution channels are: direct, one-stop type, and two-stop type; and three-stop types, where stop type is a warehouse, distribution centre, or consolidation centre. Distribution channels should be developed for defined logistics pathways.

Examples of distribution channels:



Source: (RSG, University of Maryland, and Vision Engineering and Planning, 2017)

The distribution channel model simulates shipments between all the buyer-supplier pairs based on the type of commodity. The manufactured goods model is applied for all commodities other than food. At this stage in the framework, the unit of analysis is shipments by all modes; therefore, the distribution channels are not mode specific and may be completed by a single mode or be multimodal (the process of selecting modes for movement of each shipment takes place in the mode and transfer model).

The below is a distribution channel from the CSIRO TraNSIT Model for agricultural movements.

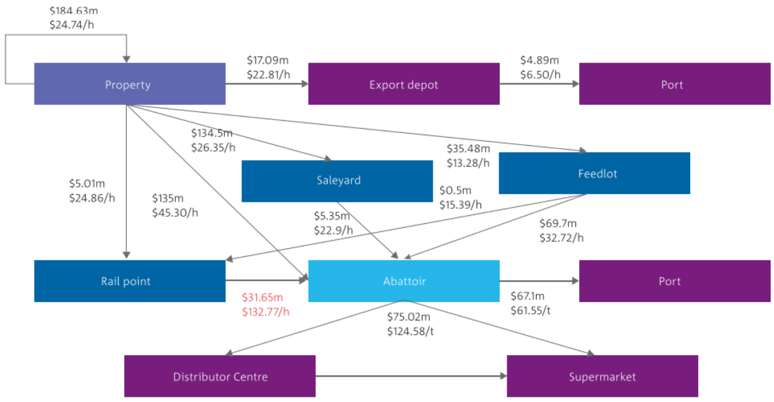


Figure 30. Modelled annual transport costs for the beef supply chain (m = million; t = tonne; hd = head). Red denotes rail costs

The below is a movement channel for dairy movements:

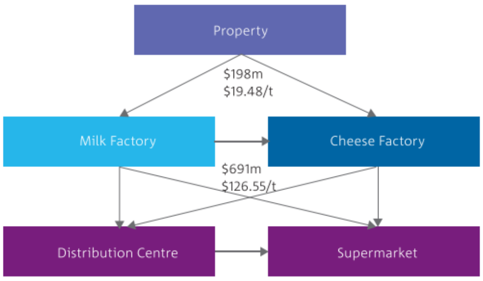


Figure 33. Modelled annual transport costs for the dairy supply chain (m = million; t = tonne)

Creating commodity flows in a Supply-chain simulation Model:

Commodity flows models use sequential probabilities to inform all flows. I.e. the probability of freight being a certain commodity and following a certain path. Probabilities are to be informed by actual data.

Examples of data informing probabilities within the flow model:

Data	Probability inference
CFS and Telematics Commodity Data	Probabilities based on samples of certain commodities moving between certain SA's on particular modes in particular vehicles.
Production data	Probability of freight of a certain commodity being generated in a certain SA.
Consumption/Population Data	Probability of certain commodities (consumables) being consumed in a certain SA.
Import Data	Probability that a certain commodity has entered NZ via a particular mode, via particular port and onto a particular unpacking location (if available from NZ Customs data)
Export Data	Probability of a particular commodity departing a particular port based on proximity to port.
Rail data	Probability of a certain commodity with a particular OD pairing being moved on rail.
Telematics and RUC Data	Probabilities of certain routes being used by time of day by OD pair.

Many other data sets can be used to inform probabilities, such as airfreight data, coastal shipping data, data from airports and ports etc

Developing probability distributions based on observed movement data
System balancing is based on providing the 'most likely' flow of freight based on obtained data. Probability distributions become more accurate the more granular data is available, for example, if considering imports and exports flowing in and out of a port then the probability of the freight moving to and from a certain SA may be highly dependent on what type of freight it is. If there is a relationship between commodity and OD distribution, then this can be tested via regression analysis. By using a Bayesian Probability method multiple factors which have relationships with OD distributions can be used to build more accurate probabilities based on increased knowledge of real-world movements.

Synthetic Data Generation
This step involves a simulation / stock and flow model which uses all the probabilities developed to create a clean synthetic data sets which is self-balancing based on known system, inputs and outputs.
This synthetic data is a clean dataset which is based on any accessible evidence to inform probabilities of something being true. Probabilities build on each other to develop granularity, layers of probabilities can be added in as more detail becomes necessary or know.
Calibration involves adjusting parameters which essentially adjust probabilities to result in what we expect to see given real world observed movements.

Route and Traffic Assignment

There are three prevailing options with regard to route/network assignment for this supply-chain modelling approach.

1) Use telematics, traffic counts, weigh-in-motion and other movement data to inform actual route assignment and include this within the supply-chain model as a probabilistic outcome (informed by actuals).

2) Produce an OD Table where trucks are converted into Passenger Car Units (PCU's) and input these into an existing strategic transport model (or in this instance that could

be Project Monty) and use that model to map routes which would take into account background traffic and impedances.

3) Follow the route assignment logic as per the Four Step Model approach above.

Ideally all three would be tested and available for use in ongoing modelling.

Truck Tour Modelling

Once commodity flows have been probabilistically distributed by the model,[25] Agent based truck tour modelling is to be used in the supply-chain simulation model. The process outlined as part of the Four-Step Model should be followed here.

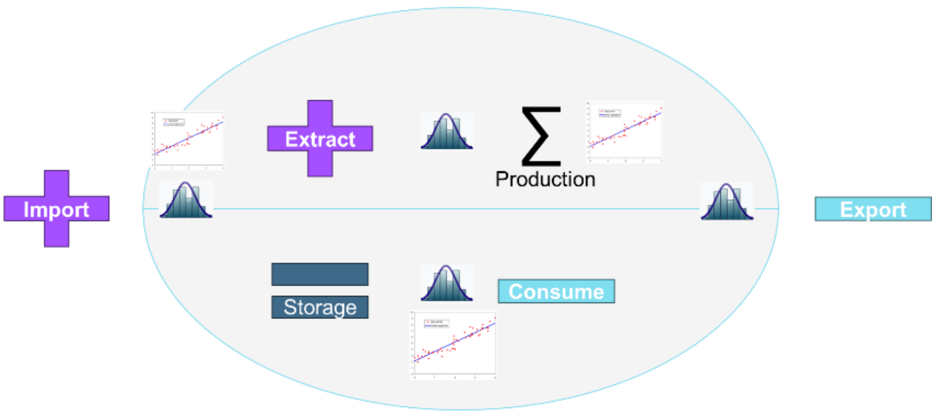
System Balancing and Calibration:

So far all data is based on samples and these samples need to be built up to reflect the total movements within the system. As opposed to linear extrapolation this system balancing method balances each node (SA) and then balances the overall model against known inflows: imports, production/extraction and outflows: exports, consumption and waste/disposal.

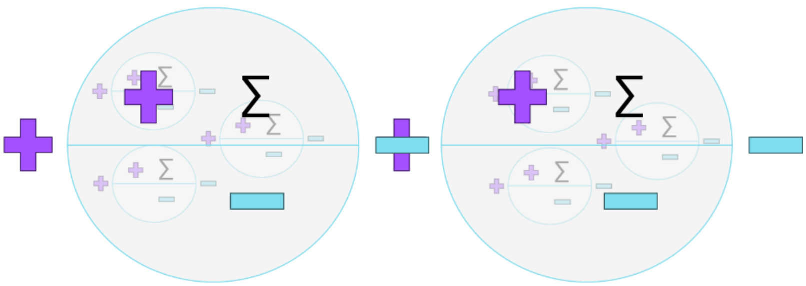
The model essentially holds probabilities true and where they do not balance there is a system accumulation or a system deficit. These accumulations need to be investigated and will may result in a calibration (adjustment) based on likely reasons or further inquiry.

The model is made of nodes which have inputs, outputs, generation (extraction), production (transformation), storage, consumption and outputs). Levels of balanced nodes reconcile to an overall system balance as illustrated below.

System Level Balance:

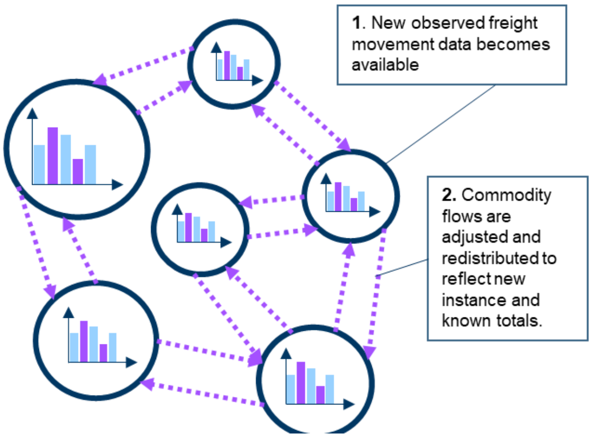
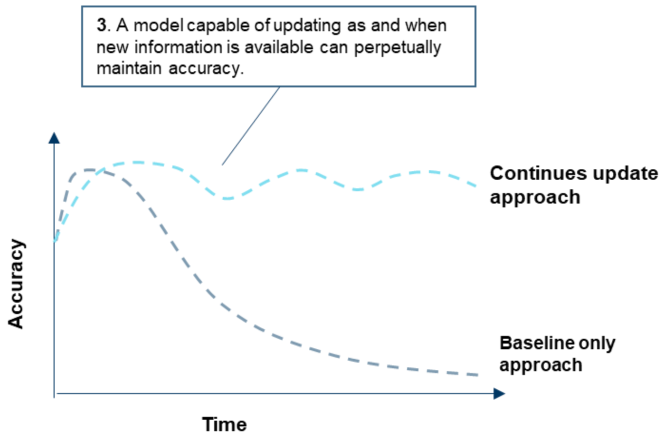


Balanced nodes at a regional level:



Balanced nodes at the most granular SA level:

[25] Not that probability-based allocation is not an all-or-nothing allocation, it's an allocation which proportionately distributes.

	
Progressive model updates and scenario development	The process of developing and updating probabilities is never complete, it is continuous. The process of updating the probabilities is to be made easy. Changing of probabilities is also how alternative scenarios are created so these need to be parameterised for the purposes of scenario development. The illustration below shows the redistribution capability of a system flow and balance model.  Supply-chain simulation and System Balance Models can be constantly updated meaning that they can stay relevant for longer as compared to models which may mean re baselining.  **Scenario Builder** For this option, the scenario builder is essentially a way to manipulate the baseline probabilities to generate synthetic data sets which represent an alternative future. Probabilities can be altered over time (i.e. increasing probability of a truck being an EV truck, or the probability of a commodity drastically reducing). This approach is deterministic as opposed to stochastic however probability can use Monte Carlo and other methods to partially add in some randomisation.
Model Validation	Same as Four Step approach above.

Model handover and user guides	Same as FourStep approach above.

Model Development	
Dynamic Simulation	

A dynamic simulation borrows aspects from the Four-Step Model process and the Supply-chain simulation and System Balance Model and adds in the use of Discrete Event Simulation (DES) and Agent Based Modelling (ABM)

Aspects from four-step and supply-chain modelling options used in this Dynamic Simulation Option:

Common Component	Application in this option
Commodity flow data	This is the same in this option, both commodity data from telematics providers and a CFS is used.
Forecasting	This is conducted in the same way.
Econometrics used to predict independent variable (commodity)	If this is proven to be valid then this data is used in this option.
Trip Generation	This uses the probabilistic approach from the supply-chain modelling. Probabilities are generated from commodity flow data which utilise econometrics if it is valid, or they use sample probabilities purely based on commodity flow data.
Tour Modelling – Agent Based	This is applied the same way but can be expanded beyond last mile.
Development of Distribution channels	This is from the supply-chain simulation approach and is used here also.
System Balancing	The dynamic simulation uses system balancing also, by SA level and nationally.

Key additions in the Dynamic Simulation approach:

The key areas of difference in this option are the use of DES and ABM to more accurately represent the transport equipment used to move freight, across all modes. This approach ultimately provides much greater ability to run meaningful scenarios and see more representative outcomes by using stochastic approaches and real-world behaviour characteristics, constraints and movement patterns.

Combining DES and ABM allows the creation of a comprehensive national freight movement model that considers both system-level processes and individual agent behaviours. The choice between methods depends on the specific aspects of freight logistics being modelled and the desired level of granularity.

Discrete Event Simulation:
DES is used to replicate modal movements which have schedules and patterns and freight which moves through various stages. This is particularly powerful and many freight movements do work to schedules and patterns. For example:

- Shipping routes schedules
- Airfreight routes and schedules
- Rail movements
- Linehaul truck services (informed by commodity flows)

These schedules can be replicated through simulation. They should also be developed to enable some flexibility to adjust up and down with demand, this flexibility should be programmed in to reflect realistic short-term, medium- term and long-term flexibility. Events

	can be fixed (schedules) or random. In any case, the idea is that they happen on a discrete basis, which would depend on the time resolution of the model (i.e. seconds, minutes, etc) When choosing which movements to replicate using DES the strengths of the method should be kept in mind: Use DES when the movement is or would benefit from: - Event driven movements: DES captures specific events (e.g., arrival, departure) and their impact on the system. - Queue Modelling: Ideal for scenarios involving queues, such as freight terminals or warehouses. The method may be applied to: - Hub Operations: Modelling freight handling at distribution centres, warehouses, and terminals. - Bulk Loading/Unloading: Simulating bulk cargo handling (e.g., containers, pallets). - Resource Allocation: Assessing optimal server (resource) allocation. Capacity constraints can also be programmed in against this flexibility to adjust movements up. DES is very useful at being able to show future capacity utilisation. **Agent Based Modelling:** ABM is used the same way for tour modelling to represent last mile deliveries but within this option its use can be extended on a needs basis. ABM can also be used for: - All truck movements including light commercial vehicles - Some more versatile rail movements - As a means to account for belly-hold air cargo - Data and information flows Importantly ABM enables agents to be programmed based on their decision-making criteria and they make individual decisions based on the exact environment at the time of making the decision. When deciding on which aspects of the model should use ABM, consider the strengths of ABM as: - Accounting for individual behaviour: ABM captures heterogeneity and individual decision-making. - Emergent Properties: It reveals emergent system-level behaviours arising from agent interactions. - Spatial Context: Useful for modelling complex spatial relationships (e.g., complex urban freight environments with many route options). The method may be applied to: - Carrier Behaviour: Modelling carriers' route choices, pricing strategies, and capacity utilization. - Network Effects: Capturing interactions between carriers, shippers, and infrastructure. - Last-Mile Delivery: ABM excels in modelling complex last-mile logistics (e.g., urban delivery routes). Model Development Process:

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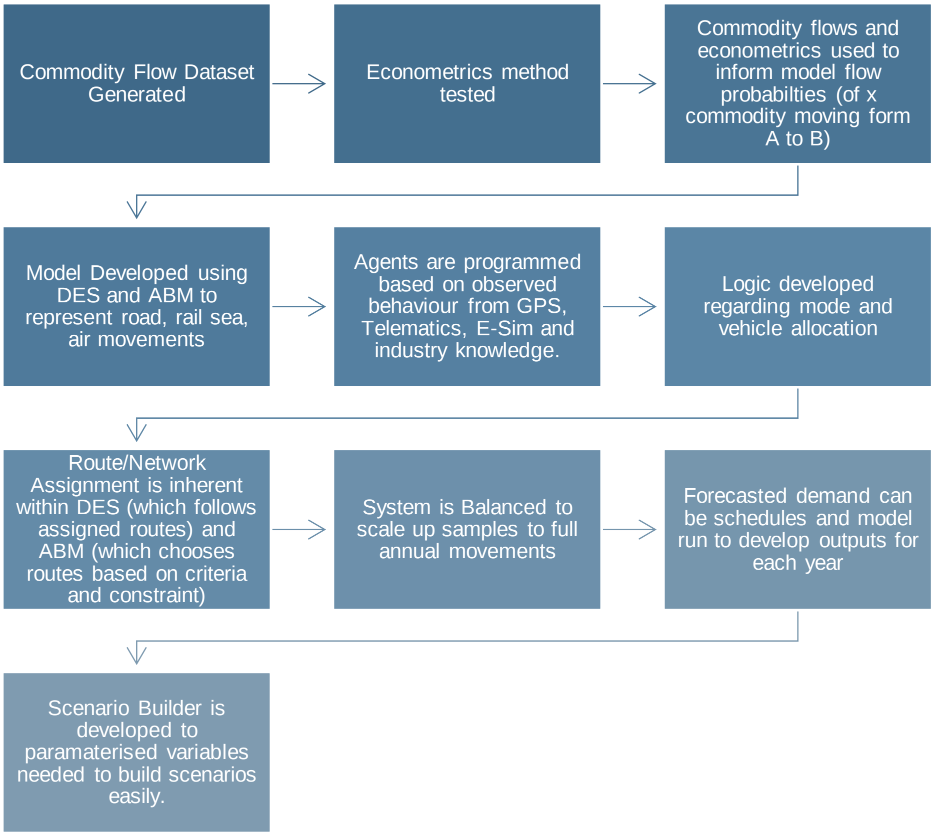

Ability to optimise system:

The dynamic simulation should be designed to be capable of optimisation and goal seeking desired outcomes. For example, the below optimisation exercises should be possible:

Unconstrained time of day movements and seek lowest cost outcomes to observe when freight would move.
Introduce electric vehicles and increase carbon price until they are the preference, observe for initial types of movement and routes used.
Constrain or close key links or nodes to observe impact and rerouting.
Constrain driver numbers in future and observe impact.
Decrease cost of rail to observe mode shift.
Create shipping delays to observe freight build ups.
Introduce higher productivity freight vehicles and observe uptake and productivity impact and utilised routes.

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<td>Model Validation</td>
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<td>Model handover and user guides</td>
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