Development of a New Zealand National Freight Matrix

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Introduction

This report documents the process and findings of a Land Transport New Zealand research study carried out between 2003 and 2005.

The study objective was to:

- develop estimates of the main (non-urban) freight movements within New Zealand, by commodity, tonnage, mode and origin-destination;
- relate these movements to the location of processing/export facilities in the case of primary flows, and
- relate them to population and industrial production in the case of manufactured and consumer goods.

In particular, the focus was on:

- longer-distance and higher tonnage movements; and on
- existing movements, rather than forecasts of future freight movements.

Freight transportation is one of the key but often overlooked areas of transport policy. Policy decisions made by government can have a substantial impact on the movement of freight. However, the requirements, patterns and complexities of the freight market are not well understood and the management of these is often left to industry to resolve. The lack of information has made it difficult to estimate impacts of policy changes and to understand and plan for freight movements to, from and within the regions.

This study aims to begin the process of filling the information void. It provides the reader with a broad overview of the types of freight transported, the methods used to move it, freight origins and destinations, and establishes a basis for further more detailed research into this topic. The focus is on the land transport modes of road and rail, with some investigation of coastal shipping (excluding inter-island ferries). The study commences with an overview of the freight transport environment and industry, and then describes the matrix and the methodology used to build it.

Overall approach to development of a freight matrix

The overall approach taken to develop the matrix of long-distance higher tonnage freight movements is outlined and the parameters around which it was constructed are summarised.

Data collection

The two elements to the collection of data used to build the initial road freight matrix are detailed, and are:

- an initial research phase, which was used to identify key industries and firms and provide a platform for further research, and
- a subsequent general data collection phase that utilised market surveys of freight consignors or carriers, and other publicly available data sources to collect background data.

Data analysis and the rail matrix

The data collected, the analysis and classification procedures used are described, and details are given of the inputs to the process of road matrix estimation and the final rail matrix. This analysis involved the collation of data from all sources, standardisation to the base year (2002) and to a common format, and the categorising of it by commodity and mode. Individual modes were then separated, allowing the complete rail matrix to be constructed directly from the available data, with rail bypassing the subsequent road matrix estimation process. Data deficiencies precluded the creation of a final sea matrix and split by commodity.

The road matrix and final matrix

The development of the road matrix of freight movements is explained. Matrix estimation formed the core part of the development of this matrix due to the limited range of road-based data available. This process began with an initial matrix based on available industry data, then used link-based data in the form of road traffic counts to update the initial matrix in an iterative process until convergence was reached. Once completed, the road matrix was combined with the rail matrix to give a total land transport matrix.

Freight-trip-end model

The development of a total freight-trip-end model is examined and compared with the total matrix to check its suitability as a simplification of the previously applied matrix estimation process. A trip-end model for freight origins/destinations takes the freight productions/attractions estimated by the matrix estimation process and tries to relate these to explanatory variables. This is simpler to implement than the full matrix approach, does not require detailed data collection, and it gives the ability to crudely estimate future year matrices. The resulting matrix is not as accurate as the fully estimated matrix.

Conclusions

Matrices of movements for the main land transport modes of road and rail are provided for the 2002 year, listing the approximate tonnages moving between and within origin and destination regions. An indication of the significant commodities and industries utilising the freight networks is also provided. This is the first time in New Zealand that such matrices have been attempted or that inter-regional freight movement has been investigated in this detail.

The main findings are:

- Of the three main modes (road, rail, shipping), road transport conveys most freight within New Zealand, having an approximate 83% share of tonnage and a 67% share of tonne-km. Rail has an approximate 13% of tonnage and 18% of tonne-km, and coastal shipping has a corresponding 4% of tonnage and 15% of tonne-km. Road has the shortest average haul of the three main modes, while coastal shipping has the longest.
- Three regions – Auckland, Waikato and Bay of Plenty – account for the production and attraction of over half of all road and rail freight, reflecting a concentration of population and industry. Canterbury, the largest region by area, is the only other region with a share of more than 10% of freight productions and attractions.

- Over two thirds of all road movements are of less than 200 km, with the Auckland region dominating with around a quarter of both the production and attraction of all freight. The greatest road tonnage corridors are, in descending order, Auckland to Auckland, Canterbury to Canterbury, Waikato to Waikato, Bay of Plenty to Bay of Plenty, Waikato to Auckland, and Waikato to Bay of Plenty. These corridors account for nearly half of all road freight tonnage and show the preponderance of short-haul movements by road.
- Higher rail tonnages correspond to the locations of major industrial plants, mines and ports. The greatest tonnage corridors for rail are, in descending order, Bay of Plenty to Bay of Plenty, West Coast to Canterbury, and Waikato to Bay of Plenty. These three corridors account for nearly half of all rail tonnage.
- A significant proportion (over half) of all freight cannot be easily classified into the specific commodity groups as defined. This includes general freight movements, and those relating to wholesale/retail, construction and other business sectors.
- The primary industries of agriculture and forestry are the largest originators of freight that can be categorised into a specific commodity group. The transport of logs, milk and livestock account for a significant share of total freight movements.
- A trip-end model for freight origins and destinations shows some correlation to the modelled matrix, but further improvements in both the data and process would be required to achieve a reasonable level of accuracy.

The results of this study have been limited by the availability of data and the associated assumptions that have had to be made. The issue of commercial confidentiality reduced both participation in the survey phase and the usefulness of the data supplied. This coupled with the lack of statistics measuring freight and commodity data by weight have restricted the detail that could be included. Additionally, the constantly evolving nature freight transport market has limited the results presented here to a snapshot only of the economy as it was in 2002. Nonetheless, the work is a considerable advance on anything available previously.

Improvements to developing a freight matrix

A number of recommended improvements could be made to the processes of developing the freight matrix presented in this report, which would allow a more detailed matrix to be developed and enhance the detail and results available.

For the full matrix such improvements would include:

- The compilation, by organisations such as Statistics New Zealand, of detailed statistics relating to weight of goods transported. Where data is currently collected, it is often recorded using measures other than weight, limiting its usefulness for tasks such as this.
- The collection of more complete observed data, by Transit New Zealand and other organisations, such as the split of heavy vehicle types at telemetry sites.
- The use of better estimates of average loads, which would improve the accuracy of the estimation process by limiting assumptions. The improvements to the collection of data listed above might allow better estimates to be prepared.

- For traffic counts, a review of the annualisation process to relate this more to the movements of commercial vehicles. Average daily flows are currently designed primarily to match general traffic patterns that are dominated by car journeys, and they may therefore underestimate the weekday-oriented patterns associated with commercial vehicles.
- Improvement of the modelled roading network and functions to take account of speed, gradient, and road curvature, etc. This would allow a more accurate model of the national transportation networks to be developed.

For the trip end approach such improvements would include:

- The collection of more disaggregated industry employment data for the trip-end model.
- The investigation of the feasibility of introducing factors to the matrix balancing process. This would allow times or costs to be modified, to correct for inaccuracies in the network or take account of perceptions and functions.

Further work

Three principal directions that future work might take are:

- The ongoing monitoring of the freight sector, which might involve the update of the model every 2-3 years, to measure historical trends and increase knowledge of the factors affecting the movement of freight in the New Zealand context.
- Use of the model to forecast future freight movements. This would be a valuable tool for the planning of future requirements for roads, railways, ports and other freight facilities.
- The application of this process to create detailed freight matrices at the regional or even TLA level. These would have a higher level of detail and could be combined as required to look at freight movements within a specific geographic area (for example, the southern South Island).

Abstract

Freight transportation is one of the key but often overlooked areas of transport policy. Policy decisions made by government can have a substantial impact on the movement of freight. However, the requirements, patterns and complexities of the freight market are not well understood and the management of these is often left to industry to resolve. The lack of information has made it difficult to estimate impacts of policy changes and to understand and plan for freight movements to, from and within the regions.

This study carried out between 2003 and 2005 aims to begin the process of filling the information void. It provides the reader with a broad overview of what freight is transported, where and how it is moved, and establishes a basis for further more detailed research into this topic. The freight transport modes that are studied are road, rail and to some extent coastal shipping.

1. Introduction

1.1 Background

This report presents the findings of a research study undertaken as part of the Land Transport New Zealand (formerly Transfund) 2004/05 Research Programme. The subject, the Development of a National Freight Matrix, was initially part of the 2003/04 Research Programme and was extended into the 2004/05 programme to allow completion.

As set out in Booz Allen Hamilton's proposal of April 2003, the objective of the study was to:

- develop estimates of the main (non-urban) freight movements within New Zealand, by commodity, tonnage, mode and origin-destination;
- relate these movements to the location of processing/export facilities in the case of primary flows, and relate them to population and industrial production in the case of manufactured and consumer goods.

In particular, the focus was on:

- longer-distance and higher tonnage movements; and on
- existing movements, rather than forecasts of future freight movements.

1.2 Report structure

The report is structured as follows:

- Chapter 2 provides a background overview of the New Zealand freight transport environment and industry.
- Chapter 3 presents an outline of the approach taken to developing the matrix and a summary of matrix parameters.
- Chapter 4 details the collection of supporting data.
- Chapter 5 describes the analysis and classification of the data, and presents the rail matrix.
- Chapter 6 explains the development of the road matrix, and presents this and the final combined road and rail matrix.
- Chapter 7 examines whether an alternative freight trip end model can be developed, and whether using such a model is a suitable simplification to the matrix estimation process.
- Conclusions are reached in Chapter 8.

2. Background

2.1 Context

Freight transportation is one of the key but often overlooked areas of transport policy. Policy decisions made by government can have a substantial impact on the movement of freight. However, the requirements, patterns and complexities of the freight market are not well understood and the management of these is often left to industry to resolve. Although earlier New Zealand studies have investigated various aspects of domestic policy in this field, none have focused on the composition of long-distance (or local) freight movements in terms of commodities moved, tonnages, origin-destination patterns and mode shares, or investigated the relationships between them. The lack of information has made it difficult for national policy makers to estimate the impacts of any policy changes (pricing, regulation, etc.), and for regional planners to understand and plan for freight movements to, from and within their regions.

This study aims to begin the process of filling the information void. It provides the reader with a broad overview of what freight is transported, where and how it is moved, and establishes a basis for further more detailed research into this topic. It commences with an overview of the freight transport environment and industry.

2.2 The freight transport environment

The movement of freight within New Zealand is governed by several influencing factors, which include both the country's geography and various forces of supply and demand (Cavana et al. 1997). These factors define the freight transport task by encouraging the production and attraction of freight to specific locations, and affect the methods and modes used to move it. The consequent links result in a complex network of transport movements.

Geographically, the most important feature from a transport perspective is the arrangement of New Zealand as two elongated main islands separated by a passage of water (Cook Strait). As a consequence of this layout, each island has complete and self-contained road and rail networks, linked with the other island via coastal shipping and inter-island road and rail ferries to form a national network, and with the outside world through gateways at international sea and to a lesser extent airports. Mountainous terrain and the distribution of population dictate the course that the land transport networks follow within each island.

Freight flows from points of supply within the system (origins), such as places of harvest in rural areas or manufacturing plants, to points of demand (destinations), such as processing plants or export ports. Figure 2.1 illustrates the general freight flows within the system. The actual flows can be highly complex and can involve many intermediate or additional steps, involving trans-shipment, warehousing, or movement between multiple manufacturing plants or distribution centres. The flows can be thought of as consisting of two types:

- 'Major' one-to-one or many-to-one flows associated with specific activities or industries. Examples would include the movement of export pulp from a manufacturing plant to a port of export, or the transport of milk from numerous small dairy farms to a single milk processing plant.
- 'Dispersed' many-to-many flows of multiple products and customers. An example of this type of flow would be distribution of products from multiple small manufacturers, via distribution centres to retailers across the country. Such flows might often entail consolidation of freight by LCL/LTL (Less than Container Load / Less Than Truck Load) carriers, and might involve the movement of anything from a single item on a one-off journey to multiple items following regular distribution channels.

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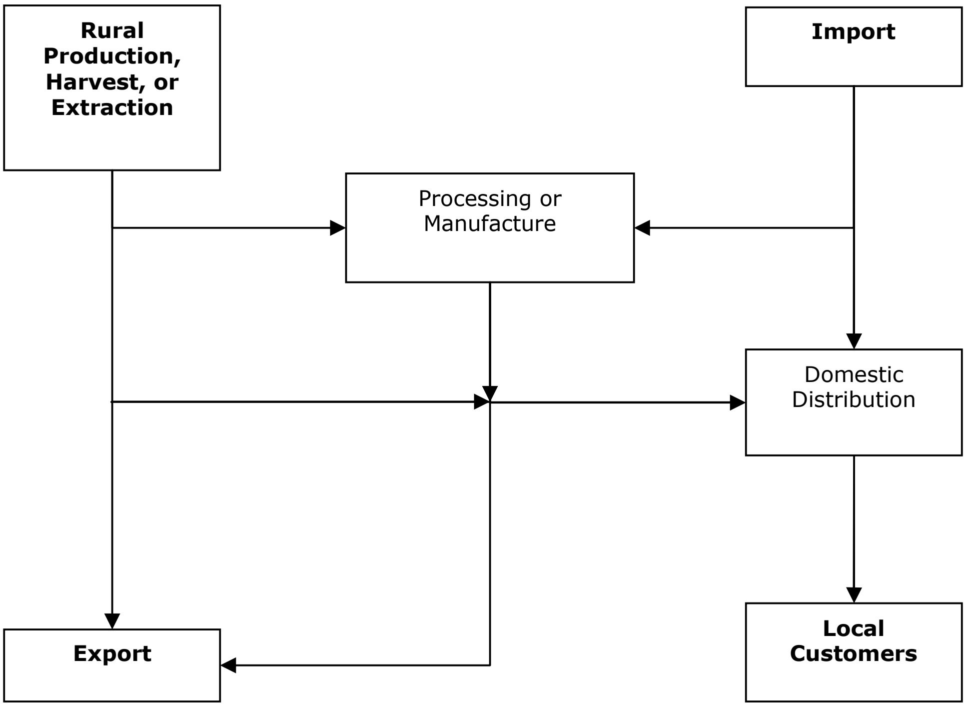

Figure 2.1 Diagram of the general freight flows in New Zealand.

Particular factors of supply and demand that are relevant to the New Zealand situation, and that form freight origins and destinations include:

- Points of rural production, harvest or extraction. In New Zealand these particularly relate to the primary industries of agriculture, forestry and horticulture, and to mining.

- The location and size of manufacturing and processing plants and the inputs that they require for production. These range from large processing plants such as Fonterra's Whareroa production facility near Hawera, to those of secondary industries that are not closely tied to local inputs.
- The distribution of population. Cavana et al. (1997) indicate that this is an important determinant of demand and, as a result, that it also influences the design of logistics and distribution channels, particularly those relating to the service industry. In the New Zealand context, population is not evenly distributed, with the northern North Island dominating in both population and industrial activity. Much of the warehousing and secondary industry is accordingly clustered around the Auckland region, resulting in consumer-related distribution flows that operate in a predominantly north-south direction. Table 2.1 shows the breakdown of population by region from the 2001 census. Table 2.2 summarises industrial activity from Appendix B, which lists the number of geographic units and employees in each region that were involved in broad industry groups in the 2002 year.

Table 2.1 Population by region from 2001 census.[1]

Region	Population	Share of National Total (%)
Northland Region	140,133	3.7
Auckland Region	1,158,891	31.0
Waikato Region	357,729	9.6
Bay of Plenty Region	239,412	6.4
Gisborne Region	43,974	1.2
Hawke's Bay Region	142,950	3.8
Taranaki Region	102,858	2.8
Manawatu-Wanganui Region	220,089	5.9
Wellington Region	423,765	11.3
Tasman Region	41,352	1.1
Nelson Region	41,568	1.1
Marlborough Region	39,558	1.1
West Coast Region	30,303	0.8
Canterbury Region	481,431	12.9
Otago Region	181,542	4.9
Southland Region	91,005	2.4
Area Outside Region	726	< 0.1
TOTAL	**3,737,286**	**100**

[1] Source: Statistics NZ (2004).

Table 2.2 Industry by region (2002).[2]

Region	Count		Share of Total		Employees / Geographic Unit
	Geographic Units[2]	Employees	Geographic Units[2] %	Employees %	
Northland Region	10,719	39,800	3.5	2.6	3.7
Auckland Region	108,789	503,650	35.1	33.4	4.6
Waikato Region	27,455	123,830	8.9	8.2	4.5
Bay of Plenty Region	18,984	83,820	6.1	5.6	4.4
Gisborne Region	2,780	14,500	0.9	1.0	5.2
Hawke's Bay Region	10,295	53,420	3.3	3.5	5.2
Taranaki Region	7,272	37,110	2.3	2.5	5.1
Manawatu-Wanganui Region	15,161	79,940	4.9	5.3	5.3
Wellington Region	36,994	200,030	11.9	13.3	5.4
West Coast Region	2,393	10,760	0.8	0.7	4.5
Canterbury Region	37,123	201,750	12.0	13.4	5.4
Otago Region	14,228	74,940	4.6	5.0	5.3
Southland Region	6,775	36,300	2.2	2.4	5.4
Tasman Region	3,108	11,350	1.0	0.8	3.7
Nelson Region	3,970	20,930	1.3	1.4	5.3
Marlborough Region	3,555	15,610	1.1	1.0	4.4
Area Outside Region	148	260	<0.1	<0.1	1.8
TOTAL	**309,749**	**1,508,000**			**4.9**

- Ports of import and export. These range from large general ports such as Tauranga, to the industry-specific ironsand export 'port' of Taharoa in the Waikato region. If oil imports through Marsden Point are excluded, Auckland can be considered the largest import port, reflecting its dominance as the most populous city and major industrial area. Tauranga is the largest export port, largely due to its proximity to major forestry and agriculture-related export industries. Tables 2.3 and 2.4 list the key import and export air- and seaports (those with tonnages over 1000 tonnes per annum), ranked by tonnage. These show that two thirds of all imports pass through the top three import ports, with over half of all exports passing through the top three export ports. Airports carry only an insignificant share of freight tonnage but this will be of particularly high value goods.

It should be noted that the freight transport market is dynamic and constantly changing. Changes in the world and local economies impact on individual industries, changing demand levels for products and consequently changing the volumes of freight moved and the methods used to move it. This study designated 2002 as the base year (refer to Section 3.3.1 for details) and it therefore reflects the patterns of supply and demand that were in place during that year.

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2 Source: Statistics NZ (2004). Refer to Appendix B for the full breakdown by industry. Geographic Units are defined as "separate operating units engaged in one or predominantly one kind of economic activity from a single physical location or base".

Table 2.3 Imports by port for year ended 2003.[3]

Port	Gross Weight (tonnes)	% Share of National Total
Whangarei / Marsden Point	5,444,743	33.7
Auckland Seaport	3,630,303	22.5
Tauranga Seaport	1,863,903	11.5
Christchurch Seaport (Lyttelton)	1,268,541	7.9
Invercargill Seaport (Bluff)	1,048,066	6.5
Wellington Seaport	1,009,034	6.2
Napier	684,084	4.2
New Plymouth	442,061	2.7
Timaru	287,243	1.8
Dunedin (Port Chalmers)	263,728	1.6
Nelson	97,679	0.6
Auckland Airport	77,044	0.5
Westport	23,805	0.1
Christchurch Airport	9,416	0.1
Wellington Airport	1,467	< 0.1
TOTAL	**16,151,117**	

Table 2.4 Exports by port for year ended 2003.[3]

Port	Gross Weight (tonnes)	% Share of National Total
Tauranga Seaport	7,864,543	31.0
New Plymouth	3,236,578	12.8
Christchurch Seaport (Lyttelton)	2,978,857	11.8
Auckland Seaport	2,006,391	7.9
Napier	1,975,668	7.8
Whangarei / Marsden Point	1,678,995	6.6
Nelson	1,132,750	4.5
Dunedin (Port Chalmers)	1,063,654	4.2
Taharoa	743,492	2.9
Wellington Seaport	634,333	2.5
Gisborne	605,786	2.4
Invercargill Seaport (Bluff)	577,218	2.3
Timaru	385,331	1.5
Picton	282,079	1.1
Auckland Airport	75,326	0.3
NZ Various	40,904	0.2
Westport	28,859	0.1
Christchurch Airport	17,840	0.1
Wellington Airport	1,338	< 0.1
TOTAL	**25,329,941**	

3 Source: Statistics NZ (2003a).

2.3 The freight transport industry

To perform the freight transport task, New Zealand has a highly competitive long-distance domestic freight transport industry. Services are provided by numerous single-mode and multi-modal freight companies which include road-based (truck) operators, rail (part of a multi-modal business that includes road and sea divisions), coastal shipping (provided by both local and international shipping companies), pipelines, and air transport carriers, with competition occurring between both operators and modes.

While many of the transport companies involved in the New Zealand industry confine themselves to a particular mode or niche area of specialisation, the trend within the industry, across all modes, is towards greater consolidation and the provision of a wider range of service offerings. Most of the major freight providers thus offer a broad array of additional logistics services, covering the entire supply chain and including such areas as warehousing and international freight. The larger freight companies do not confine themselves to one transport mode, but instead use multiple modes to take advantage of the particular time/cost/capacity advantages that each alternative offers.

This report focuses on the three main freight transport modes in terms of tonne-km: road, rail, and coastal shipping. Figure 2.2 indicates that these provide the majority (over 99%) of non-pipeline freight transportation. Pipelines are used primarily to move gas and petroleum products; with the most important being the Marsden Point-Auckland petroleum products pipeline (conveying one third of the Marsden Point oil refinery's output) and the Maui and NGC long-distance gas transmission pipelines. Air freight is primarily used to carry time-sensitive or perishable products (Cavana et al. 1997), reflecting its comparatively high cost and low capacity, and it therefore has only a minor share of the freight tonnage carried and tonne-km travelled. Figure 2.3 indicates the approximate share of tonnage carried by the respective modes.

The dynamic market for freight transportation described in Section 2.2, and intense competition between transport industry participants, has led to a continuously changing industry environment. Some of the more noteworthy changes that have occurred since the 2002 base year include:

- The 2003 acquisition of the railway company Tranz Rail (following financial difficulties) by an Australian logistics company Toll Holdings, and the subsequent transfer of the track and associated infrastructure to government ownership.
- A number of amalgamations between other freight carriers, the biggest of which was the 2003 consolidation of two of the largest transport companies, Mainfreight and Owens Group.
- A reduction in the number of vessels employed on coastal routes by the main New Zealand-based coastal shipping operators.

Figure 2.2 Estimated mode share by tonne-km (2002).[4]

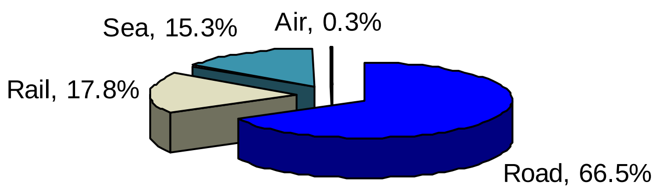
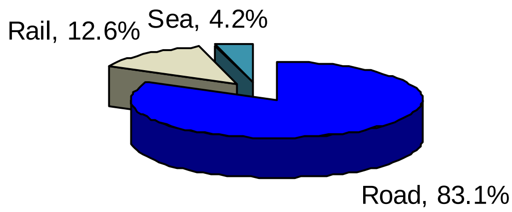


Figure 2.3 Estimated mode share by tonnes carried (2002).[5]



2.3.1 Road transport

Road transport is the dominant freight transport mode, with an estimated 67% of the total tonne-km moved (Figure 2.2). Many of the road movements that contribute to this mode share are short distance local moves; however a substantial number are longer distance movements that often compete directly against other modes utilising the 10,700 kilometres of the state highway network. The principal advantage of road stems from its ability to serve customers directly, accessing and using the roading network as required. Rail and coastal shipping do not serve most freight customers directly and must therefore rely on road transport to 'bridge' freight to their networks.

The transport of freight by road has increased considerably over time, particularly since the 1983 removal of restrictions that prevented road transport from operating in direct competition with rail. A recent profile of the heavy vehicle fleet by TERNZ[6] (2004) estimated that 19,450 million road freight tonne-km were operated in 2003, based on the collection of Road User Charges (RUC), which compared to RUC-based estimates of 13,134 million tonne-km in 1996 and 8,854 million tonne-km in 1990 (Cavana et al. 1997). The TERNZ estimate compares with the lower 2002 figures of 12,923 tonne-km

4 Note: Intended as a guide only. Road and rail shares are based on the findings of this study, coastal shipping (sea) share is calculated from Ministry of Transport (2005a) and excludes inter-island ferry traffic, air share is extrapolated from Cavana et al. (1997).

5 Note: Intended as a guide only. Road and rail shares are based on the findings of this study, coastal shipping (sea) share is calculated from Ministry of Transport (2005a) and excludes inter-island ferry traffic.

6 TERNZ: Transport Engineering Research NZ.

calculated by this study, and 15,782 million tonne-km calculated (and used as an input for this study) from the 1999 figures of the HVLP project[7] by Transit NZ (2001). However the RUC-based estimates are based on a number of assumptions and are susceptible to inaccuracies associated with the correct purchase of RUCs.

The road tonne-km were operated by three component groups:

- public carriers, which sold transport services to the market;
- own-account or private carriers, which performed an 'in-house' task hauling their owners' freight; and
- contract carriers, which contracted services to the two previous groups.

The commercial road freight transport industry, consisting primarily of public and contract carriers, operated approximately 30% of the heavy vehicles over four tonnes[8] in 2003. The balance of vehicles were owned and operated by groups not primarily involved in road transport, such as tradespeople, contractors, local councils and manufacturers.

The commercial industry is characterised by a large number of small operators, with 80% of firms having five or fewer employees or vehicles (Road Transport Forum NZ 2004), which is comparable with the road industry in other similar countries such as Australia. This characteristic has not varied considerably from pre-deregulation levels as an early 1970's study by King (1971) showed that 87% of firms had five or fewer vehicles at that time, although it should be noted that modern vehicles are larger (up to 44 tonnes) and operate over longer distances than their 1970's counterparts did. Many of the smaller operators provide contract services to the bigger operators and larger transport firms often make significant use of a contracted owner-driver base.

2.3.2 Rail transport

Rail is the second largest mode in terms of freight tonne-km moved, with an approximate 18% market share (Figure 2.2). Because of its cost structure, it tends to be more competitive in the high tonnage and/or long distance freight markets and consequently has a greater market share in those areas than in the short distance or lower tonnage markets.

The New Zealand rail system covers a network of 3898 kilometres, stretching from Otiria in Northland to Bluff in Southland. A main trunk line runs from Auckland to Invercargill via Hamilton, Palmerston North, Wellington, Christchurch, and Dunedin, and most other major towns are served by either secondary or branch lines. Inter-island road/rail ferries between Wellington and Picton link the lines in each island.

7 The HVLP study (Heavy Vehicle Limits Project) contained a comprehensive investigation into the level of payload tonne-km for the 1999 year. It was selected for its ability to provide a tonne-km breakdown by region and commodity.

8 22,900 of the 82,700 vehicles over four tonnes (Road Transport Forum (RTF) 2004).

In the base year of this study, 2002, the rail network was owned by one vertically-integrated company – Tranz Rail – that also operated all freight services over the system. This firm, then named New Zealand Rail, had been purchased from the government in 1993. In 2003, following a period of financial difficulty, a majority stake in Tranz Rail was acquired by the Australian company Toll Holdings. As part of that transaction, ownership of the rail infrastructure (such as track, signalling and related staff and assets) was transferred back to government ownership in mid-2004 (to the New Zealand Railways Corporation, now known as ONTRACK). Under the associated agreement, Tranz Rail, since renamed Toll New Zealand, has exclusive rights to operate all freight services until 2070, subject to the maintenance of minimum traffic levels.

Toll NZ, which has renamed its railway division Toll Rail, operated a fleet of 232 locomotives and 4048 wagons, and carried 14.8 million tonnes of freight equating to 3853 million tonne-km in 2003 (Tranz Rail 2003). In spite of the financial problems that led to the recent ownership changes, rail tonne-km have grown markedly since deregulation and later privatisation, moving from 2735 million net tonne-km in 1990 (Cavana et al. 1997) to the current level.

Toll currently operates three main types of freight services that were previously introduced as part of a strategic reorganisation by Tranz Rail in 2001:

- 'ITP' intermodal (container) trains;
- 'Sprint' trains aimed at freight forwarder business between the major cities; and
- 'Bulk' trains carrying bulk commodities such as coal, milk and logs.

A separate division, Toll Tranzlink (formerly Tranzlink). has a large road transport component and provides distribution services utilising all modes, while another division, The Interisland Line, operates the ferry services.

2.3.3 Coastal Shipping

Coastal shipping accounts for an approximate 15% share of total tonne-km moved (Figure 2.2). It can be divided into three component groups: inter-island road and rail ferry (not included in the estimate of mode share), private bulk shipping, and general 'public' coastal shipping. Excluding inter-island ferry traffic, this mode carried an estimated 4.9 million tonnes in 2003 (calculated from Ministry of Transport 2005a), equating to an approximate level of 3200 million tonne-km, a decline from the estimated 4800 million tonne-km handled in 1990 (Cavana et al. 1997).

Ferry services operate between the North and South Islands, linking the road and rail networks principally between Wellington and Picton. The Interisland Line and its predecessors have dominated this market, operating road and road/rail ferries between Wellington and Picton for over 40 years. The company currently operates three vessels. The main alternative, Strait Shipping, has operated between Wellington, Picton and Nelson since 1992. It diversified into the passenger service market in 2003 and currently operates two vessels.

Petroleum products, cement, coal and gas are the key bulk products transported by coastal shipping. Petroleum products, the most significant of these with over half of all non-ferry tonnage, are distributed by Silver Fern Shipping using two dedicated vessels, operating from the Marsden Point refinery to 10 regional port terminals. The vessels also back-haul condensate from New Plymouth to Marsden Point. Cement is distributed to regional distribution centres by three bulk vessels, one operated by Golden Bay Cement from the Portland cement plant near Whangarei, and the other two by Holcim NZ from the Westport cement plant. Coal is barged from the South Island West Coast to New Plymouth, Lyttelton (to supplement rail transport), and to the cement plant at Portland. Gas (LPG) is distributed by foreign vessels (that have replaced a previously dedicated domestic vessel), which are hired as required to perform coastal distribution.

Pacifica Shipping is the main domestic provider of general coastal shipping freight services and currently operates two vessels. It is supplemented by Strait Shipping. Both companies face direct competition from international shipping lines, which compete for containerised, break-bulk and odd-sized cargoes, and have an estimated 15% share of the coastal shipping market (P. Nicholas, New Zealand Shipping Federation, personal communication, July 23, 2004; verified by Ministry of Transport 2005a). This competition is a consequence of the partial deregulation of the industry in 1995, which allowed international vessels visiting the country to transport cargo between ports in competition with the domestic shipping. Prior to that, coastal shipping had been restricted to domestic operators following the international practice of cabotage. International vessels compete primarily for north-south traffic, utilising spare capacity between the unloading of imports in northern ports and the loading of exports in southern ports. Both Pacifica and Strait Shipping reduced their services and the number of vessels operated to the current level in 2003, as a result of intense price competition from the international lines (R. Grout, Pacifica Transport Group, personal communication, October 28, 2004).

3. Overall approach to matrix development

3.1 Introduction

This chapter presents an outline of the overall approach taken to develop the matrix of freight movements, and summarises the parameters around which it was constructed.

3.2 Methodology

The methodology was governed by the project's objectives, which were to estimate the main long-distance, higher tonnage freight movements, define these by commodity, tonnage, mode, origin and destination, and to relate them to the location of processing/ export facilities and to population. Given the complexity and detail required, a 'bottom–up' approach, based around the freight flows and factors of supply and demand discussed in Chapter 2 was employed to research and build the matrix. This was seen as the most accurate way of gaining the detail needed to replicate the freight transport system.

The process involved the following steps, which have also been used as a basis for the structure of the remainder of this report:

- Establishment of parameters relating to the research required for construction of the matrix. This included the definition of 'long-distance' and 'higher tonnage' in the context of this study.
- Assessment of the key industries responsible for the production and attraction of freight, to serve as a basis for the collection of data relating to 'major' freight flows. This step was undertaken in parallel with the previous step.
- Collection of data through the market survey of freight consignors for 'major' flows and freight carriers for 'dispersed' flows (defined in Section 2.2), to build a matrix of movements with known origin, destination, tonnage, commodity and mode, that could be used as a basis for the final matrix.
- Collection of data from other publicly available sources, to supplement the matrix movements collected through the market surveys. This data could then be processed to produce freight origins or destinations based on total production/ attraction of freight. Undertaken in parallel with the market survey step.
- Analysis and classification of all data collected, with separation by mode to allow a rail matrix to be constructed and a matrix estimation process to be used to estimate the balance of unknown road movements. An intended coastal shipping matrix could not be completed.
- Development of the road matrix using the matrix estimation process. There was always an expectation that this step would be required to build the road matrix, given the high complexity and disaggregated nature of the road industry.

Known road movements were utilised to develop a seed matrix, and other information about origins and destinations was then used to build a final matrix.

- Assembly of the final total freight matrix based on the estimated road matrix and known rail matrix.
- Examination of whether a total freight trip end model could be developed and whether it would be a suitable simplification to the matrix estimation process.

3.3 Parameters

A number of parameters were defined at the start of the project. These related to the base year for the study, the classification of commodities, spatial classification (of freight origins and destinations), and other details relating to the transport movements. These were developed in parallel with the initial research into industrial activity (Section 4.2).

3.3.1 Base year

2002 was set as the base year for the study. This was selected as the year offering the greatest range of published statistical data, and was subsequently found to be the year for which survey participants most commonly provided data. For the purposes of this study, the '2002 year' was defined as any twelve-month period ending during 2002, reflecting the fact that some data related to the calendar year, while others related to financial or statistical years ending in months other than December.

To match data from other years to the base year, the 2002 levels were estimated using a freight growth index derived from Gross Domestic Product (GDP). This used constant price (Real) GDP[9] for the year ending June (selected as the mid-point of the year), multiplied by a freight growth elasticity of 1.96. This figure was calculated from inter-island freight growth for a 2003 ferry study (Booz Allen Hamilton 2003). It was supported by a 2002 report by the NZ Institute of Economic Research (NZIER 2002), which indicated that the average annual growth in Real GDP between 1988 and 2002 had been 2.3% while corresponding average annual transport growth over the same period had been 4.5%. Table 3.1 shows the growth rates used to estimate freight growth for each year.

It should be noted that tonnages estimated using these rates are an approximation only and might be inaccurate in a number of ways. The above freight growth multiplier is higher than that used in some similar studies, for example TERNZ (2003) used a multiplier closer to 1.5, and freight growth in years of high GDP growth may have been overestimated as a result.

Additionally, growth was applied uniformly to all data irrespective of trends within individual industries, so the growth in movements of some commodities might have been either under- or overestimated as a result.

9 GDP sourced from the seasonally adjusted chain-volume series in 1995/96 prices published by Statistics New Zealand (2004).

Table 3.1 Freight growth rates at a GDP multiplier of 1.96.

Year Ended (June)	GDP Growth (%)[9]	Estimated Freight Growth (%)
1995	5.1	9.9
1996	3.8	7.5
1997	3.5	6.8
1998	0.4	0.9
1999	1.4	2.7
2000	5.5	10.9
2001	1.9	3.8
2002	3.9	7.6
2003	4.1	8.0
2004	4.4	8.6

Finally, the assumption was that logistics networks had remained static for the purposes of the study, and no account was taken of the changes to individual transport routes or modes that may have occurred between the data source year and the 2002 base year.

3.3.2 Commodity groups

The classification of movements by commodity was one of the main objectives of this project. It was originally envisaged that such information would be readily available through the identification of freight flows, and that it would provide an extra dimension to the final matrix by identifying key origin-destination (O-D) patterns for individual commodities.

The New Zealand Harmonised Classification (NZHC) system, used by Statistics New Zealand and the New Zealand Customs Service, was initially chosen for the classification of commodity data. Its 98 'Chapters' (categories) were expected to provide a good level of detail. However the system was found to be unnecessarily complex for this purpose and generally did not match directly with the high tonnage commodity groupings identified (see Section 4.2). It was subsequently decided that a classification system with a reduced number of groups would provide a clearer picture of the major commodities moved, and a higher level system with a reduced number of categories (16) was created, with the groups based upon the key commodities identified and those chosen for a similar study by Austroads (2003) in Australia.

All freight movements were thus assigned to one of the sixteen groups, either to one of fifteen main commodity-based groups or to an 'Other' group (all movements that could not be allocated to one of the main groups). The 'Other' group embraced a diverse range of freight movements, including (but not limited to) general freight, wholesale and retail supply, furniture removal and construction movements. Table 3.2 lists the sixteen commodity groups, ranked by their estimated share of total road net-tonne-km, while Table 3.3 provides the final definition of each group. Appendix D gives additional details of assumptions relating to some groups. It should be noted that the composition of the groups changed slightly over the course of the study, reflecting the availability of data.

Table 3.2 Commodity groups sorted by share.

Commodity Group	Estimated Share of Total Road Tonne-km (%)[10]
Other	60.8
Logs	11.7
Milk	6.6
Livestock	6.4
Sawn Timber	2.9
Oil Products	2.6
Fertiliser	2.1
Coal	1.9
Wood Products	1.5
Produce	1.1
Cement	1.0
Minerals	0.5
Wool	0.4
Dairy	0.2
Metals	0.2
Meat	0.1
Total	**100**

Table 3.3 Final commodity group descriptions.

Commodity Group	Booz Allen Description
Other	All freight movements not fitting into the main commodity groups listed below
Logs	Logs moving from points of harvest to processing plants and ports of export (includes woodchips)
Milk	Unprocessed bulk milk moving from farms to processing plants
Livestock	Live sheep, lambs and cattle moving from farms to processing plants or export ports
Sawn Timber	Sawn timber moving from sawmills to local consumption and ports of export
Oil Products	Refined petroleum products moving from the Marsden Point refinery to retail distribution
Fertiliser	Fertiliser moving from manufacturing plants to local consumption
Coal	Coal moving from mines to local consumption or export
Wood Products	Pulp, paper and wood panel products moving from production plants to local consumption / export ports
Produce	Unprocessed fruit, vegetables and grains moving to points of consumption, export or processing
Cement	Cement moving from manufacturing plants to local consumption
Minerals	Non-coal minerals, principally lime or marble moving from points of extraction to manufacturing/distribution
Wool	Wool moving from farms to wool scourers and then to points of export or manufacture
Dairy	Processed milk products moving from processing plants to consumption or export
Metals	Steel and aluminium moving from manufacturing plants to local consumption and export
Meat	Beef, veal, lamb, mutton, pigmeat and poultry moving from processing plants to local consumption and export

Note: Other studies, such as those sourced for tonne-km references may define commodities differently.

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10 Extrapolated from Cavana et al. (1997) and Transit New Zealand (2001).

It should be noted that, while information was gathered and classified by commodity during the data collection and analysis phases, data gaps precluded the inclusion of a breakdown by commodity in the matrix building process. As a result, the final completed matrix does not classify movements by commodity as originally intended. This is discussed further in Sections 5.4 and 6.6.

3.3.3 Spatial classification

The complexity of the final matrix was dependent on the spatial level at which data was to be collected. The Territorial Local Authority (TLA) was selected as the best level to at which to work, with two advantages: it enabled New Zealand to be divided into 74 localised zones (excluding the Chatham Islands), permitting intra-regional movements to be tracked; and it allowed the use of statistical data already collected at TLA level by Statistics New Zealand and other organisations. The larger cities (Auckland and Wellington) were to be incorporated into the final matrix on a regional basis to reduce the impact of their complex localised inter-TLA movements.

All freight origins and destinations were assigned to a TLA. Where data was supplied on a regional or national basis, two principal methods were used to allocate the traffic to the correct TLA or multiple TLAs. The preferred method was to assign origins or destinations based on the statistics of some driver of supply or demand, such as the number of people employed in a relevant industry (full-time equivalents), the capacity/location of ports, the number of animals farmed, or the number of hectares planted within each TLA in the region. Where this method could not be applied, supply or demand was assigned to the largest town- or city-based TLA within a region (for example Christchurch in Canterbury), on the assumption that business and population would concentrate economic activity in that area.

All data were subsequently categorised and analysed at the TLA level, however final details have been presented at a regional level, both for clarity and because of the data confidentiality requirements described elsewhere in this report. All movements are thus assigned to fourteen region-based zones in the final matrices, which are based on regional government areas, and not to the previously identified 74 TLA-based zones.

3.3.4 Transport movements

The focus of the study was on long-distance, high tonnage transport movements, made by the main modes as previously described. Standards relating to the definition of distance, tonnage and mode were defined at an early stage to ensure that there would be consistency in the collection and processing of data.

As indicated in Section 3.3.3 above, the TLA was selected as the spatial level at which data were to be collected. This effectively defined 'long-distance' as any inter-TLA movement, and 'short-distance' as any intra-TLA movement. The complication of the variability in size between large (i.e. Southland) and small (i.e. Napier) TLAs was disregarded to maintain consistency in the approach to data collection, as was the fact that some inter-TLA movements would be localised and therefore not relevant to the study. To downplay these factors, the minimum threshold for inclusion in the study was specified as inter-TLA movements of more than 50 km and this was communicated to those approached during the survey stage (Section 4.3).

The standard unit of measurement was set as the net weight in tonnes per annum. High tonnage movements were defined as those of more than 5000 tonnes per annum to minimise the effect of irregular movements and encourage survey response. Where data was supplied in greater detail, it was included to a minimum level of 100 tonnes per annum to take advantage of availability. Where data was supplied or available in measures other than in weight (for example the number of containers/pallets moved or the volume in litres) it was converted to a weight in tonnes using a conversion factor (such as the density of 0.8 kg per litre for petroleum fuel) to allow inclusion.

Rules were also created for the definition of the mode of transport. Movements by a single mode were considered to be by a single vehicle/train/vessel for the entire journey and not split into component movements.

Movements by multiple modes (multi-modal journeys), such as barge-truck or truck-rail, were broken into their separate component movements where known.

Where the component movements were not known, it was assumed that inter-island movements would not be transhipped, and that rail and ship traffic would move by these modes for most or all of the journey (excluding local pickup/delivery), except in areas further from railheads/ports where it was assumed that there was transhipment to road.

Where the mode of transport was not specified, the movement was assumed to be by road unless data from rail and coastal shipping operators showed otherwise.

4. Data collection

4.1 Introduction

This chapter details the collection of data used to build the matrix. There were two elements to this step:

- an initial research phase, which was used to identify key industries and firms and provide a platform for further research (Section 4.2); and
- a subsequent general data collection phase that utilised market surveys of freight consignors or carriers (Section 4.3) and other publicly available data sources (Section 4.4) to collect background data.

4.2 Key industries

Initial research into key industries was undertaken at an early stage, in parallel with the development of matrix parameters. It was used to provide a platform for subsequent research by identifying the major freight generating industries and the key freight flows related to these (the 'major' flows in Section 2.2). This research allowed later research to be targeted towards the most important long distance freight flows.

A review of key industries and firms was produced. While not intended to be comprehensive, it identified major commodities using the country's freight transport system, estimated the annual road tonne-km (as a guide to total tonne-km) and national production tonnage for each commodity where possible, and provided a profile of the relevant industry and suggested key firms within it. Data was sourced from the Ministry of Economic Development, Statistics New Zealand, the Ministry of Agriculture and Forestry (MAF), and reports from a variety of other sources, and used to construct a list of significant commodities or industries and provide an approximate ranking of these by tonne-km carried. As expected given their dominance as exports, most of the high tonne-km and/or tonnage groups related to the primary industries such as agriculture and forestry, or to minerals such as coal. A copy of the industry review, with reference sources, is included as Appendix C of this report and its key findings are summarised in Table 4.1.

As described above, the commodity groups identified at this stage became the basis for the direction of further industry-based research. All groups were subsequently investigated in greater detail, although some such as the large 'Sand, Rock, Gravel, etc.' group were later excluded from the matrix because of the short-distance localised nature of the associated freight movements. Other categories such as 'Wholesale and Retail' were included in the matrix, but these were incorporated into the 'Other' group, largely because of the difficulty in identifying and quantifying most movements.

Table 4.1 Summary of key industries and firms listed in Appendix C.

Preliminary Commodity Group	Estimated 2002 Road Tonne-km (million)	Total Industry Production (million tonnes)	Road Tonne-km / Production (distance in km)
Logs	1466	20.94	70
Milk	827	14.37	58
Livestock	804	N/A	N/A
Sand, Rock, Gravel, etc.	705	31.01	23
Bulk Wood Products	545	7.10	77
Wholesale & Retail	539	N/A	N/A
Construction/Materials	456	N/A	N/A
Lime & Fertiliser	322	7.83	41
Liquid Fuels	322	N/A	N/A
Coal	240	4.46	54
Horticulture	141	N/A	N/A
Grain	59	N/A	N/A
Wool	44	0.20	226
Dairy Products	29	1.71	17
Meat	16	1.05	15
Cement	N/A	1.05	N/A
Gas Fuels (LPG)	N/A	0.22	N/A
Steel	N/A	0.20	N/A
Aluminium	N/A	0.05	N/A

Note:

(1) N/A indicates that this information was not available.

(2) Road Tonne-km/Production serves as a rough approximation of average haul in km. This is a guide only, as it is based on estimated tonne-km and assumes that all production of each commodity is transported once by road. No allowance is made for transport by other modes (rail, sea or air) or for inconsistent definitions of each commodity across data sources. It is particularly evident that this figure is higher than expected for wool. Wool production has declined by approximately 20% since the 1994 year on which the tonne-km figures are based and accounting for this would reduce average haul to around 180 km. This is still higher than expected, so it may be that other wool-related movements are included in the tonne-km estimate.

4.3 Market survey

The market survey followed on from the initial industry research, and was used to collect a matrix of movements with known origin, destination, tonnage, commodity and mode. These were intended to be used as the basis for the building of the complete freight matrix as discussed in Chapters 5 and 6.

Two types of flow were identified (see Section 2.2):

- 'major' (one-to-one or many-to-one) flows associated with specific activities or industries, and
- 'dispersed' many-to-many flows of multiple products and customers.

At the beginning of the study it was envisaged that each type of flow would require a different research approach. Information on the 'major' flows was to be obtained by approaching freight consignors (or consignees where applicable) to obtain information on their transport tasks, and information on 'dispersed' flows was to be obtained by approaching the carriers. It was expected that the overlap between the two sources of data would provide a level of cross-checking.

4.3.1 Freight consignors

The primary source for information on 'major' flows was the surveying of freight consignors. The firms that had been identified by the initial research as important consignors within each of the commodity groups (see Section 4.2 and Appendix C) were approached by telephone and email and invited to contribute information on their freight flows to the study.

Additional firms were contacted as they became identified as significant freight consignors. Industry organisations, such as the New Zealand Forest Owners Association (NZFOA), were also surveyed to provide additional sources of information, particularly for industries where tonnages were estimated to be high but where industry disaggregation made it difficult to identify dominant firms.

Organisations were asked to provide estimates of their principal annual freight movements (both inbound and outbound) for the most recent available year (with 2002 or 2003 stated as preferences), including commodity, origin and destination, tonnage, and transport mode or modes. A standard spreadsheet template was offered to provide guidance as to the type and format of data required and to standardise the response. To simplify the task and to concentrate on the longer distance higher tonnage movements, survey participants were asked to only include journeys of over 50 km with annual tonnages of over 5000 tonnes. These were given as guideline minimum thresholds for inclusion in the study (refer to Section 3.3.4).

This stage was a significant undertaking. In excess of 70 companies and industry organisations were contacted and invited to contribute data to the project. The response was disappointing given the commitment of resources, although it was in line with the anticipated response for a survey of this type. Of those approached 26 companies provided full or partial details of their logistics operations, which represented a 38% response rate. Another nine organisations, representing a further 13% of those contacted, indicated that their freight movements would not be relevant to the study, either because tonnages were minor or because movements were of a short-haul nature only. The aggregate sector (of sand, gravel and rock) exemplified this situation, having short distance (if high tonnage) movements related to the low value of the product.

The detail of freight movements for some commodity groups was able to be gathered to a reasonably complete point at the survey stage. The Coal, Minerals, Cement, Fertilisers and Metals groups were well covered, largely as a result of the limited number of participants in these industries, but also due to the willingness of most to contribute to the study. An acceptable level of data was also gathered for the Meat, Oil Products, Logs, Sawn Timber, Wood Products and Other categories, although most forestry related data came from existing research rather than direct industry participation. The Livestock, Wool, Milk, Dairy and Produce groups proved very difficult to research, having little or no input from industry.

A number of critical issues appear to have limited the response from freight consignors. Principal amongst these was the issue of commercial confidentiality, which was the most common reason given for non-participation in the study. Confidentiality was also requested by most commercial organisations that did choose to participate, and the majority of the information was supplied only on the basis that it would be kept confidential. This issue reflects the small size of the New Zealand economy and the corresponding minimal number of participants in most industrial sectors. Another problem was that many organisations did not retain records of freight weights or volumes, and as a consequence were unable to provide more than a rough estimate of tonnages for this study. Finally, the issue of industry disaggregation made it difficult to obtain information for some commodity groups with expected high tonnages. The wool industry illustrated this situation, having relatively high tonnages but many independent industry players and no central industry organisation co-ordinating or recording activities.

4.3.2 Freight carriers

The primary source for information on 'dispersed' flows was the surveying of freight carriers, with different approaches undertaken for each mode. It was originally intended that only the land transport modes – road and rail – would be included in the study. However, coastal shipping was later added in recognition of its 'strategic fit' and significant market share, particularly in the areas of inter-island and bulk freight. The other transport modes – air transport and pipeline – were excluded as discussed in Section 2.3.

Road proved to be the most difficult mode for which to obtain data, a situation not entirely unexpected given the dispersed nature of the road industry. The original methodology had proposed that road transport operators would be surveyed in a similar way to freight consignors, and it anticipated that a response rate of approximately 25-30% by numbers and up to 50% by tonnage could be expected. An initial approach was made to the Road Transport Forum,[11] to gain their input and help in contacting and surveying operators. They declined to participate, and indicated that they expected that the fast-changing and competitive nature of the industry, along with concerns about commercial confidentiality, would prevent a reliable response from road operators and

[11] This organisation describes itself as "the authoritative voice of the road transport industry…..created as a national body in 1997 to responsibly promote and advance the interest of the road transport industry and its member road transport operators. Over 80 percent of commercial road transport operators in New Zealand are members……[and it] acts for everyone involved in the industry: owner drivers, fleet operators, in-house road transport operators and suppliers of goods and services to the road transport industry, regardless of size, location or type of business" (Road Transport Forum 2005).

limit accuracy. For these and other reasons, road transport surveys were not subsequently undertaken, and data from other sources and a process of elimination were instead used to provide information on road transport tonnages.

In contrast to the difficulties in obtaining road data, a full matrix of rail tonnage data for the 2002 year was supplied by Toll Rail. This information was made available on condition that certain aspects were kept confidential.

Coastal shipping data were obtained through the survey of operators and the local shipping industry organisation, the New Zealand Shipping Federation. Inter-island ferries were treated as extensions of the road and rail networks and disregarded to avoid the double-counting of movements. As with the survey of freight consignors, response rates were variable, with confidentiality again proving a considerable barrier. Good detail was obtained on the transport of bulk products such as petroleum products, cement and coal, but it proved more difficult to quantify general freight movements, particularly the details and level of domestic freight carried by foreign vessels in relation to the issue of cabotage and, as a result, it was not possible to build a final matrix of sea-based freight movements. A recently published report by the Ministry of Transport (2005) has investigated the effects of the cabotage issue in greater detail.

4.4 Supplementary data sources

Additional data were collected from sources other than through the survey of freight consignors and carriers, and these are discussed in more detail below and listed in the appendices. Most of this information was publicly available; and was used to supplement survey data, enabling analysis of commodities where survey response from industry was weak, not available, or not requested; or to allow the cross-checking of other data.

The supplementary data sources generally provided information on single trip ends, as commodity tonnages either originating or terminating, which contrasted with the matrices of origin-destination pairs supplied by the survey sourced data. Information in this form was less useful than the full matrix movements, however it was still valuable to the process and it allowed lists of vector inputs to be created in preparation for the matrix estimation stage (discussed in Section 5.3).

A number of issues limited the usefulness of much of the available information. Many sources classified data by region rather than by TLA, or did not break national data down into smaller units at all. Further, the definition of 'region' often varied depending on the source and purpose for which it had been collected (for example, forestry regions differ from regional government regions). Similarly, most data were not available by weight (tonnage), with much publicly available information commonly quoted in either financial units (for example, sales in dollars) or units of area (for example, hectares in production).

4.4.1 Production data

Production data were used to estimate approximate tonnages of primary products produced by TLAs. They were obtained from a variety of government sources including the Ministry of Economic Development, MAF, and Statistics New Zealand (for example, Agriculture Statistics 2002 (Statistics NZ 2003b)); and was supplemented by data sourced from industry organisations such as NZFOA, Meat and Wool Innovation Economic Service, and the Livestock Improvement Corporation.

4.4.2 Export data

Export data were used to determine the tonnage and port of departure for exports, and in some cases to quantify imports. Export data were obtained principally from Statistics New Zealand's database of exports and imports by port, but they were also supplemented with MAF and port company information.

4.4.3 Industry data

Industry data were used to determine locations and production levels of manufacturing plants and the origins and destinations of freight relating to these. In some cases they enabled transport paths to be traced from source through to points of export or consumption. Data were obtained from Statistics New Zealand (principally data relating to industry within each TLA), from industry organisations such as those listed in Section 4.4.1, and from other industry sources such as annual reports and commercial web sites.

4.4.4 Other sources

Two studies were referenced for estimates of the freight task in tonne-km. The Heavy Vehicle Limits Project (HVLP) report for Transit New Zealand (2001) estimated the 1999 road freight task by region and industry, in payload tonne-km; while the Freight Transport Industry in New Zealand working paper, by Cavana et al. (1997), provided 1994/95 estimates for major commodities moved by truck in addition to other general transport information. These were used to estimate commodity group and total movements by road, and provide a cross-check of information gathered from other sources.

Additional key sources included the Heavy Vehicle Movements in New Zealand report for the Land Transport Safety Authority by TERNZ (2003) (which provided assessments of heavy transport movements for some commodities) and various regional reports. TERNZ also supplied background research data relating to forestry industry transport movements.

5. Data analysis and the rail matrix

5.1 Introduction

This chapter describes the data collected, the analysis and classification procedures used, and provides details of the inputs to the road matrix estimation process and the final rail matrix. The analysis process involved the collation of data from all sources, standardisation to the base year and common format, and classification by commodity and mode. Individual modes were then separated, allowing the rail matrix to be calculated.

5.2 Survey returns

Survey returns were received in a variety of formats, with many containing incomplete or aggregated data that were often in a form that was difficult to use. All were put into the standard format listing commodity, origin, destination, tonnage and transport mode for each movement specified. Any data gaps were filled where possible, using the processes described in Section 3.3. Processed data was then added to a series of standard commodity tables, as described in more detail in Section 5.4 below.

5.3 Supplementary industry analysis

Additional analysis, using data obtained from sources other than from the surveys, was performed on a number of commodity groups in two situations. The first was where the survey returns were not considered to have provided a satisfactory proportion of the total estimated movements of a commodity. This applied to the Milk, Livestock, Produce, Wool and Meat groups. The second situation was where the freight consignors within a commodity group had not been approached during the survey phase, where sufficient public and carrier data were deemed to be available to map freight movements without directly approaching the industry concerned. This applied only to the forestry related commodity groups of Logs, Sawn Timber, and Wood Products.

This analysis was primarily aimed at providing an estimate of bulk movements relating to the first stage of the production process: from collection/harvest/production in rural areas to the initial points of processing or manufacture, although it was also used to estimate further stages of the logistics process for the Wool, Meat, Sawn Timber and Timber Products groups. It was not possible to produce a full matrix of origin-destination movements for each commodity using this approach; rather two separate lists were generated, one listing the estimated originating tonnages by TLA and the other listing estimated terminating tonnages by TLA. These origins and destinations were then added as vectors into the matrix estimation process as described in Section 6.5.

The processing of this data involved a series of steps and assumptions, which are detailed for each group (where applicable) in Appendix D. The main stages were:

- Generation of TLA origin tonnages: a level of production was estimated for the commodity within each TLA, either using some type of production per unit (for example, production per hectare multiplied by hectares planted per TLA), or alternatively by allocating a national or regional production total to each TLA (as described in Section 3.3.3).
- Generation of TLA terminating or destination tonnages: a level of consumption was estimated for the commodity within each TLA, based on local drivers of demand, such as exports by port, industrial activity, or population. This was done by calculating the difference between total originating tonnage (identified in the previous stage) and total exports, then allocating this difference to each TLA according to a measure of industrial activity or population (using the same methods as above). Any local exports could then be re-added to give a total consumption for each TLA.
- Correction for known matrix movements: any 'actual' known matrix movements (i.e. full origin-destination movements) were subtracted from the TLA origin and destination tonnages generated above. This gave the final lists of unallocated road origins and destinations by TLA (since all rail and most sea movements were known), which could then be added to the commodity tables.

5.4 Commodity tables

A summary table was created for each commodity group. Both matrix- and vector-based movements were then added to the appropriate tables to create a summary database of information collected from all sources. As data were added to the tables, origins and destinations were assigned to the appropriate TLA (where this had not already been done) and tonnages were aligned to the base year using the process described in Section 3.3.1. Tonnages were then assigned to the appropriate mode to allow 2002 mode totals to be generated for each commodity.

The road tonnages from the commodity tables were retained and used as inputs to the matrix estimation process. Rail and sea tonnages supplied by freight consignors were disregarded, and operator-supplied data, being deemed more accurate, was instead used to provide information on the movements relating to these modes. Coastal shipping was excluded from further consideration at this point because of a shortage of data and, as a consequence, a final sea matrix was not constructed. Table 5.1 presents a summary by commodity of the road and rail tonnages used to create freight matrices for these modes. Table 5.2 provides additional detail for road only (these figures are a guide only and may not tally due to numerical rounding).

Table 5.1 Summary of 2002 tonnage data from the commodity tables.

Commodity Group	Available Road Commodity Tonnage (million tonnes)	Rail Commodity Tonnage* (million tonnes)	Total Available Tonnage (million tonnes)
Other	1.6	2.5	4.2
Logs	18.8	3.6	22.4
Milk	13.0	0.8	13.7
Livestock	1.1	0.0	1.1
Sawn Timber	3.8	0.1	3.8
Oil Products	1.5	0.0	1.5
Fertiliser	1.9	0.2	2.1
Coal	1.1	2.7	3.8
Wood Products	2.0	1.4	3.3
Produce	3.1	0.2	3.4
Cement	1.2	N/A	1.2
Minerals	0.4	0.1	0.6
Wool	0.3	0.2	0.5
Dairy	N/A	1.0	1.0
Metals	0.3	0.3	0.6
Meat	1.0	0.5	1.5
Total	**51.1**	**13.6**	**64.7**

* Rail commodity tonnages are estimated only. They have been matched as closely as possible to the Booz Allen commodity groups; however they should be used only as a guide, due to potential differences in definitions and classifications.

Table 5.1 should be viewed only as a summary of the data gathered and applied to build the road and rail matrices. It is clear that, although all rail movements are known, only a portion of road tonnages have been explained (50-60% based on the later matrix estimation) even though nearly 51.1 million tonnes of freight movements were accounted for during the research stage. Road tonne-km data and industry production data provide an insight into those areas where there is a particular shortfall (see Section 5.5 below).

The issues of confidentiality, insufficient survey matrix data, and a lack of road link-based/traffic count information at a commodity level precluded the further use of this information at a commodity level. Further stages used commodity data only for reference purposes and, as a result, the final completed matrices do not break movements down by commodity as originally intended.

5.5 Road matrix inputs

Table 5.2 lists the inputs that were used to build the road freight matrix. Matrix and vector tonnages sourced from the commodity tables served as direct inputs to the matrix estimation process, while the tonne-km data was used to provide check totals to the estimation process (refer to Chapter 6 for further detail).

Table 5.2 Inputs used to build the road freight matrix.

Commodity Group	Road Matrix Tonnage (million tonnes)	Road Vector Tonnage (million tonnes)	Total Matrix + Vector Tonnage (million tonnes)	Estimated Road Tonne-km (million)[12]
Other	1.64	0	1.64	7,614
Logs	0	18.80	18.80	1,466
Milk	0	12.95	12.95	827
Livestock	0.27	0.83	1.10	804
Sawn Timber	0	3.75	3.75	357
Oil Products	1.51	0	1.51	322
Fertiliser	1.89	0	1.89	262
Coal	1.12	0	1.12	240
Wood Products	0	1.96	1.96	187
Produce	0.25	2.89	3.14	141
Cement	1.23	0	1.23	123
Minerals	0.43	0	0.43	60
Wool	0	0.31	0.31	44
Dairy	0	0	0	29
Metals	0.29	0	0.29	29
Meat	0.15	0.85	0.99	16
Total Calculated	**8.78**	**42.34**	**51.11**	**12,523**
Total from HVLP				**15,782**

Note:

(1) Tonnage figures are based on the available data collected for this research. They therefore represent only partial data as explained in Section 5.4.

(2) Tonne-km are provided only to indicate the relative magnitude of the transport task for each commodity. They are not comparable with tonnage figures, because of the inconsistent definitions of each commodity across data sources.

A comparison of road tonnages for each group, with estimated road tonne-km and industry production levels (Table 4.1), reveals those commodity groups with a deficiency of road tonnage data. It is particularly apparent that only a small share of the total likely tonnage for the large 'Other' group has been collected (as expected, given the diversity of road freight traffic), although many of these movements might be over short distances and not relevant to this study. Other groups that appear to require much greater detail are the 'Livestock' and 'Dairy' groups. The remaining groups have been assessed to an acceptable level, although tonnage estimates are dependent on estimated values and associated assumptions.

There is a variance of approximately 20% between the total tonne-km figure extrapolated from the HVLP total and that calculated from the sum of the commodity groups. This can be explained by the use of more than one source for commodity group tonne-km and the difference in commodity definitions used by each source, and also by the possible variance between individual commodity growth rates and the overall freight growth rate applied to the study as a whole (Section 3.3.1).

12 Extrapolated from Cavana et al. (1997) and Transit New Zealand (2001).

5.6 Rail matrix

The completed rail matrix is shown in Table 5.3. This can be interpreted by reading origin regions (producers) vertically and the corresponding destination regions (attractors) horizontally. For example, 282,000 tonnes originates in Auckland and terminates in the Bay of Plenty.

From the matrix, it is clear that a high proportion of rail tonnage is related to the productions and attractions associated with the locations of major industrial plants, mines and ports. This is to be expected, given that heavier train movements occur where tonnage is higher and these usually relate to the locations of the above facilities.

Two corridors can be used as examples. From Manawatu-Wanganui the highest tonnage destination is Taranaki, and this is the location of a major dairy processing plant that serves as a terminating point for unit milk trains from the Manawatu area. The most important destination for rail tonnage originating on the West Coast is Canterbury, the location of the export port of Lyttelton which serves as a terminating point for unit coal trains from the Buller and Grey districts on the West Coast.

Examining the final matrix in further detail shows that Bay of Plenty region with its large port (Tauranga), major forestry-related industry and good rail links, is both the largest producer (22% of total) and attractor (35% of total) of rail freight. Waikato (with large agriculture and forestry industries) and the West Coast (with a significant coal mining industry) are the next largest producers of rail freight, with 20% and 15% shares of the total respectively. Canterbury is the only additional significant attractor of freight (above 10% share) with 23% of the total, most likely related to the previously mentioned coal exports and its role as an important distribution centre. Somewhat surprisingly, intra-regional movements are significant in most parts of the country, although it is likely that most of these are moving over longer distances within each region.

Figure 5.1 provides a trip length distribution for the rail matrix, displaying the number of freight tonnes moved within each distance band, with each 200 km range shown in a separate colour for clarity. It can be compared with similar plots for the road (Figure 6.8) and total matrices (Figure 6.11), and is shown in the same scale as these to allow comparison. This distribution shows that rail has a fairly even spread of tonnage over most distances, with a slight predominance towards mid-length journeys in the region of 200 km. Table 6.8 compares road and rail statistics and shows that the average trip length for rail is approximately 250 km.

Figure 5.1 Distribution of trip length (km) of rail freight matrix.

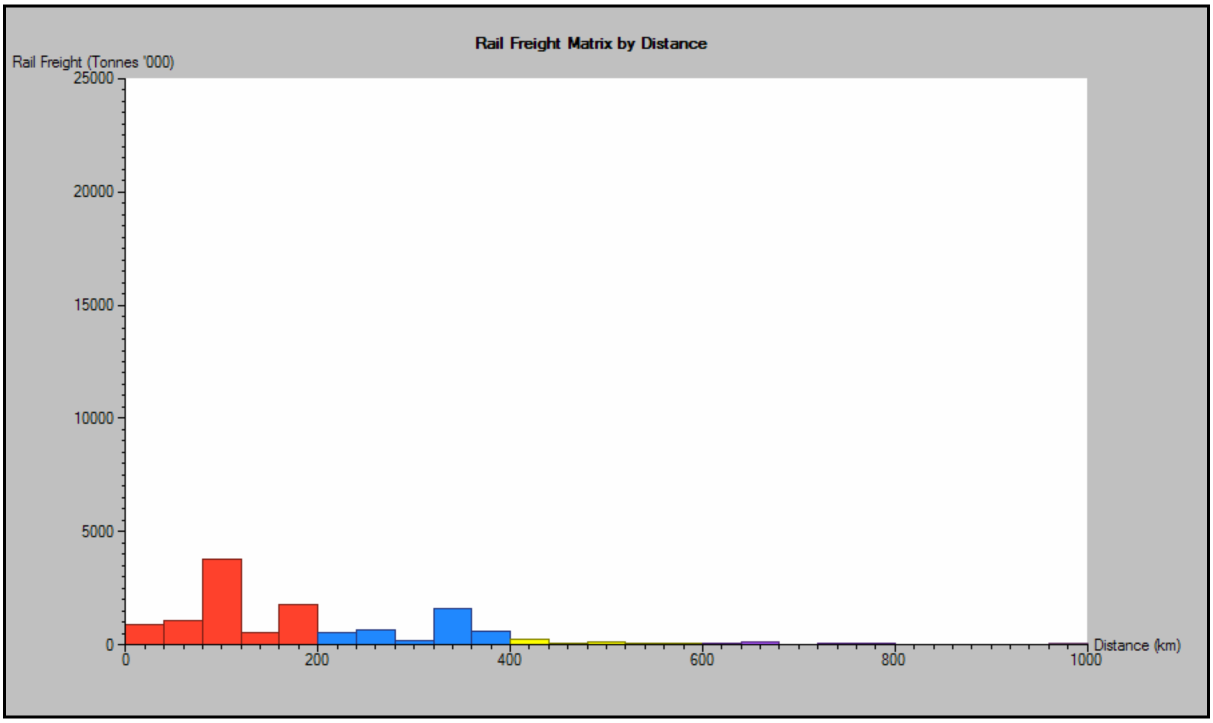

Table 5.3 Total rail freight matrix (annual tonnes '000).

From \ To	Northland	Auckland	Waikato	Bay of Plenty	Gisborne	Hawke's Bay	Taranaki	Manawatu-Wanganui	Wellington	Tasman	Nelson	Marlborough	West Coast	Canterbury	Otago	Southland	**TOTAL**
Northland	405	157	5	43	-	0	0	0	0	-	0	0	0	1	0	1	**613**
Auckland	82	44	17	282	0	25	27	49	81	-	6	15	1	282	29	10	**949**
Waikato	8	76	777	1,862	0	1	6	6	4	-	1	0	0	33	4	2	**2,780**
Bay of Plenty	1	487	43	2,338	0	4	11	6	27	-	0	2	0	29	4	2	**2,955**
Gisborne	-	0	0	0	-	2	0	0	0	-	0	0	-	0	0	0	**4**
Hawke's Bay	1	53	3	8	25	143	46	111	37	-	1	1	0	38	1	3	**471**
Taranaki	0	68	19	132	0	5	179	8	49	-	2	2	1	29	5	1	**499**
Manawatu-Wanganui	0	56	3	18	0	43	730	27	163	-	1	1	0	35	3	2	**1,082**
Wellington	1	21	1	11	0	11	4	70	73	-	1	5	1	17	4	1	**221**
Tasman	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
Nelson	0	7	1	1	0	1	0	1	2	-	22	2	0	8	0	0	**46**
Marlborough	0	37	0	8	0	2	1	3	16	-	8	9	0	20	5	2	**111**
West Coast	0	1	0	1	0	0	0	0	1	-	0	0	14	2,011	9	0	**2,038**
Canterbury	1	138	38	35	0	8	22	77	34	-	16	15	12	371	254	83	**1,107**
Otago	0	28	2	3	0	2	4	8	7	-	1	3	0	95	48	31	**232**
Southland	0	15	4	3	0	6	4	4	4	-	0	1	1	173	189	103	**506**
TOTAL	**500**	**1,189**	**912**	**4,746**	**27**	**252**	**1,034**	**371**	**497**	**-**	**59**	**55**	**31**	**3,142**	**556**	**242**	**13,613**

6. The road matrix and the final matrix

6.1 Introduction

This chapter explains the development of the road freight matrix and its amalgamation with the rail matrix to form a total freight matrix.

Matrix estimation formed the core part of the development of the road matrix. This technique was used to relate matrix-based data (TLA to TLA freight movements) to link-based data (highway road vehicle counts), which was then used to update the matrix in an iterative process until a convergence criterion was reached. A similar approach was used for the Commercial Transport Study (CTS) in Sydney (Transport & Population Data Centre 2002)[13].

The process took data inputs relating to production and attraction of freight at specific locations, as outlined in previous sections. Where full information was given, no further processing was required; however where data was incomplete, estimation processes filled the gaps to give a best estimate of a road freight matrix. This first matrix (or 'seed' matrix) was then used as an input to further estimation processes which attempted to match matrix information with flow-based information (Transit New Zealand vehicle count data), with the output giving the best estimate matrix. Finally, the road freight matrix was combined with the rail freight matrix, to give a total land-based freight matrix.

6.2 Process

Figure 6.1 outlines the road-freight matrix estimation process, with each number referring to an associated section in the report.

6.3 Emme/2 overview

Emme/2, the transport modelling package used for the estimation process, was developed by INRO Consultants of Canada. It has the ability to model road and public transport services and the interaction between them, and is well placed as a transport modelling tool at a strategic level. Emme/2-based models are currently used in Auckland (through ART and APT[14]) and Wellington (through WTSM[14]). The matrix estimation process primarily uses matrix addition, matrix balancing, network calculation, and assignment routines of the package. Appendix E provides additional information on Emme/2 and its capabilities.

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[13] The Commercial Transport Study (CTS) Trip Table Estimation Procedure provides 2002- and base year (1996)-estimates of trips by light commercial, rigid and articulated trucks between each travel zone in the Greater Metropolitan Region of Sydney, Australia (T&PDC 2002).

[14] ART Auckland Regional Transport; APT Auckland Public Transport; WTSM Wellington Transport Strategic Model.

6.4 Base network

The base New Zealand network used for the freight matrix estimation project was developed in Emme/2 to model a number of aspects of the Surface Transport Costs & Charges Study for the Ministry of Transport (2005b). The network itself encompassed both the rail and the main highway networks, and consisted of approximately 275 zones, 800 nodes, and 2650 directional links. It also included 12 modes (10 being rail/bus based, 1 transfer, and 1 auto), although only the highway (auto) mode was used for this particular road-only modelling task.

No supporting documentation was available for the model network, and so a series of checks were undertaken to ensure that it was valid and had a reasonable representation of routes and corresponding distances. Such checks are vital to any matrix estimation process. As a result, link-based distances were adjusted to broadly match observed distances as described in Appendix E. Note that the highway network did not include volume delay functions, and as such congestion has not been modelled, although this was not seen as a significant issue as most long-distance freight movements would be either outside the hours of congestion or on highways where congestion was not an issue. Gradient and road curvature were also not modelled.

Checks relating to connectivity of links and zones were also undertaken. Where two links were used to represent one piece of road, one was removed so that all demand assigned on a link during the assignment process would be comparable with the observed information and not located on adjoining links.

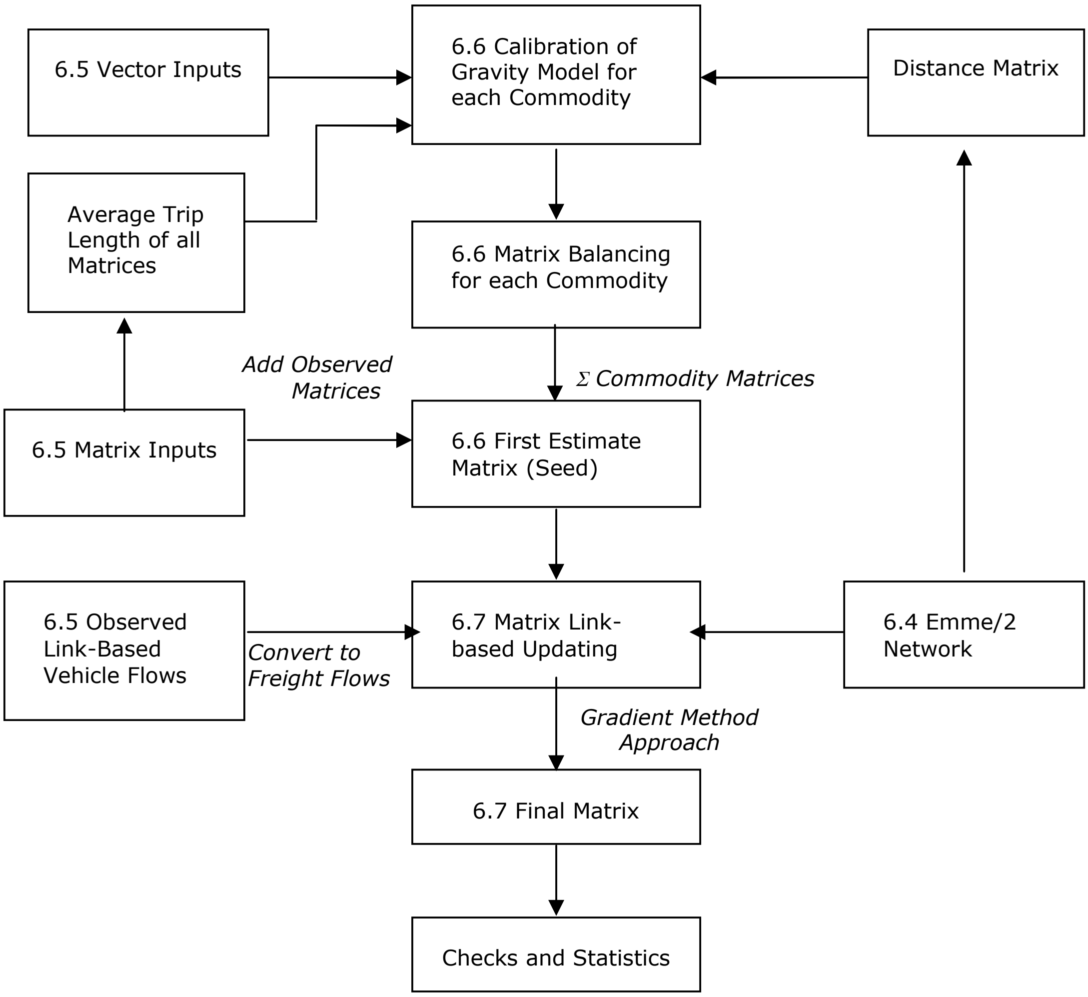
Freight movements were provided at a TLA level (as described in Section 3.3) but the zone system in the Emme/2 network provided greater detail. Since there was no basis on which to disaggregate the TLA data further, a representative zone was selected within each TLA and all movements were assumed as going from (or to) this zone. A network attribute was also created to represent the region that a particular highway link fell within and this attribute was used to add region-specific average loads for link-based heavy-vehicle flow data (see Figure 6.1).

6.5 Data inputs

Data inputs took the form of two distinct types: matrix-based and link-based inputs. The matrix-based information was used as a starting point (since this did not include all operators and commodities), and the link-based information gave an independent and more complete source with which to improve the starting point.

Matrix-based input information took the form of either a full matrix, where complete origin/destination matrix data was available; or a vector form, where information on origins and/or destinations was available but not in matrix form. Chapter 5 discussed these inputs.

Figure 6.1 Flow diagram showing the matrix estimation process.

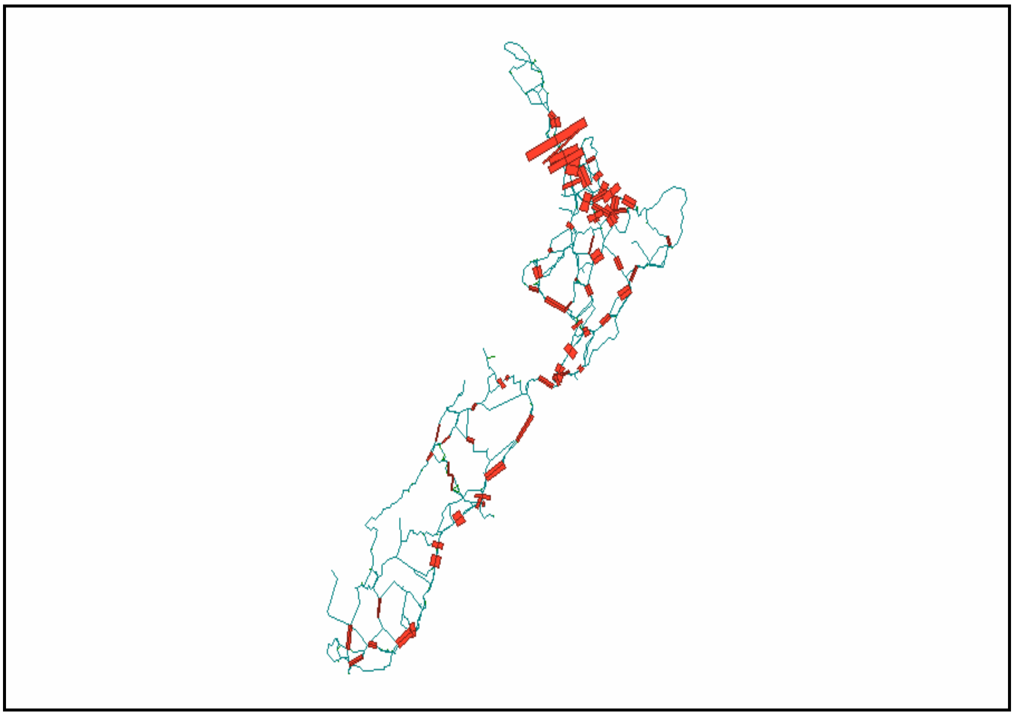


6.4, 6.5, 6.6, 6.7 – refer to Sections 6.4, 6.5, 6.6, 6.7

Link-based traffic information, based on data collected at telemetry sites, was provided by Transit New Zealand for the 2002 year. This gave average annual daily total flows at 12 directional and 67 non-directional link locations on the state highway network, and the proportion of heavy vehicles (HVs) at each location. These were used to give average annual daily heavy vehicle movements.

Figure 6.2 shows the observed HV count locations and their relative magnitude. It would have been useful to have had this data disaggregated further, by vehicle size, to better determine average tonnage estimates at these locations, but this detail was not available. Data were available at some (but not at most) locations by direction, and analysis of the links where the direction could be determined showed that the average split was around 50:50, indicating that the flows were fairly symmetrical. It was therefore assumed that where the direction could not be determined, flow would be split evenly in both directions.

Figure 6.2 Observed HV count locations.



Representative links within the Emme/2 model were determined and observed flows read in as one of the link attributes. Because flows were received as 'average daily vehicles' they were converted to annual tonnes to match the matrix. The converted annual tonnage by link was saved in another attribute and calculated using the following formula:

$$Tonnes_{i,j,r} = AADT_{i,j} \times AveLoad_r \times Annualisation$$

where:

$Tonnes_{i,j,r}$: Annual tonnage for link 'i,j' within region 'r' (tonnes/year)

$AADT_{i,j}$: Average Daily Traffic (HMV's) for link 'i,j' (vehicles/day)

$AveLoad_r$: Average load factor within region 'r' (tonnes/vehicle)

Annualisation: 365 (days) as traffic is average annual daily traffic (AADT)

Average load factors (Table 6.1) were determined using data from the Heavy Vehicle Limits Project (Transit NZ 2001), which gave annual vehicle km and payload tonne-km by region and vehicle type for 1999. This classified vehicles as A (articulated), B (B-train) and R (rigid) types, and also included a category called 'other vehicle' which appeared to relate to smaller commercial vehicles (having an average payload of 3.3 tonnes). The average payload took account of both empty running and partly laden travel.

Table 6.1 Average heavy vehicle payload by region (tonnes).[15]

Region	All Vehicles	Excluding 'Other'	Midpoint
Northland	6.3	11.1	*8.7*
Auckland	5.5	11.0	*8.2*
Waikato	7.9	14.7	*11.3*
Bay of Plenty	7.9	14.8	*11.4*
Gisborne	7.4	13.9	*10.7*
Hawke's Bay	6.4	11.6	*9.0*
Taranaki	7.3	12.9	*10.1*
Wanganui-Manawatu	6.7	11.8	*9.2*
Wellington	5.5	11.5	*8.5*
Nelson-Marlborough	6.1	11.1	*8.6*
Canterbury	6.4	11.7	*9.0*
West Coast	7.0	11.2	*9.1*
Otago	7.0	13.3	*10.1*
Southland	7.1	13.1	*10.1*
National Average	**6.6**	**12.5**	***9.5***

Comparing across regions, Waikato and the Bay of Plenty had the heaviest average payload, while Auckland and Wellington had the lightest (when smaller vehicles were included). The variation is probably related to the types of commodities carried in each region, the proportion of larger commercial vehicles, and the proportion of empty or part-laden travel.

The table shows that there is a large variation in average payload when the 'other' vehicles are included, as these dominate the vehicle-km and tonne-km statistics. For some links in the network (such as the Auckland Harbour Bridge or Ngauranga Gorge), smaller freight moves would be more significant. However they would generally form a lower proportion of longer distance travel, the focus of this freight study. We understand that there may be a breakdown of heavy vehicles at a more disaggregated level at telemetry locations, but this information was not available for this study (although more work could be undertaken using this information).

15 Source: Transit New Zealand (2001).

In light of these difficulties, it was decided that a middle ground would be used as the central case (the midpoint column), and that sensitivities on the other two assumptions would also be provided (see Table 6.7). It happens that the resulting freight matrix is very sensitive to this assumption, and further research or data gathering is recommended to give a better distribution of commercial vehicle types at counting locations.

There are issues relating to the annualisation factor used, in that the average daily flows are designed predominantly to match car travel patterns rather than heavy vehicle patterns. With heavy vehicle traffic concentrated during the week rather than at the weekend, the averaging process may underestimate the number of heavy vehicles using the network. However there was no basis on which to determine whether this was significant, or to re-estimate this effect, and the annualisation factor has been left as is. This could be another area for further investigation.

6.6 Developing the seed matrix

The 'seed' matrix was the starting matrix whereby assigned network flows were matched to observed network flows. It was created using road matrix data inputs described in Sections 5.5 and 6.5, and represented the best initial matrix based on the available information.

The process of estimating a best road freight matrix took a number of steps, using the matrix and vector data inputs as a starting point. Table 6.2 outlines the proportion supplied in either a matrix form (i.e. where the full journey was known), or in vector form (where total outputs and inputs were known but the individual movements were not). Overall, only 17% of the total tonnage supplied was in a matrix form and, consequently, most of the starting or seed matrix had to be estimated.

The first part of the estimation process was to convert vector-based information to a matrix form, with specific origin to destination flows. This was achieved by taking the row and column totals (origin and destination vectors) and distributing trips between them based on a distance function (to represent utility), to ensure an average trip length. An entropy model was used for this purpose (described in Appendix E).

The usual approach is to change the scaling parameter in the model so that the average trip length of the resulting matrix matches an observed or known total. Research into average trip lengths for freight movements did not result in any data that could be applied in this case (in total, let alone by commodity), and the only alternative was to base average trip lengths on the commodity matrices supplied. These gave average trips ranging from 62 km to 228 km. However, as the commodity matrices provided only a small share of supplied tonnage (17% on average), the use of commodity-specific trip lengths was deemed inappropriate, particularly since much of this information was available for only one consignor and/or one region (and not representative of the national situation), or not available at all.

Table 6.2 Proportion of data by commodity and type.

Commodity	Matrix Proportion (%)	Vector Proportion (%)
Other	100	0
Logs	0	100
Milk	0	100
Livestock	24	76
Sawn Timber	0	100
Oil Products	100	0
Fertiliser	100	0
Coal	100	0
Wood Products	0	100
Produce	8	92
Cement	100	0
Minerals	100	0
Wool	0	100
Dairy	No data	No data
Metals	100	0
Meat	15	85
Share of total tonnage %	**17**	**83**

As a result, the average trip length of all commodities combined, 137.3 km, was selected as the final average trip length. It should be noted that the use of commodity-specific trip lengths would have made little difference to the resulting matrix in totality, as such numbers would have changed only the allocation of tonne-km within individual commodities. Additionally, the lack of commodity-related link-based (traffic-count) information would have prevented estimation at a commodity level in any case.

Evidence suggested that trip lengths for the Produce group were significantly shorter than the average of 137.3 km. For this reason, a much lower trip length of 69 km was assumed for this group, based on the existing matrix information. Since Produce data was available only at the origin end, a singly constrained balancing approach (used in situations where one trip end is unknown) was used to allocate trips.

Emme/2 has a matrix balancing function within the modelling suite to ensure that row and column totals are in balance. It is an iterative approach, which stops when the maximum percentage change in balancing coefficients is within a certain tolerance. A series of balancing factors are determined for each origin and destination zone so that, multiplied with the entropy matrix, the row and column totals match the origin and destination vectors. The sum of the balanced matrices and the full supplied matrices forms the 'seed' matrix to be used in the assignment-based matrix re-estimation. This matrix is somewhat representative of relative freight movements. However it reflects data availability, so it is not a true representation of actual freight movements.

The seed matrix (Table 6.3) distributes the 51.1 million tonnes (see Table 5.2), with approximately 50% of tonnage within region. It mirrors the greater availability of information relating to rural industries, and so does not provide a true representation of actual movements. It indicates that the largest generator of freight is the Waikato region, which is shown as having around a third of all freight production. This is followed by Canterbury, with around 10% of the total. Waikato is also shown to be the largest freight destination, attracting almost a quarter of the total, and this is followed by Bay of Plenty with close to 20% of the total, probably related to the large port at Tauranga. Other notable destinations include Auckland and Canterbury with around 9% each. Auckland is not dominant in the seed matrix however, and it is likely that this is because of a lack of information about industries that prevail in that region, such as secondary manufacturing and distribution.

6.7 Developing the final road matrix

The seed matrix was used as an input to a link-based form of matrix estimation. Observed freight tonnages by link were loaded onto the highway network. The starting matrix was then assigned on the network and assigned link flows compared with the observed, with the difference computed. A gradient matrix was then determined, and used to adjust the freight matrix in the right direction based on the largest discrepancy, so as to minimise the total impact on the seed matrix. This routine was repeated until the correlation of observed to modelled after assignment was high (50 iterations). Since the factors are multiplicative, and the updating process only changes cells that have a value other than zero, each zero-cell was given a minimum value of 0.001 to allow trips to be generated where required (a standard procedure in matrix estimation).

Figures 6.3 and 6.4 show the convergence of the process. The objective function in Figure 6.3 is related to the sum-of-squares of the difference between observed and modelled between iterations, with the difference reducing as the number of iterations increases. Similarly, the correlation plot of observed versus modelled flows in Figure 6.4 shows how well the assigned matrix fits the link-based tonnages and this indicates a significant improvement through the process. Initially the fit of observed versus modelled flows was not particularly good at around 0.2 (Figure 6.5).

This was driven by some significant outliers, particularly over the Auckland Harbour Bridge where the seed matrix did not include some of the shorter freight journeys that occur within the Auckland suburban boundary. Subsequent iterations improved the correlation measure to be significantly closer to ‘1’ (a perfect match), so that after 15 iterations the modified matrix explained 90% of the observed variation, and that at 50 iterations it approached 99% with no significant outliers (Figure 6.6).

Figure 6.3 Objective function value by iteration.

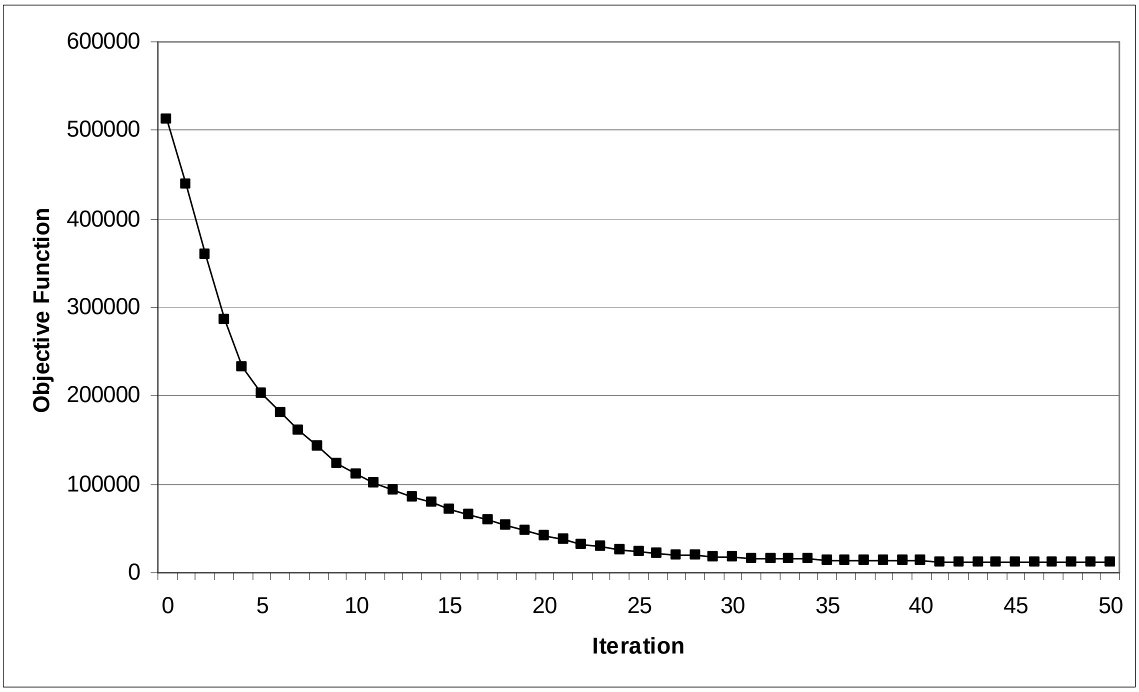


Figure 6.4 Correlation of observed versus modelled road flows by iteration.

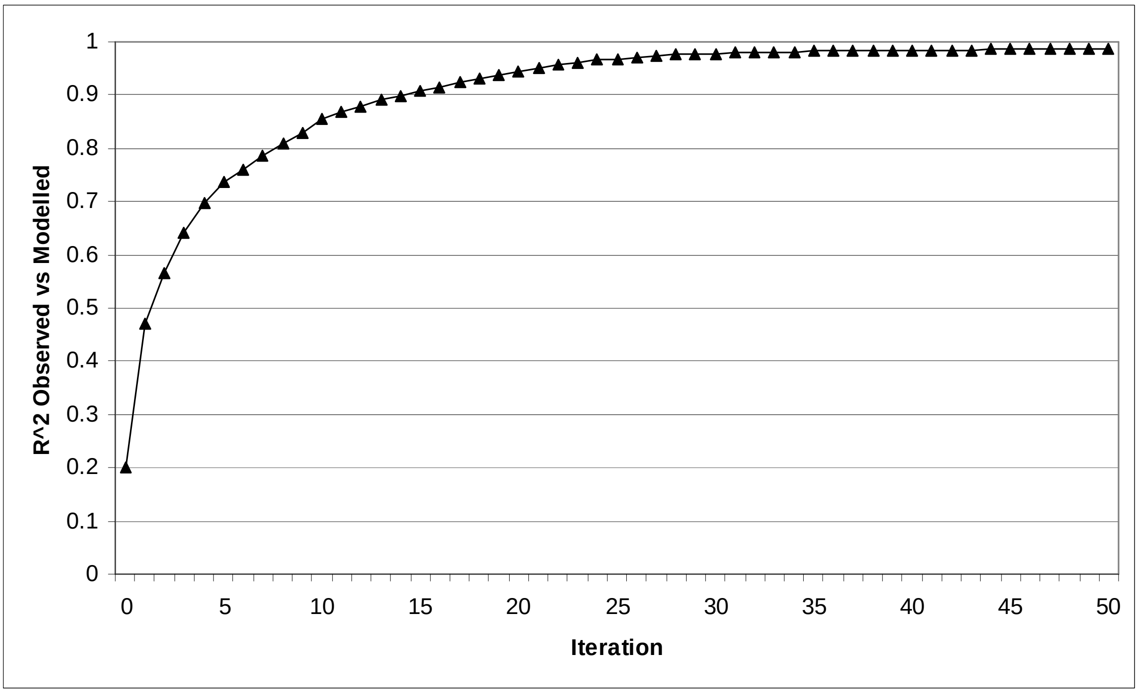


Table 6.3 Seed matrix for assignment-based estimation (annual tonnes '000).

From \ To	Northland	Auckland	Waikato	Bay of Plenty	Gisborne	Hawke's Bay	Taranaki	Manawatu-Wanganui	Wellington	Tasman	Nelson	Marlborough	West Coast	Canterbury	Otago	Southland	**TOTAL**
Northland	1,822	733	154	64	1	2	12	3	0	0	0	0	0	0	0	0	**2,790**
Auckland	398	1,263	680	234	6	24	24	44	33	0	0	0	0	6	0	0	**2,713**
Waikato	590	1,639	7,908	4,777	164	786	477	416	98	9	12	16	1	5	0	0	**16,898**
Bay of Plenty	64	531	1,536	2,262	44	75	87	100	13	0	0	1	0	0	0	0	**4,714**
Gisborne	10	15	127	461	520	210	4	19	11	1	1	1	0	0	0	0	**1,380**
Hawke's Bay	43	82	411	426	227	1,396	71	371	127	4	5	7	1	3	1	0	**3,174**
Taranaki	32	122	336	136	4	31	1,454	174	26	1	1	1	0	0	0	0	**2,319**
Manawatu-Wanganui	23	81	332	238	17	214	406	662	237	8	9	14	1	6	0	0	**2,248**
Wellington	3	9	57	39	7	89	143	424	615	16	34	41	2	14	1	0	**1,493**
Tasman	1	1	12	7	1	9	32	36	134	766	702	127	51	44	7	0	**1,930**
Nelson	0	0	1	1	0	1	0	2	31	63	111	67	36	15	4	0	**334**
Marlborough	1	1	20	15	2	18	36	50	196	131	188	281	25	65	1	0	**1,030**
West Coast	0	1	7	2	0	1	31	25	22	55	47	42	359	166	21	2	**779**
Canterbury	1	5	21	8	1	4	84	76	36	87	115	156	256	3,854	290	85	**5,078**
Otago	0	0	0	0	0	0	1	1	1	2	2	2	8	319	1,053	631	**2,021**
Southland	0	0	0	0	0	0	2	1	0	2	1	1	19	198	488	1,508	**2,221**
TOTAL	**2,988**	**4,483**	**11,601**	**8,670**	**995**	**2,861**	**2,863**	**2,404**	**1,581**	**1,145**	**1,230**	**757**	**760**	**4,693**	**1,865**	**2,226**	**51,123**

Figure 6.5 Observed versus modelled (road seed matrix) assigned flows.

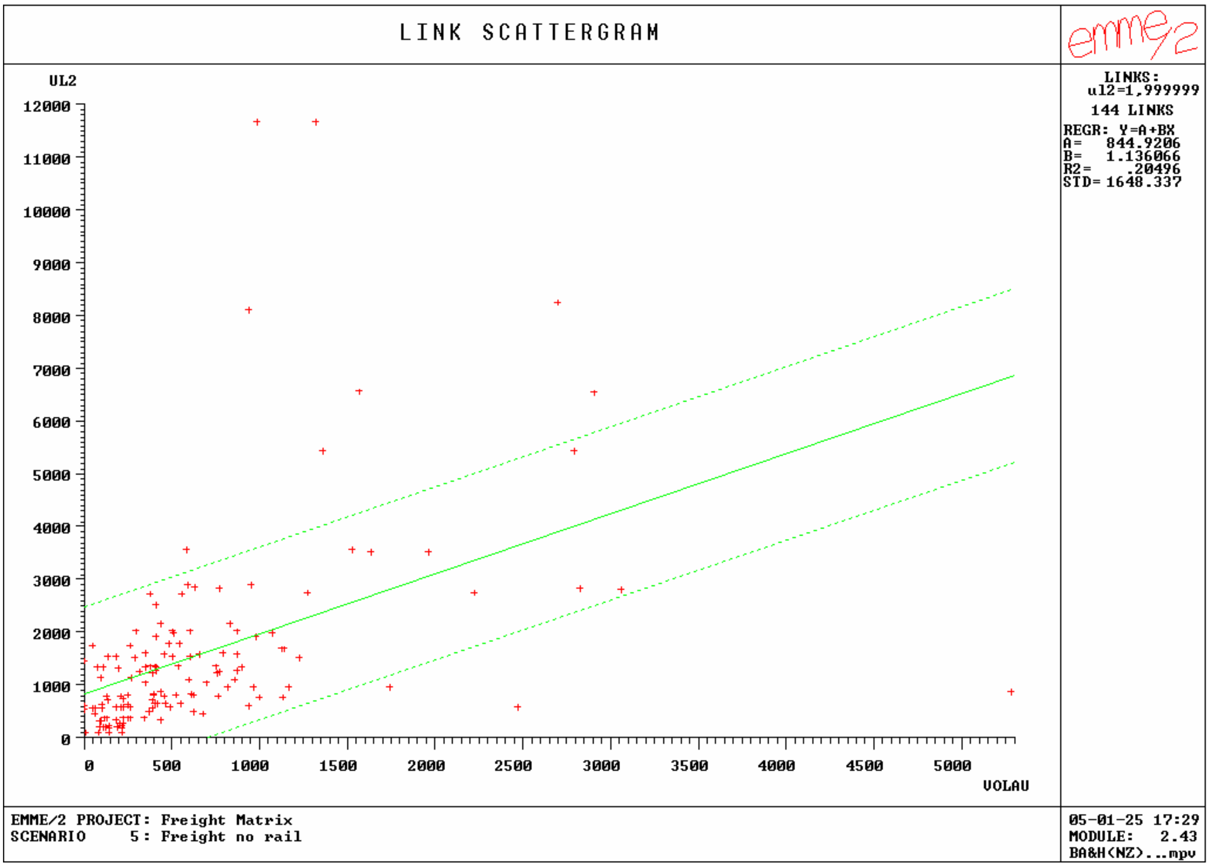
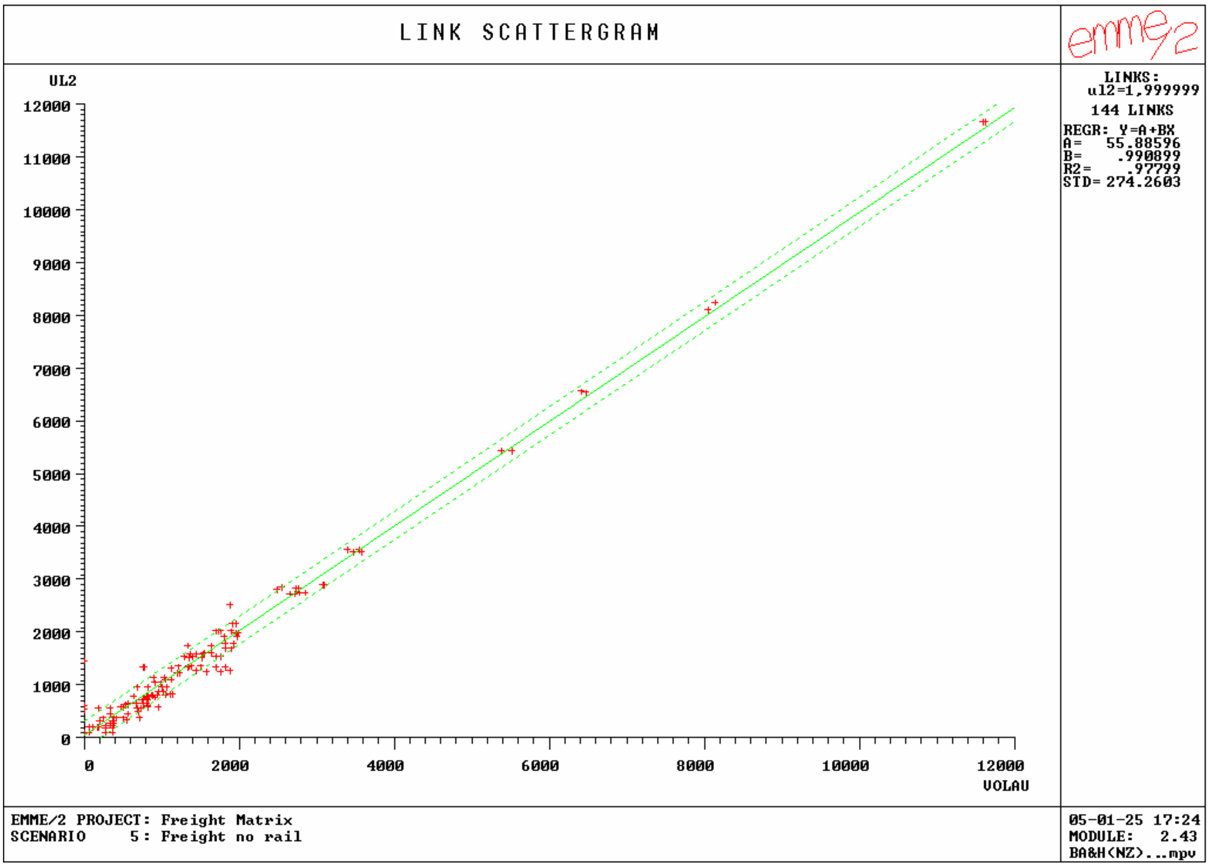


Figure 6.6 Observed versus modelled (road final matrix) assigned flows.



The resulting final road matrix after 50 iterations is much larger than the seed, by around 75% in volume and 90% in tonne-km. Freight volumes not explained by the seed matrix have a longer average trip length than the seed (158 km v 133 km), which in turn increases the average trip length of the final matrix to 144 km. While there are no corresponding observed volumes to compare against, tonne-km estimates from the HVLP study (Transit New Zealand 2001) gave a total of 12.8 billion (bn) tonne-km across all vehicles for 1999. This compares well with our 2002 estimate of 12.9 bn tonne-km. It is difficult to identify exactly how the freight market has changed since 1999, but with freight movements somewhat correlated with GDP, we would expect them to be higher in the 2002 year of our matrix. Using the growth estimates discussed in Section 3.3.1 and the 1999 HVLP figures, the total tonne-km level could be as high as 15.8 bn tonne-km. As such, our estimate may well be on the conservative side, accounting for 82% of tonne-km by this measure (12.9 bn v 15.8 bn tonne-km), but it is clearly in the right order of magnitude. It should be noted that this study and the HVLP have reached these figures in an independent way.

As a further check, the tonne-km were divided by the average load factor to give vehicle-km, and compared with the HVLP. The 12.9 bn tonne-km equates to approximately 1.36 bn vehicle-km (VKM) (using the national average load factor of 9.5 under the midpoint scenario, see Table 6.1), while the HVLP study gave the total nationwide vehicle-km as 0.69 bn VKM for A, B and R type vehicles,[16] and 1.24 bn VKM for other smaller commercial vehicles. In constructing our matrix we used a weighting of ½ for the smaller commercial vehicles (to give the average payload), so weighting the smaller commercial vehicles by ½ gave a nationwide vehicle-km value of 1.32 bn VKM (0.69+0.5×1.24). This is around 3% lower than our value, and the difference can be partially explained by a difference in base year, but it does indicate that the matrix is broadly consistent with other information.

Table 6.4 Seed, final and difference road matrix statistics.

Matrix	Tonnage (million)	Tonne-km (million)	Ave Trip Length
Seed	51.1	6818	133.4
Difference	38.5	6105	158.5
Total	***89.6***	***12923***	***144.2***
Seed	57%	53%	
Difference	43%	47%	

Table 6.4 presents summary statistics of the seed, final and difference (between the seed and final) road matrices. The actual final road matrix is shown in Table 6.5 and the difference matrix is shown in Table 6.6. Figures 6.7 to 6.9 display the number of freight tonnes moved within each distance band of each matrix.

16 A – Articulated; B – B-train; R – rigid vehicles.

Examining the final road matrix (Table 6.5) in detail shows that the Auckland region is a significantly larger player in both the production (23% of total) and attraction (25% of total) of freight movements than in the seed matrix. This reflects the dominant role of that city noted in Chapter 2. Waikato (contributing 20% of productions and 16% of attractions) and Canterbury (13% productions and 12% attractions) are still very important, and Bay of Plenty also remains as both a strong producer and attractor of road freight. Intra-regional freight movements now comprise around 55% of the total (rather than 50% in the seed matrix), indicating a higher proportion of shorter distance trips.

The seed matrix (the distribution for which is shown in Figure 6.7) contains around 75% of freight movements within 200 km, and a further 15% between 200 km and 400 km. In comparison, the final matrix (the distribution for which is shown in Figure 6.8) has a lower proportion of trips of less than 200 km (around 73%) and a higher proportion between 200 km and 400 km (around 20%). This indicates the matrix estimation process increased the proportion of medium and longer distance movements at the expense of shorter distance movements. The difference-matrix trip-length distribution (Figure 6.9) shows shorter distance (less than 200 km) freight movements comprise around 68% of the total, while medium length (200-400 km) movements comprise around 24%.

Figure 6.7 Trip length distribution of road seed matrix.

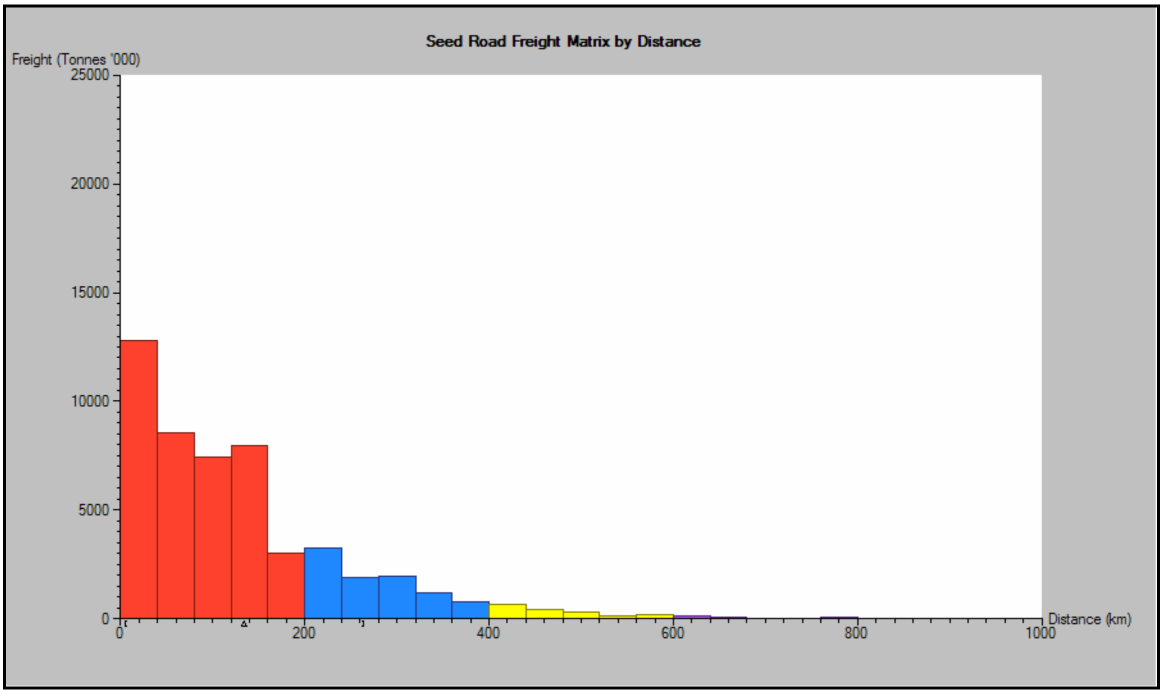


Figure 6.8 Trip length distribution of road final matrix.

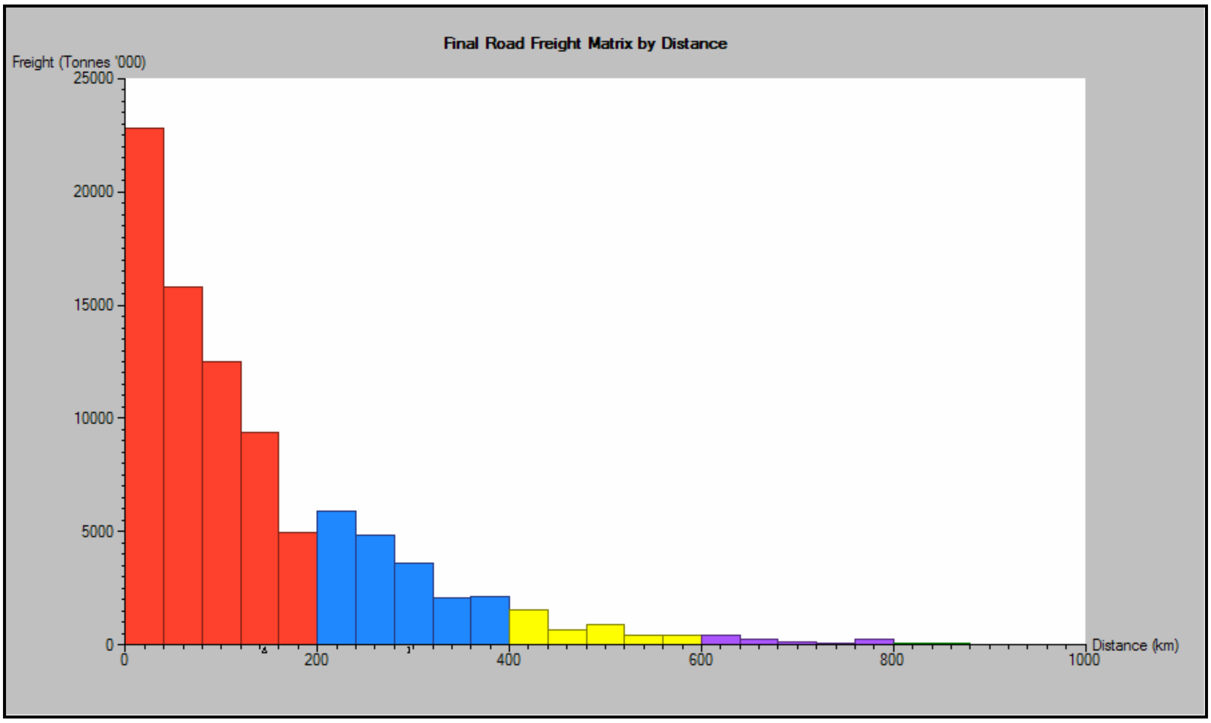


Figure 6.9 Trip length distribution of road difference matrix.

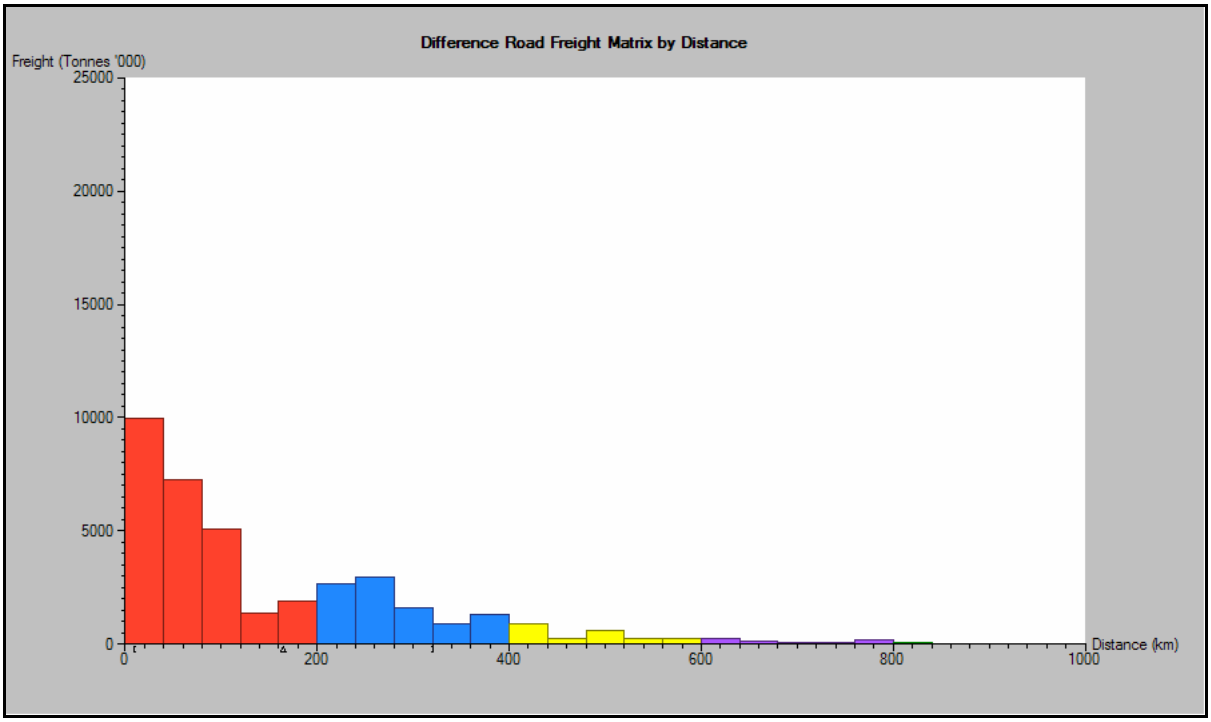


Table 6.5 Road final estimated matrix (annual tonnes '000).

From \ To	Northland	Auckland	Waikato	Bay of Plenty	Gisborne	Hawke's Bay	Taranaki	Manawatu-Wanganui	Wellington	Tasman	Nelson	Marlborough	West Coast	Canterbury	Otago	Southland	**TOTAL**
Northland	1,822	312	290	65	3	2	18	5	0	0	0	0	-	0	-	-	**2,516**
Auckland	485	15,333	2,944	1,309	55	66	73	118	98	0	0	0	0	58	0	-	**20,539**
Waikato	263	4,014	7,535	3,538	93	330	753	771	446	45	11	25	1	41	3	1	**17,871**
Bay of Plenty	43	1,724	1,649	5,251	219	48	163	283	81	2	0	1	0	1	0	0	**9,466**
Gisborne	6	57	98	384	520	131	12	98	85	9	3	6	0	6	1	0	**1,415**
Hawke's Bay	4	33	190	228	201	1,309	79	358	194	15	4	9	0	15	6	0	**2,645**
Taranaki	19	250	499	105	29	94	1,826	457	269	5	1	2	0	3	0	0	**3,558**
Manawatu-Wanganui	9	161	476	571	244	327	426	760	946	19	4	11	0	35	3	0	**3,991**
Wellington	2	119	185	218	125	117	323	1,108	1,912	122	50	88	3	164	27	3	**4,565**
Tasman	0	1	13	18	11	7	18	24	138	766	746	197	28	81	42	0	**2,091**
Nelson	0	0	1	2	2	1	0	2	30	342	111	99	113	156	116	0	**975**
Marlborough	0	0	14	22	17	10	11	20	137	410	107	274	16	489	44	11	**1,583**
West Coast	0	0	2	2	0	0	5	6	7	31	24	26	366	427	17	3	**916**
Canterbury	1	3	25	34	6	4	60	97	43	124	303	730	450	8,146	928	359	**11,314**
Otago	0	0	2	3	1	1	5	5	6	11	15	37	7	529	1,700	728	**3,050**
Southland	0	0	1	1	0	0	4	4	1	3	2	15	22	356	669	2,056	**3,134**
TOTAL	**2,653**	**22,007**	**13,926**	**11,749**	**1,525**	**2,446**	**3,776**	**4,117**	**4,391**	**1,904**	**1,382**	**1,520**	**1,008**	**10,507**	**3,556**	**3,162**	**89,630**

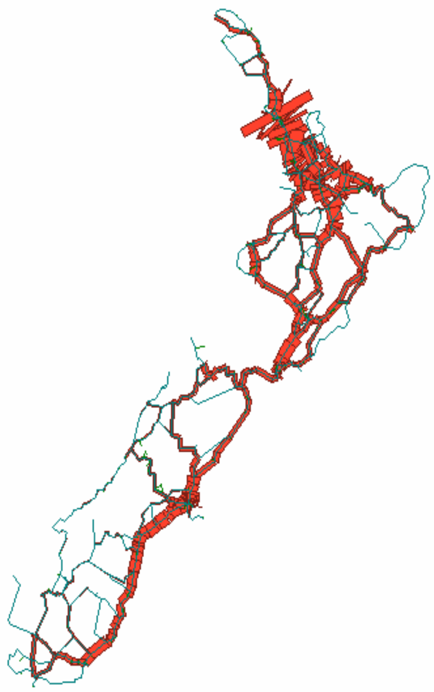
Table 6.6 Road difference matrix of final minus seed (annual tonnes '000).

(Final matrix tonnages that are lower than those of the seed matrix are in parentheses)

From \ To	Northland	Auckland	Waikato	Bay of Plenty	Gisborne	Hawke's Bay	Taranaki	Manawatu-Wanganui	Wellington	Tasman	Nelson	Marlborough	West Coast	Canterbury	Otago	Southland	**TOTAL**
Northland	-	(421)	136	1	2	(0)	5	2	0	0	(0)	(0)	-	0	-	-	**(274)**
Auckland	87	14,069	2,264	1,074	49	41	49	74	65	0	(0)	0	-	52	0	-	**17,825**
Waikato	(327)	2,375	(373)	(1,238)	(71)	(456)	276	355	348	36	(1)	10	(0)	36	3	1	**973**
Bay of Plenty	(21)	1,193	112	2,989	174	(27)	76	183	67	2	0	1	0	1	0	0	**4,752**
Gisborne	(4)	42	(29)	(77)	-	(79)	8	79	74	9	1	4	0	6	1	0	**35**
Hawke's Bay	(39)	(49)	(220)	(198)	(26)	(87)	8	(13)	66	11	(1)	2	(0)	12	5	0	**(528)**
Taranaki	(13)	128	163	(32)	25	63	372	283	243	4	(0)	1	(0)	2	0	0	**1,239**
Manawatu-Wanganui	(14)	81	144	333	227	113	19	98	709	11	(5)	(3)	(1)	29	3	0	**1,744**
Wellington	(1)	109	129	179	117	28	180	685	1,297	106	16	47	1	150	27	3	**3,072**
Tasman	(1)	(0)	1	11	10	(1)	(15)	(12)	4	-	45	70	(23)	37	34	(0)	**161**
Nelson	(0)	-	0	1	2	(0)	0	(1)	(2)	279	-	31	77	141	112	0	**641**
Marlborough	(1)	(1)	(5)	7	15	(8)	(24)	(30)	(59)	279	(81)	(7)	(9)	424	43	11	**553**
West Coast	(0)	(1)	(5)	0	0	(0)	(25)	(19)	(15)	(23)	(23)	(16)	7	261	(4)	0	**138**
Canterbury	(1)	(2)	5	26	5	(0)	(24)	21	7	37	188	575	194	4,292	638	274	**6,236**
Otago	-	0	2	3	1	0	4	4	5	9	12	34	(1)	210	647	98	**1,029**
Southland	-	0	1	1	0	0	2	3	1	0	1	14	3	158	181	548	**913**
TOTAL	**(335)**	**17,523**	**2,325**	**3,079**	**530**	**(415)**	**913**	**1,713**	**2,811**	**759**	**152**	**764**	**248**	**5,814**	**1,691**	**935**	**38,507**

Figure 6.10 shows the road freight flows throughout New Zealand, with the width of the grey bar reflecting flow magnitude. Most North Island activity is centred on the Auckland, Waikato and Bay of Plenty regions, while most South Island activity is restricted to its East Coast. It should be noted that some of the paths chosen between two points may not be the most optimal, because speed, gradient and road curvature have not been included in the Emme/2 assignment attributes.

Figure 6.10 Assigned freight movements from road final matrix.



6.8 Sensitivity of average load

As explained in Section 6.5, there is a large variation in heavy vehicle average loads between the regions. While observed heavy vehicle flows provide a total proportion on each road segment, they do not give a breakdown of flow composition. Some observed links within urban areas, such as the Auckland Harbour Bridge or Ngauranga Gorge, can be assumed to contain a higher proportion of shorter distance movements; however the majority are likely to relate to longer-distance freight movements. The inclusion/exclusion of 'other' vehicle types (smaller loads) changes payloads significantly, with the New Zealand average almost doubling, from 6.6 to 12.5 tonnes, when 'other' is removed from the calculation. For this reason, the midpoint of the two extremes has been used as the best estimate of average load, and two sensitivities have been undertaken to give a range of low and high extreme values.

The midpoint payload is used in the conversion from link-based vehicle flows to freight flows. Changing the assumption about average payload only affects the second part of the matrix estimation process, from the seed matrix to the final matrix, and therefore, all three scenarios have the same seed matrix.

Table 6.7 shows the impact of changing the assumption about average payload. As shown in the previous section, the 'midpoint load' assumption results in 89.6 million tonnes and 12.9 billion tonne-km. A more conservative view of average payloads ('low load') reduces the total freight movements to 70.2 million tonnes (-22%) and tonne-km to 9.4 billion (-27%). The average trip length is also lower at 134 km (-7%). The upper bound (or 'high load') dramatically increases the final matrix, with freight movements at 180 million tonnes (+21%) and tonne-km at 16.5 billion (+28%). The average trip length under this scenario is also higher at 153 km (+6%). Changing the assumptions relating to average payload gives a +/-20% bound for freight movements and +/-30% bound for freight km, with the larger payloads encouraging longer trips.

Because of the large sensitivity of the matrix to these assumptions, further work needs to be undertaken on average loads at each of the heavy-vehicle reporting sites. A breakdown in the proportion of A, B, and R-type vehicles would be useful in that it could be related to the HVLP and a better estimate at each site (rather than at a regional level) could be undertaken.

Table 6.7 Impact of load assumptions on final road matrix.

Matrix	Tonnage (million)	Tonne-km (million)	Average Trip Length (km)
Seed (used for all)	51.1	6818	133.4
Midpoint Load			
Difference	38.5	6,105	158.5
Total Midpoint Load	***89.6***	***12,923***	***144.2***
Low Load			
Difference	19.1	2,591	135.6
Total Low Load	***70.2***	***9,409***	***134.0***
High Load			
Difference	57.1	9,723	170.3
Total High Load	***108.2***	***16,541***	***152.9***

6.9 Combining road with rail

Once the road matrix had been generated through the modelling process, it was combined with the previously described rail matrix (Section 5.6) to create a total land transport matrix of freight movements, shown in Table 6.8. This total matrix largely reflects the road matrix trends (as expected given the high mode share of road) and shows that the Auckland region again dominates in both production (21% of total) and attraction (22% of total) of freight movements. Waikato (contributing 20% of productions and 14% of attractions), Bay of Plenty (12% of productions and 16% of attractions) and Canterbury (12% productions and 13% attractions) are also large players. The shares attributed to each region are in accordance with the types of freight flows noted in Chapter 2.

Table 6.8 summarises some key background statistics relating to the land-based modes, giving a comparison of tonnage carried, tonne-km travelled and corresponding average trip length and mode shares. It shows that the average trip length of rail is significantly higher than road and that while rail provides 13% of freight tonnage, its contribution to tonne-km is much higher at 21%. This confirms the expectation that rail is predominantly used to move freight over longer distances than road.

Table 6.8 Road and rail matrix statistics.

Matrix	Tonnage (million)	Tonne-km (million)	Ave Trip Length (km)
Road	89.6	12,923	144.2
Rail	13.6	3,463	254.4
Total	***103.2***	***16,386***	***158.7***
Road	87%	79%	
Rail	13%	21%	

Note:
(1) Tonnage and tonne-km are based on midpoint payload, as discussed in Section 6.8.
(2) Tonne-km are calculated using model distances and may differ from tonne-km calculated using other methods.

Figure 6.11 Trip length distribution of road + rail matrix.

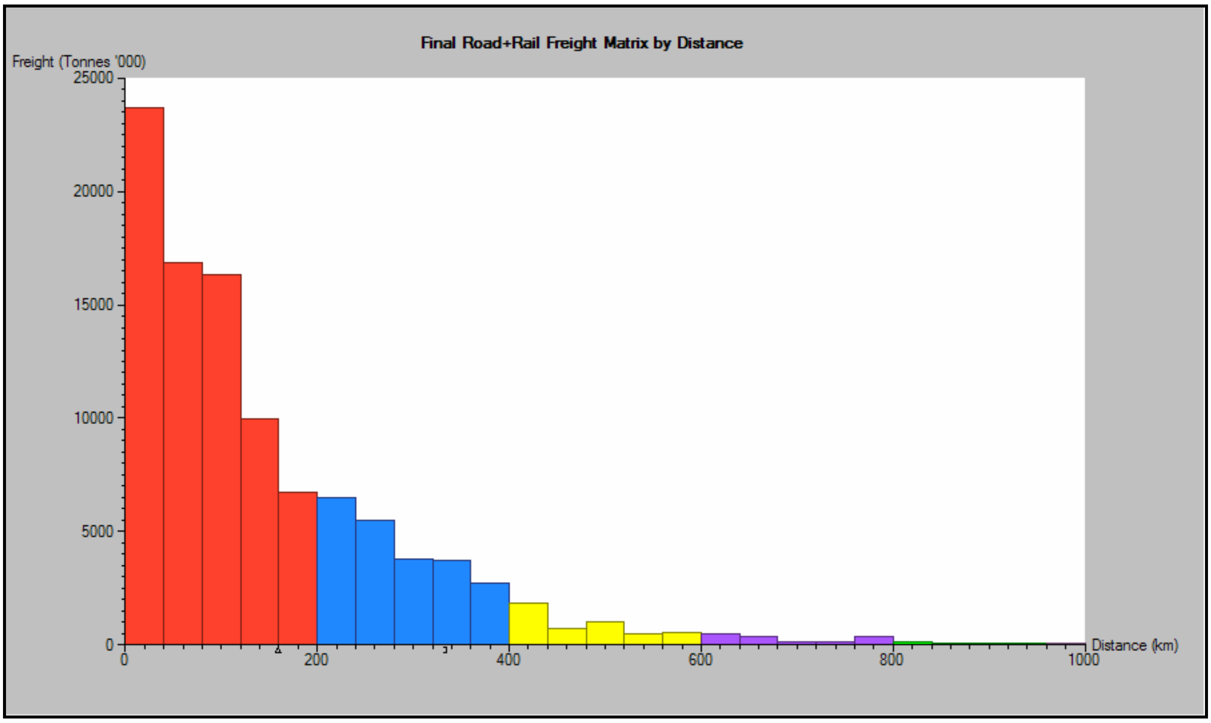


Figure 6.11 provides a trip length distribution of the combined road and rail matrix. This distribution contains virtually the same proportion of freight movements of less than 200 km when compared with road. However it shows a greater proportion of movements between 200 km and 400 km (at 22% rather than 20%) indicating that a larger proportion of rail freight is of medium distance.

In summary, the final matrix shows that Auckland, Waikato, Bay of Plenty and Canterbury are the dominant freight producing and receiving regions. Many freight movements are intra-regional, and most are over the relatively short distances in which road dominates, with a high proportion of less than 200 km distance. Rail has greatest mode share in the medium and longer distance freight corridors.

Table 6.9 Estimated road and rail freight matrix (annual tonnes '000).

From \ To	Northland	Auckland	Waikato	Bay of Plenty	Gisborne	Hawke's Bay	Taranaki	Manawatu-Wanganui	Wellington	Tasman	Nelson	Marlborough	West Coast	Canterbury	Otago	Southland	**TOTAL**
Northland	2,226	469	295	108	3	2	18	5	1	0	0	0	0	1	0	1	**3,129**
Auckland	567	15,377	2,961	1,590	55	91	100	167	179	0	6	15	1	340	29	10	**21,488**
Waikato	271	4,090	8,312	5,400	94	331	760	777	449	45	12	26	1	74	6	3	**20,651**
Bay of Plenty	44	2,211	1,692	7,589	219	52	174	290	108	2	1	3	0	30	4	2	**12,421**
Gisborne	6	57	98	384	520	133	12	98	85	9	3	6	0	7	1	0	**1,419**
Hawke's Bay	5	86	193	236	226	1,452	124	470	230	15	5	10	0	53	7	3	**3,116**
Taranaki	19	318	517	236	29	98	2,005	465	319	5	3	4	1	31	5	1	**4,057**
Manawatu-Wanganui	9	217	479	589	245	370	1,156	787	1,109	19	5	12	1	70	5	2	**5,074**
Wellington	3	139	186	229	125	127	327	1,178	1,985	122	51	94	4	181	32	4	**4,785**
Tasman	0	1	13	18	11	7	18	24	138	766	746	197	28	81	42	0	**2,091**
Nelson	0	7	2	3	2	2	0	3	32	342	133	100	113	164	117	0	**1,021**
Marlborough	0	37	15	30	17	11	13	23	153	410	115	282	16	509	49	13	**1,694**
West Coast	0	2	2	3	0	0	5	6	8	31	24	26	380	2,439	26	3	**2,955**
Canterbury	2	142	63	69	6	12	83	174	77	124	319	746	462	8,517	1,183	442	**12,421**
Otago	0	28	4	6	1	3	9	13	13	11	16	40	7	624	1,748	759	**3,282**
Southland	0	15	6	4	0	6	8	8	5	3	2	15	23	529	858	2,159	**3,640**
TOTAL	**3,153**	**23,196**	**14,838**	**16,495**	**1,552**	**2,698**	**4,810**	**4,488**	**4,889**	**1,904**	**1,441**	**1,575**	**1,039**	**13,649**	**4,112**	**3,404**	**103,243**

7. Examination of freight-trip-end model

7.1 Introduction

This chapter examines the possibility of developing a total freight-trip-end model (i.e. including both road and rail), and whether it would be a suitable simplification to the previously applied matrix estimation process.

A trip-end model for freight origins takes the matrix-estimated freight productions (total freight originating by TLA in this case) and tries to relate these to explanatory variables (also at a TLA level). A similar approach can be taken for freight destinations. Explanatory variables are assumed to relate linearly to the productions/attractions, and accordingly multiple linear regression is the statistical technique used.

Trip-end productions (by origin) and attractions (by destination) can be used in conjunction with a distance matrix (using a gravity model as used in the matrix estimation process) to give a new matrix estimate assuming the same average trip length. The advantage of this process over the full matrix estimation approach is that it is simpler to implement (once models are determined), does not require detailed data collection from industry or freight operators, and gives the ability to crudely estimate future year matrices. All that is potentially needed for future forecasts is a projection of the explanatory variables and a view of any changes in average trip length. Note that the resulting matrix is not as accurate as the fully estimated matrix, but it can be viewed as a good approximation of it.

7.2 Data used

The variables used in this analysis were obtained from the Statistics New Zealand website, which has datasets for the 2001 year that can be downloaded at a TLA level. These include demographic information, such as population by age group and total number of households, and employment statistics by industry and by full or part-time classification (full-time equivalent (FTE) employment was estimated by taking full-time + 0.5 × part-time).

Table 7.1 shows employment segments and the associated FTE total for the whole country. A final column has been added to the table to show the expected directed influence of the employment sector on freight production and/or attraction. We would expect some sectors to be generators of freight (such as agriculture, forestry and fishing; mining; or manufacturing) and these are shown with a plus (+), while others to have a negative impact on freight (such as service-based industries or education) and these are shown with a minus (-). Some industries are not as easy to classify and so have been given a question mark (?). These were the hypotheses by which conclusions were drawn regarding the suitability of trip-end relationships that were derived.

Table 7.1 Employment variables used for trip-end model examination.

Employment Segment	Description	Total NZ FTE Employed	Expected Impact on Freight
AFF	Agriculture, Forestry and Fishing	111,384	+
MIN	Mining	2,622	+
MAN	Manufacturing	191,609	+
EGW	Electricity, Gas and Water	4,968	+
CON	Construction	69,465	+
WST	Wholesale Trade	83,057	+
RLT	Retail Trade	158,508	+
ACR	Accommodation, Cafes and Restaurants	58,554	?
TAS	Transport and Storage	48,887	?
COM	Communication Services	17.421	–
FIN	Finance and Insurance	44,322	–
PRO	Property and Business Services	156,906	–
GAD	Government Admin. And Defence	50,793	–
EDU	Education	101,352	–
HCS	Health and Community Services	105,102	–
CRS	Cultural and Recreational Services	31,014	–
PER	Personal and other Services	48,539	?
POP	2001 Total Population	3,736,101	?

7.3 Origin and Destination trip-end model estimation

The trip-end models are linear multi-variate, and relate freight productions/attractions by origin/destination TLA, with TLA specific employment by sector and/or population. One of the difficulties when using employment by sector is that there is a high level of correlation between most of the variables. Correlation is a measure of the degree to which behaviour of one variable mirrors the behaviour of another: if correlation is high (close to +/- 1) then either variable could be used as a substitute for the other. Including both variables in the equation does not add anything to the model, and may affect the significance or sign of the coefficient of the other.

The correlation matrix (refer Table E4 in Appendix E) shows that only AFF and MIN are distinctly different from the other variables, with low correlation values. GAD is only marginally correlated, while the rest are extremely similar and could be substitutes for each other in the equation. As such, developing a robust set of equations is difficult, as removal of a highly correlated variable from the analysis is likely to change other variables it is correlated with, particularly in terms of sign and significance.

To derive an appropriate trip-end model, all variables were included in the initial model. One by one, variables were excluded and the model re-estimated, a process known as step-wise regression. Exclusion of variables was based on the extent to which a variable's parameter value was statistically significantly different from zero, whether it was highly correlated with another variable that had been included, or whether the expected sign of the coefficient was correct (positive or negative). A constant was also included to allow for any freight not explained by the variables.

After initial model estimations, significant outliers (where the modelled estimation was very different from the observed values) were found. Further examination identified some of these as TLAs with ports and it was found that employment categories were not disaggregated enough to give an indication of port-based activity. It would be expected that the loading/unloading of freight at ports would have a positive impact on freight movements to/from port TLAs and, for this reason, two further variables were created to represent port existence and relative size (see Appendix E).

7.3.1 Origin trip-end model

The following process was undertaken to arrive at an origin trip-end final formulation. The number in brackets represents the adjusted R^2, which indicates the level to which the model corresponds to the observed data taking into account the number of variables used. As variables are excluded, the adjusted R^2 should increase if the model is improved:

- Start: All variables (0.616)
- Step 1: Exclude CON as not significant and wrong sign (0.622)
- Step 2: Exclude POP as not significant and wrong sign (0.629)
- Step 3: Exclude MAN as not significant and wrong sign (0.635)
- Step 4: Exclude RLT as not significant (0.640)
- Step 5: Exclude EGW as not significant (0.644)
- Step 6: Exclude COM as not significant (0.646)
- Step 7: Exclude GAD as not significant (0.650)
- Step 8: Exclude EDU as not significant and wrong sign (0.654)
- Step 9: Exclude CRS as not significant (0.655)
- Excluding any more variables had a negative impact on the adjusted R^2

The final origin model parameters are listed in Table 7.2 which shows that all parameters (other than the constant) are highly significant (different from zero, as indicated by a P-value close to zero) to at least 10%.

A positive constant indicates that there are positive TLA freight production drivers not explained by the variables included. A value of 5582 (5.6 million tonnes) for PORTORIG gives an estimate of what the largest general import port (Auckland) would unload. This compares with an observed figure of around 3.3 million tonnes for 2002. While the estimated figure is higher, it should be noted that the observed number does not include any coastal sea freight movements.

Table 7.2 Estimated origin trip-end model coefficients.

Variable	Coefficient	Significance (P-Value)
CONSTANT	277.24	0.22
PORTORIG	5582.44	0.00
AFF	0.35	0.00
MIN	4.15	0.06
WST	1.99	0.00
TAS	–1.04	0.00
ACR	0.67	0.05
FIN	2.57	0.00
PRO	–1.76	0.00
HCS	–0.64	0.02
PER	1.97	0.03

As expected the AFF, MIN and WST coefficients are positive, and the PRO and HCS coefficients are negative. TAS somewhat surprisingly has a negative impact on freight, but this might be driven by 'transport' rather than 'storage' employment. ACR has a positive impact on freight movements, probably driven by supply of local restaurant services. PER is also positive, and might be a proxy for other variables that are not included but related to personal services. The surprising variable is FIN, which was strong and positive. Its inclusion might be related to economic activity.

The value of the coefficient indicates the relative output of each worker for a given industry. For example, the coefficient for mining (MIN) is 4.15, indicating that each full-time equivalent worker in the mining industry produces 415,000 tonnes of freight on average. Conversely an agriculture worker produces only 35,000 tonnes. A negative value is a measure of competition for use of land and resources.

7.3.2 Destination trip-end model

The process was repeated for destinations, using total freight arriving at a TLA as the observed variable.

- Start: All variables (0.648)
- Step 1: Exclude GAD as not significant (0.654)
- Step 2: Exclude MAN as not significant (0.660)
- Step 3: Exclude PER as not significant (0.666)
- Step 4: Exclude RLT as not significant (0.672)
- Step 5: Exclude MIN as not significant and wrong sign (0.677)
- Step 6: Exclude POP as not significant (0.681)
- Step 7: Exclude CRS as not significant (0.684)

- Step 8: Exclude EGW as not significant and wrong sign (0.687)
- Step 9: Exclude EDU as not significant and wrong sign (0.690)
- Step 10: Exclude COM as not significant (0.693)
- Excluding any more variables had a negative impact on the adjusted R^2

The final destination model parameters are listed in Table 7.3. All parameters other than HCS are significant to at least 20%. Interestingly, the variables resulting from the model estimation process bear a strong resemblance to the origin model in terms of sign and magnitude. MIN is excluded and CON included, indicating that mining is a strong generator of freight, and construction a strong attractor. PER is also excluded from the destination model.

Table 7.3 Estimated destination trip-end model coefficients.

Variable	Coefficient	Significance (P-Value)
CONSTANT	315.90	0.17
PORTDEST	6201.14	0.00
AFF	0.28	0.01
CON	0.59	0.14
WST	1.79	0.00
TAS	–1.00	0.00
ACR	0.51	0.18
FIN	2.67	0.00
PRO	–1.49	0.00
HCS	–0.24	0.27

A positive constant indicates that there are positive TLA freight attractor drivers not explained by the variables included. A value of 6201 (6.2 million tonnes) for PORTDEST gives an estimate of what the largest export port (Tauranga) would load. This compares favourably with observed data of around 7.1 million tonnes for 2002.

All signs are consistent with the origin model, with parameter values being of a similar magnitude, and most variables found to be significant in this model are also contained in the origin model. This highlights the complex nature of freight movements, where an industry can be a producer of freight in one leg of the process, but then an attractor further down the production line (and vice versa).

7.3.3 Outliers

There are some significant outliers for both the origin and destination trip-end models. These typically relate to areas where specific freight production or attraction facilities have not been captured in the employment data.

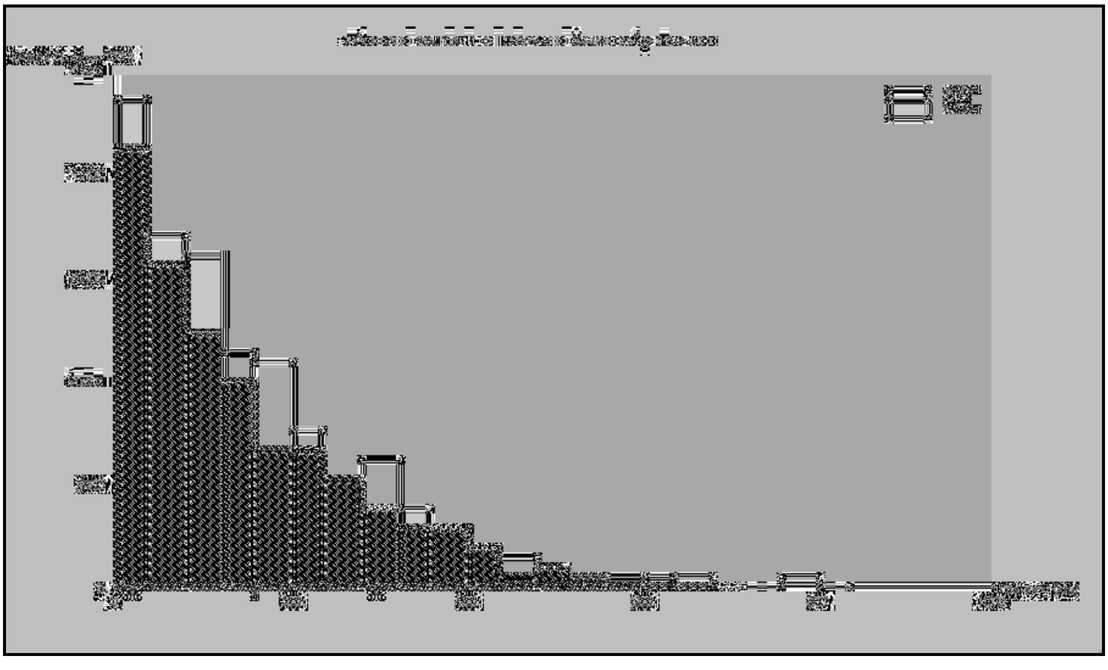
However with such general industry groupings it was not possible to represent these more accurately. The exploration of industry employment at a more disaggregated level would reduce the impact of this problem and might be an area for further work from this project. Such data would provide a more detailed representation of the spread of relevant industrial activity and allow the creation of a more accurate trip-end model.

7.4 Application

The purpose of this application was to produce an estimated matrix (Table 7.4) which could be compared with the fully estimated matrix through matrix estimation procedures. To achieve this, the trip-end origin and destination models and variable inputs were used to create two vectors, providing an estimate of the total tonnage starting and finishing in each TLA. These vectors were then read into the Emme/2 transport modelling package, and a matrix-balancing procedure using an entropy function (see Chapter 6) was undertaken to distribute trips by origin against trips by destination. This assumed the same trip length as the final total freight matrix (158.7 km). The estimated matrix was then compared with the total fully estimated matrix.

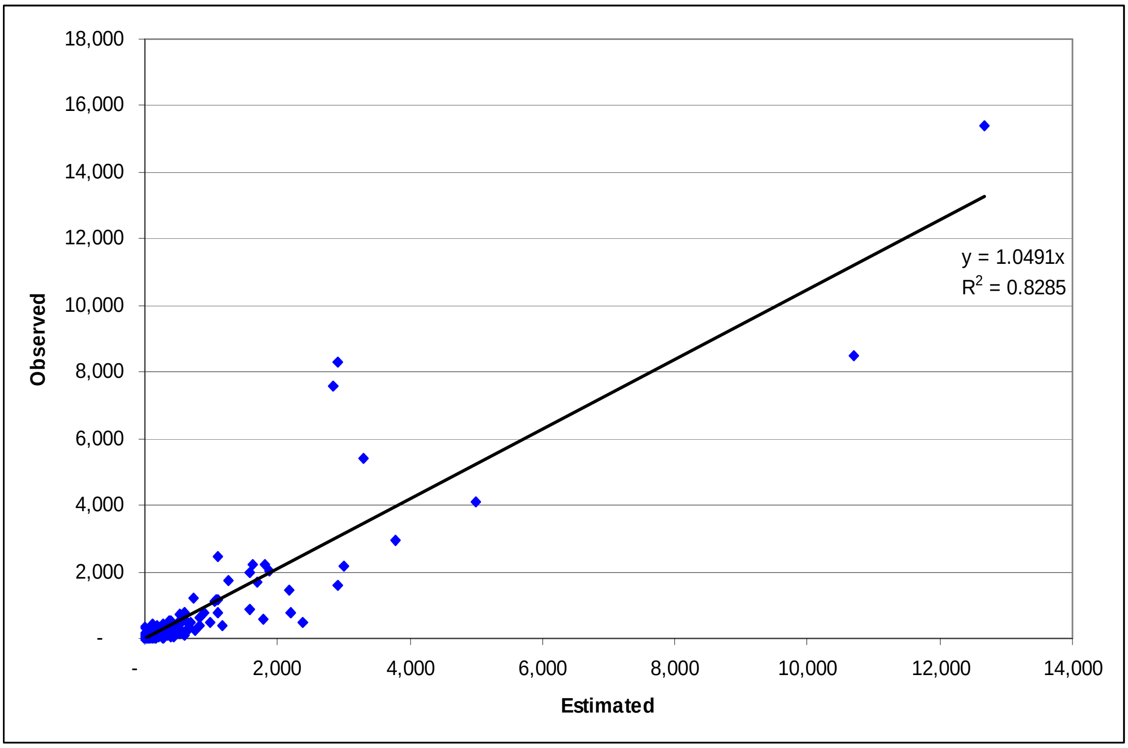
Initially the simplified regression process was found to overestimate shorter distance trips and underestimate longer distance trips. To overcome this, differential functions (see Appendix E for more information) were used for distances of less than and greater than 40 km. Figure 7.1 compares the final matrix (grey) with the estimated matrix using a trip-end approach (white). The shaded area shows the overlap between the two.

Figure 7.1 Observed versus trip-end-estimated freight matrices by distance.



Overall shorter-distance trips are underestimated by the trip-end approach, and medium-distance trips are overestimated. Comparison of the two matrices at a TLA level gives poor results (correlation of around 0.3), due to large differences being inherited from the trip-end models. However, a comparison at a regional level (Figure 7.2) is more favourable, with a correlation of 0.83 (where a correlation of '1' would indicate a perfect fit).

Figure 7.2 Scatterplot of fully-estimated versus trip-end-estimated regional freight movements.



A comparison of the resulting matrices from the two approaches (see difference matrices in Tables 7.5 and 7.6) indicates an underestimation of intra-regional freight movements by the trip-end approach (particularly for North Island regions), and an overestimation of longer distance movements. Total freight movements are preserved through the regression process which controls the constant to match the total. The largest origin discrepancies relate to freight generated from Waikato and Bay of Plenty (which are underestimated), and Hawke's Bay and Manawatu-Wanganui (which are overestimated). These regions also have the largest differences at the destination end. Trip-end total differences indicate the fit of the trip-end regression models as discussed in Section 7.3.

The percentage differences between the fully-estimated and trip-end-estimated matrices are large. All extreme values relate to minor flows and should be ignored, as a process such as this is designed to represent larger flows, and it is assumed that the minor flows would remain minor.

There are large differences at a regional level, both in terms of productions and attractions. These differences relate to the accuracy of the trip-end regression models in matching actual levels. The use of a more disaggregated industry breakdown of employment data might improve accuracy of the trip-end models in this respect. Any errors in trip-ends have significant implications for individual region to region movements, and these are indicated by the percentage differences in individual cells being generally larger than the row or column differences.

While a fixed trip length gives an adequate fit, it does not provide a good representation of short versus long distance freight. Further investigation would be required to determine a more complex trip distribution function, which might be segmented into two or three distance bands. A distribution function based on time rather than distance would allow the development of a more representative road network, which might also improve model fit.

Finally, the introduction of 'k-factors' could be explored. These would be used to modify times/costs at a regional level within the matrix, to either correct for inaccuracies in the network (to allow for the loading/unloading of freight over Cook Strait or for steep winding roads that might be deterrent for freight travel for example) or to take into account freight-movement perceptions/functions that could not be represented solely in cost or travel time terms (such as contracts).

In summary, the trip-end approach does have some merit, giving a matrix of the same broad shape as the fully-estimated approach whilst preserving total movements. However, individual region to region movements have large errors, which are a function of the accuracy of the regression equations and the trip length distribution used.

Table 7.4 Trip-end-estimated total freight matrix (annual tonnes '000).

From \ To	Northland	Auckland	Waikato	Bay of Plenty	Gisborne	Hawke's Bay	Taranaki	Manawatu-Wanganui	Wellington	Tasman	Nelson	Marlborough	West Coast	Canterbury	Otago	Southland	**TOTAL**
Northland	1,620	2,391	345	228	10	27	47	25	4	0	0	0	0	0	-	-	**4,698**
Auckland	1,786	12,668	3,778	2,916	126	341	597	320	56	3	2	6	1	3	0	0	**22,603**
Waikato	354	4,985	2,918	3,298	179	669	892	603	118	5	5	13	2	6	0	0	**14,046**
Bay of Plenty	105	1,807	1,692	2,843	351	447	290	285	62	3	3	6	1	3	0	0	**7,899**
Gisborne	6	96	105	349	400	342	23	74	31	1	1	3	0	1	0	-	**1,431**
Hawke's Bay	25	425	609	756	556	2,174	257	988	436	16	15	36	4	16	0	0	**6,313**
Taranaki	28	488	528	351	27	197	1,878	677	203	9	9	22	3	10	0	0	**4,429**
Manawatu-Wanganui	28	477	640	583	146	1,166	1,072	2,191	1,065	48	45	112	13	49	1	0	**7,636**
Wellington	5	88	132	134	63	533	320	1,108	1,581	120	113	279	33	122	1	0	**4,634**
Tasman	0	7	11	11	4	34	27	90	206	597	570	244	140	166	3	1	**2,111**
Nelson	0	2	2	2	1	7	6	19	42	125	60	50	21	25	0	0	**364**
Marlborough	1	14	20	20	7	63	49	166	377	193	181	304	62	375	4	1	**1,837**
West Coast	0	6	9	8	3	27	21	70	160	395	273	214	814	1,099	35	21	**3,156**
Canterbury	1	10	14	14	5	44	35	117	266	211	146	536	560	10,705	742	284	**13,689**
Otago	0	0	0	0	0	1	1	2	5	6	4	10	33	820	1,262	1,093	**3,236**
Southland	0	0	0	0	0	0	0	1	3	5	3	6	30	527	1,577	3,013	**5,166**
TOTAL	**3,959**	**23,464**	**10,803**	**11,514**	**1,881**	**6,071**	**5,513**	**6,736**	**4,615**	**1,738**	**1,430**	**1,841**	**1,718**	**13,925**	**3,625**	**4,414**	**103,247**

Table 7.5 Absolute difference of fully-estimated minus trip-end-estimated freight matrix (annual tonnes '000).

From \ To	Northland	Auckland	Waikato	Bay of Plenty	Gisborne	Hawke's Bay	Taranaki	Manawatu-Wanganui	Wellington	Tasman	Nelson	Marlborough	West Coast	Canterbury	Otago	Southland	**TOTAL**
Northland	607	(1,922)	(50)	(120)	(7)	(25)	(29)	(20)	(4)	(0)	(0)	(0)	(0)	0	0	1	**(1,569)**
Auckland	(1,219)	2,708	(818)	(1,326)	(71)	(250)	(497)	(153)	124	(2)	3	9	1	337	29	10	**(1,115)**
Waikato	(84)	(895)	5,394	2,102	(85)	(338)	(132)	174	332	39	7	13	(0)	69	6	3	**6,606**
Bay of Plenty	(61)	403	(1)	4,746	(132)	(395)	(116)	5	46	(1)	(2)	(4)	(0)	27	4	2	**4,522**
Gisborne	1	(39)	(6)	35	119	(208)	(11)	24	54	8	2	3	(0)	6	1	0	**(12)**
Hawke's Bay	(19)	(339)	(416)	(520)	(330)	(722)	(132)	(518)	(206)	(0)	(9)	(26)	(4)	37	7	3	**(3,196)**
Taranaki	(10)	(170)	(10)	(115)	2	(98)	127	(211)	116	(5)	(6)	(18)	(2)	21	5	1	**(372)**
Manawatu-Wanganui	(19)	(259)	(161)	6	99	(796)	84	(1,404)	43	(30)	(40)	(100)	(12)	21	5	2	**(2,562)**
Wellington	(2)	51	54	94	61	(405)	6	70	403	2	(62)	(185)	(29)	59	30	4	**151**
Tasman	(0)	(7)	2	7	7	(27)	(9)	(66)	(68)	168	177	(47)	(112)	(84)	39	(1)	**(21)**
Nelson	(0)	6	(1)	1	1	(5)	(5)	(16)	(11)	217	73	50	92	139	116	0	**657**
Marlborough	(1)	24	(5)	10	10	(51)	(37)	(143)	(224)	217	(66)	(22)	(46)	134	45	12	**(143)**
West Coast	(0)	(4)	(6)	(5)	(3)	(26)	(16)	(65)	(152)	(364)	(249)	(188)	(435)	1,339	(9)	(18)	**(201)**
Canterbury	1	132	49	55	1	(32)	48	57	(190)	(87)	173	210	(98)	(2,187)	441	159	**(1,267)**
Otago	0	28	4	5	1	2	8	11	8	6	12	30	(25)	(196)	486	(334)	**46**
Southland	0	15	5	4	0	5	7	7	2	(2)	(2)	10	(7)	2	(719)	(854)	**(1,526)**
TOTAL	**(806)**	**(268)**	**4,035**	**4,981**	**(328)**	**(3,373)**	**(703)**	**(2,248)**	**274**	**166**	**11**	**(265)**	**(679)**	**(276)**	**487**	**(1,011)**	**(4)**

Table 7.6 Percentage difference (%) of fully-estimated minus trip-end-estimated freight matrix.

From \ To	Northland	Auckland	Waikato	Bay of Plenty	Gisborne	Hawke's Bay	Taranaki	Manawatu-Wanganui	Wellington	Tasman	Nelson	Marlborough	West Coast	Canterbury	Otago	Southland	**TOTAL**
Northland	27	-410	-17	-111	-246	-1201	-163	-389	-729	-567	-428	-840	-1400	70	100	100	**−50**
Auckland	-215	18	-28	-83	-128	-276	-497	-92	69	-1268	57	59	48	99	100	100	**−5**
Waikato	-31	-22	65	39	-91	-102	-17	22	74	88	58	51	-1	93	99	99	**32**
Bay of Plenty	-139	18	0	63	-61	-757	-66	2	43	-23	-319	-128	-78	90	99	99	**36**
Gisborne	11	-68	-7	9	23	-156	-93	25	64	88	61	55	-20	84	99	100	**−1**
Hawke's Bay	-368	-393	-216	-220	-146	-50	-106	-110	-89	-3	-181	-274	-956	70	97	98	**−103**
Taranaki	-52	-53	-2	-49	5	-100	6	-45	36	-107	-185	-393	-228	69	98	97	**−9**
Manawatu-Wanganui	-209	-119	-34	1	40	-215	7	-178	4	-160	-833	-853	-1479	30	90	92	**−50**
Wellington	-70	37	29	41	49	-318	2	6	20	1	-122	-197	-753	32	96	88	**3**
Tasman	-330	-1267	16	40	64	-375	-53	-270	-49	22	24	-24	-399	-104	94	-316	**−1**
Nelson	-73	79	-35	25	52	-236	-1384	-632	-33	63	55	50	81	85	100	47	**64**
Marlborough	-282	64	-35	33	56	-450	-292	-626	-146	53	-57	-8	-286	26	92	89	**−8**
West Coast	-286	-281	-295	-176	-1224	-8106	-298	-1103	-1957	-1163	-1034	-723	-115	55	-33	-583	**−7**
Canterbury	71	93	78	80	13	-268	58	33	-248	-70	54	28	-21	-26	37	36	**−10**
Otago	85	99	94	95	91	72	93	84	62	49	75	76	-345	-31	28	-44	**1**
Southland	88	99	97	97	43	91	95	84	37	-86	-85	62	-30	0	-84	-40	**−42**
TOTAL %	**–26**	**–1**	**27**	**30**	**–21**	**–125**	**–15**	**–50**	**6**	**9**	**1**	**–17**	**–65**	**–2**	**12**	**−30**	**0**

8. Conclusions

8.1 Main findings

This study has investigated the movement of freight within New Zealand. Through the survey of freight consignors and carriers, the use of other data sources and the Emme/2-based estimation process, it has estimated the main long-distance high tonnage freight movements within the country during the year 2002. It has assembled matrices of movements for the main land transport modes of road and rail, listing the approximate tonnages moving between and within origin and destination regions during that year. An indication of the significant commodities and industries utilising the freight networks has also been provided, although such information has not been incorporated into the matrices. This is the first time in New Zealand that such matrices have been attempted or that inter-regional freight movement has been investigated in this detail.

The main findings are:

- Of the three main modes (road, rail, shipping), road transport conveys the majority of freight within New Zealand, having an approximate 83% share of tonnage and a 67% share of tonne-km. Rail has an approximate 13% of tonnage and 18% of tonne-km, and coastal shipping has a corresponding 4% of tonnage and 15% of tonne-km. Road has the shortest average haul of the three main modes, while coastal shipping (excluding the inter-island ferries) has the longest.
- Three regions – Auckland, Waikato and Bay of Plenty – are responsible for the production and attraction of over half of all road and rail freight, reflecting a concentration of population and industry. Canterbury, the largest region by area, is the only other region with a share of more than 10% of freight productions and attractions.
- Over two thirds of all road movements are of less than 200 km, with the Auckland region dominating with around a quarter of both the production and attraction of all freight. The greatest road tonnage corridors are, in descending order, Auckland to Auckland, Canterbury to Canterbury, Waikato to Waikato, Bay of Plenty to Bay of Plenty, Waikato to Auckland, and Waikato to Bay of Plenty. These corridors account for nearly half of all road freight tonnage and show a preponderance by road to short-haul movements.
- Higher rail tonnages correspond to the locations of major industrial plants, mines and ports. The greatest tonnage corridors for rail are, in descending order, Bay of Plenty to Bay of Plenty, West Coast to Canterbury, and Waikato to Bay of Plenty. These three corridors account for nearly half of all rail tonnage.
- A significant proportion (over half) of all freight cannot be easily classified into the specific commodity groups as defined. This includes general freight movements, and those relating to wholesale/retail, construction and other business sectors.

- The primary industries of agriculture and forestry are the largest originators of freight that can be categorised into a specific commodity group. The transport of logs, milk and livestock account for a significant share of total freight movements.
- A trip-end model for freight origins and destinations shows some correlation to the modelled matrix, but further improvements in both the data and process would be required to achieve a reasonable level of accuracy.

It should be noted that the results of this study have been limited by the availability of data and the associated assumptions that have been made. The issue of commercial confidentiality reduced both participation in the survey phase and the usefulness of the data supplied. This coupled with the lack of statistics measuring freight and commodity data by weight have restricted the detail that could be included. Additionally, the constantly evolving nature freight transport market has limited the results presented here to a snapshot only, of the economy as it was in 2002. Nonetheless, the work is a considerable advance on anything available previously.

8.2 Improvements to developing a freight matrix

A number of recommended improvements could be made to the processes of developing the freight matrix presented in this report, which would allow a more detailed matrix to be developed and enhance the detail and results available.

For the full matrix such improvements would include:

- The compilation, by organisations such as Statistics New Zealand, of detailed statistics relating to weight of goods transported. Where data is currently collected, it is often recorded using measures other than weight, limiting its usefulness for tasks such as this.
- The collection of more complete observed data, by Transit New Zealand and other organisations, such as the split of heavy vehicle types at telemetry sites.
- The use of better estimates of average loads, which would improve the accuracy of the estimation process by limiting assumptions. The improvements to the collection of data listed above might allow better estimates to be prepared.
- Review the annualisation factor used in conjunction with AADT to relate this more to the movements of commercial vehicles. Average daily flows are currently designed primarily to match general traffic patterns that are dominated by car journeys, and they may therefore underestimate the weekday-oriented patterns associated with commercial vehicles.
- Improvement of the Emme/2 network and functions to take account of speed, gradient, and road curvature, etc. This would allow a more accurate model of the national transportation networks to be developed.

For the trip end approach such improvements would include:

- The collection of more disaggregated industry employment data for the trip end model.

- The investigation of the feasibility of introducing k-factors to balancing process. This would allow times or costs to be modified, to correct for inaccuracies in the network or take account of perceptions and functions.

8.3 Further work

Three principal directions that future work might take are:

- The ongoing monitoring of the freight sector, which might involve the update of the model every 2-3 years, to measure historical trends and increase knowledge of the factors affecting the movement of freight in the New Zealand context.
- Use of the model to forecast future freight movements. This would be a valuable tool for the planning of future requirements for roads, railways, ports and other freight facilities.
- The application of this process to create detailed freight matrices at the regional or even TLA level. These would have a higher level of detail and could be combined as required to look at freight movements within a specific geographic area (for example, the southern South Island).

Appendix A References

The references contained in the main report and the appendices are listed here.

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