Methods to Establish Design Traffic Loading

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Executive summary

1. General

This project has involved the performance of a series of traffic surveys and data analyses with the following objectives:

- to develop guidelines for estimating the design traffic parameter with respect to the damaging effect on the subgrade and bound layers using data typically collected in New Zealand;
- to determine Traffic Distribution Design (TDD) Factors to take into account the different exponents used in the ESA relationship (4^{th} power) and the AUSTROADS performance criteria (5^{th}, 7^{th} and 12^{th} powers).

The project objectives have been addressed in this report and the main conclusions that can be drawn from this study are presented in the following sections.

2. Analysis of Weigh-In-Motion (WIM) Data

Traffic surveys were carried out by videotaping the vehicles passing four of Transit New Zealand's weigh-in-motion (WIM) sites for periods of eight hours each. A timer on the video allowed the image of each heavy vehicle passing the WIM sites to be matched against the axle loads and other data included in the corresponding WIM record. This was a relatively successful process with only 2% of the 7746 video taped records being unmatched.

Using the video records, commodities were assigned to the corresponding WIM records so that axle loads could be correlated against commodity being carried. A standard set of commodities were used in this process. While some commodities were easily recognised, or could be established from the vehicle livery, many were covered and therefore the *No Load Description* commodity category was very large.

The distribution of gross weights for the heavy vehicle records were examined for each of the four WIM sites. This showed that the distributions were relatively consistent from location to location. Therefore, is was considered to be reasonable to combine the data from the four surveys into one overall data set.

Equivalent Standard Axle (ESA) values for each heavy vehicle (Load Factor) were calculated using values of 4, 5, 7 and 12 as exponents in the ESA relationship. The overall data showed mean results of 1.7, 1.8, 2.6 and 16.7 for the four exponents respectively. The fourth power Load Factor of 1.7 is somewhat higher than previously published data (Bartley Consultants Limited 1996).

Traffic Distribution Design Factors (TDDF) are used to account for the different exponents used in the relationships for axle damaging effect (4^{th} power) and the performance criteria for various pavment components, i.e. 5^{th} power for asphalt, 7^{th} power for subgrade soil, and 12^{th} power for cemented layers. The TDDF values, based on the mean ESA results, were calculated to be 1.1, 1.1 and 3.0 for subgrade, asphalt and cemented layers respectively for "normal" loading conditions. The TDDF values increase to 2.4, 1.3 and 25 respectively for "heavy" loading conditions. These values compare reasonably well with other published TDDF values, e.g. 1.1, 1.1 and 10 which are currently in use in New Zealand and Australia. The TDDF values also fit within the ranges of values determined by Koniditsiotis (1998).

The mean ESA values were examined with respect to number of axles and the Transfund New Zealand Project Evaluation Manual (PEM) vehicle classifications and the results are presented in the report. The number of axles classification was further divided into vehicle groups comprising two axles, three, four and five axles, and six-plus axles.

At the outset of the project it was envisaged that vehicle length may have been a reasonable parameter by which vehicles could be classified. However, vehicle length did not register well on the WIM records and therefore this parameter has not been pursued further. Further investigations to determine the reason for the poor records would be beneficial.

3. Electronic Massing Unit (EMU) Survey Data

An Electronic Massing Unit (EMU) traffic survey was carried out to provide supplementary data for the main WIM data. This involved stopping all heavy vehicles to weigh the axles and determine commodities being carried. The ESA data obtained from the EMU survey was significantly lower than that obtained from the WIM records. This may have been caused by the survey location, timing, or heavily laden trucks avoiding the survey location.

4. Daily and Annual Traffic Factors

One component of establishing procedures for estimating the design traffic parameter was to investigate the factors required to transform eight-hour traffic surveys to equivalent 24-hour data and then to equivalent annual data. These factors were termed Daily and Annual Factors respectively. Screened, full year (1998) WIM data was available for the Te Puke and Tokoroa sites and this was used to establish Daily and Annual Factors. The Te Puke data showed a relatively uniform Daily Factor of 1.35 for weekday surveys. The Tokoroa data was slightly more variable with a mean Daily Factor of 1.80. The mean Annual Factor from both sites was approximately 370. Further investigations using WIM data from other sites to better establish the Daily and Annual Factors would be beneficial.

5. Procedures for Estimating the Design Traffic Parameter

Finally, six procedures have been described for establishing the design traffic parameter. These are as follows:

- Procedure One - Presumptive Values
- Procedure Two - Manual Traffic Counts with Load Factors
- Procedure Three - Automated Traffic Counts with Load Factors

- Procedure Four - Load Factors with Respect to Axle Numbers
- Procedure Five - Load Factors with Respect to PEM Classifications
- Procedure Six - Load Factors with Respect to Commodities
- Procedure Seven - Load Factors from Commodities and Vehicle Axles
- Procedure Eight - Load Factors from Commodities and PEM Classification

The suitability of each procedure is generally dependent on the significance of the pavement in question and the availability of data. A brief description of each procedure is presented in the report.

ABSTRACT

The report describes the collection and analysis of heavy vehicle data with the objectives of developing appropriate procedures for establishing the design traffic parameter and determining Traffic Distribution Design Factors.

Heavy vehicle data has been obtained by video-taping four Weigh-in-Motion (WIM) sites around New Zealand and relating the video images to the axle load records so that the damaging effect of trucks carrying various commodities can be determined.

Traffic Distribution Factors have been calculated to allow for the difference in the exponent in the relationships for the damaging effect of axles and the performance of subgrade, asphalt and cement materials. The resulting factors are compared with the values currently in use in New Zealand as well as those found in a recent Australian study.

Daily and Annual Traffic Factors (TDDF) have been investigated so that the data obtained in eight-hour traffic surveys can be converted to equivalent 24-hour data and then equivalent annual data. This has been investigated for two WIM sites.

Finally, a series of procedures have been developed for establishing the design traffic parameter for pavement design. The procedures range in complexity from the use of simple presumptive values to the use of commodity surveys with or without vehicle classifications.

1 Introduction

1.1 General

The AUSTROADS mechanistic pavement design procedures are currently used in New Zealand. These procedures are presented in the publication *Pavement Design: A Guide to the Structural Design of Road Pavements* (AUSTROADS 1992). The influences of various characteristics that are unique to New Zealand, e.g. materials, climate and traffic loading, are described in a separate document entitled *New Zealand Supplement to Pavement Design: A Guide to the Structural Design of Road Pavements* (Transit New Zealand 1999).

This research project has been managed by Transit New Zealand, with consultants being utilised for performing traffic surveys (Traffic Design Group Ltd) and for data analysis and reporting (Bartley Consultants Ltd). It seeks to improve the accuracy and consistency by which the ***design traffic*** parameter is established for the purpose of designing new and rehabilitated pavements in New Zealand. The ultimate output of the project will be a revision of the Traffic Loading section of the New Zealand Supplement document to reflect the results of the research.

The project follows-on from a previous study reported in Transfund New Zealand Research Report No. 76, *Design Traffic Data for the New Zealand Supplement to the AUSTROADS Pavement Design Guide* (Bartley Consultants Ltd, 1996).

1.2 Objectives

The objectives of this project are as follows:

- To develop guidelines for estimating the design traffic parameter from data typically collected in New Zealand. The guidelines should incorporate the damaging effect of axle loads on various critical pavement materials, i.e. subgrade, asphalt and cemented materials.
- To determine Traffic Distribution Design Factors (TDDF) to take into account the different exponents used in the Equivalent Standard Axle and the various AUSTROADS performance criteria relationships.

1.3 Background

The ***design traffic*** is one of the fundamental parameters involved in any new or rehabilitated pavement design. Under most mechanistic pavement design procedures the performance of a proposed pavement structure will be dependent upon several aspects of the axle loads that will be imposed on the pavement during its service life. These include:

- the total number of axle passes;
- the axle configurations;
- the weight carried on the axles;
- the configuration of the wheels and tyres;
- the degree of dynamic loading; and,
- the response of the pavement structure to repeated loading.

The effects of a number of the factors identified above have been incorporated into a parameter known as the *Equivalent Standard Axle* (ESA). The ESA normalises the damaging effect of the spectrum of axle loads and configurations expected on a pavement to the equivalent number of passes of a dual-tyred single axle carrying 8.2t. In general, the ESA value is determined using a fourth power relationship of the following form:

$$ESA = \left(\frac{axle\,load}{reference\,load} \right)^4$$

where:

axle load = weighed axle group load;
reference load = 53 kN for a single axle with single tyres;
= 80 kN for a single axle with dual tyres;
= 135 kN for a tandem axle with dual tyres;
= 181 kN for triple axle with dual tyres;

The design traffic parameter is taken as the sum of the ESA values for the traffic spectrum over the life of the pavement. Issues such as expected growth and changes in traffic patterns should be included in the analyses, however these issues are outside the scope of this study.

The AUSTROADS mechanistic design procedure is based around establishing the critical strains occurring in a proposed pavement model and then relating the magnitude of the strains to expected ***service life*** values using performance criteria. If the expected *service life* meets or exceeds the required *design life* then the proposed structure is deemed to be adequate. The design process is repeated until the proposed pavement structure is optimised to achieve the most cost-effective solution.

Three pavement components are included in the analysis of the critical strain. These are:

- the maximum vertical compressive strain at the top of the subgrade,
- the maximum horizontal tensile strain at the underside of any asphalt layers,
- the maximum horizontal tensile strain at the underside of any cemented layers.

The performance criteria take the form:

$$N = \left(\frac{k}{\mu\varepsilon} \right)^x$$

where:

N = expected service life;
k = a material constant;
$\mu\varepsilon$ = critical strain under standard loading conditions; and,
x = 7.14 for subgrade soils;
= 5 for asphalt; and,
= 12 for cemented materials.

AUSTROADS (1992) recommends that the design traffic parameter be determined using the same exponent as that used in the performance criteria outlined above. This means that a pavement may need to be analysed using more than one design life value depending on the configuration of the pavement layers. The TDDF is used to convert ESA values determined using the fourth power relationship to corresponding values for the 7^{th}, 5^{th} or 12^{th} powers for subgrade, asphalt and cemented layers respectively. The magnitude of the TDDF is dependent on the prevailing distribution of axle loads and configurations. Therefore the TDDF values that are appropriate in Australia may not be appropriate for use in New Zealand. Currently, New Zealand designers use the Australian factors, i.e. 1.1 for both subgrade and asphalt layers and 10.0 for cemented layers.

Koniditsiotis (1998) analysed a large number of traffic surveys in Australia and determined updated TDDF values for various classes of road pavement. The factors varied from 1.10 to 3.99 for subgrade layers, from 0.99 to 1.52 for asphalt layers, and from 2.16 to 69.31 for cemented layers.

2 Methodology

2.1 Weigh-in-motion (WIM) Traffic Surveys

Detailed traffic surveys were required to obtain the relevant data required to achieve the project objectives. The main surveys involved monitoring selected weigh-in-motion (WIM) sites for eight-hour periods to obtain representative data samples. The WIM sites were located as shown in Table 2.1.

Table 2.1 WIM sites used in the main traffic surveys.

WIM Site	AADT (vpd)	% Heavy Vehicles
SH1 Dury (south of Auckland)	30,000	9
SH2 Te Puke (south of Tauranga)	15,000	12
Tokoroa	7,500	12
SH1 Waipara (near Christchurch)	5,000	9

The WIM equipment is triggered by all vehicles with a gross weight of 3.5 t or more passing the site. These are referred to as *heavy vehicles* in the remainder of this report. The following data is recorded for each heavy vehicle:

- time and date of vehicle passage;
- vehicle length;
- number of axles;
- weight on each axle;
- axle spacing;
- vehicle speed; and,
- vehicle classification code.

Transit New Zealand collects the WIM data by telemetry and consolidates the information into a manageable format. The data is also screened to remove any records that are obviously flawed, e.g. unreasonably high speed, excessive number of axles or inordinate axle spacings.

While the WIM equipment is able to provide a significant amount of useful data it cannot establish the commodities being carried by the passing vehicles. Traffic Design Group staff video-taped the WIM sites for eight-hour periods and used the timing on the video-tape and the WIM records to identify the particular vehicle corresponding to each WIM record. This allowed the commodities to be established.

The positioning of the video camera was important as it was vital that the vehicles could be clearly observed on the tape. The Drury site was videotaped from an adjacent overbridge which had the benefit of allowing the contents of high-sided vehicles and trailers to be observed while still being able to see the vehicle's livery.

The WIM data and video-tape record has the disadvantage that it cannot distinguish some basic vehicle parameters such as where single (normal or super-single) tyred axles are used instead of dual tyred axles.

The WIM and commodity data was supplied to Bartley Consultants Limited in the form of a series of spreadsheets. The spreadsheets were manipulated by Bartley Consultants to obtain the required ESA data.

2.2 Electronic Massing Unit Traffic Survey

Traffic Design Group staff attended an Electronic Massing Unit (EMU) survey carried out by the New Zealand Police at the Plimmerton Weighstation, near Wellington. EMU surveys are primarily used for enforcement purposes and they involve stopping every heavy vehicle to interview the driver and determine vehicle dimensions and axle weights.

EMU surveys have the advantage that they sample the entire heavy vehicle traffic stream passing a certain location and all the data that is of interest regarding axle loads, wheel configurations, vehicle dimensions and commodities carried can be obtained. This advantage is also in fact a disadvantage in that the EMU surveys provide a level of detail that cannot be achieved in more routine traffic survey procedures. For this reason, the EMU data obtained in this project has been used as a supplement to the main WIM survey data rather than providing additional data for inclusion in the analyses.

3 Data analysis

3.1 General

A total of 7746 WIM records were obtained from the four WIM sites described in Table 2.1. Of this data, 7577 were deemed to be viable records. The 169 records (2.2%) that were discarded either could not be matched against the video taped records or they contained incomplete or unreasonable data that wasn't identified in the initial data screening. The low percentage of discarded records was considered to be reasonable and vindicated the use of the video procedure.

In the consolidation of the video records, Traffic Design Group endeavoured to assign a commodity code to each vehicle. A standard set of commodities and associated codes was used (see Appendix A). The set of commodity codes reported in the Transit New Zealand State Highway Pavement Design and Rehabilitation Manual (TNZ 1989) was initially adopted, however it was later revised to the list shown in Appendix A so as to reduce the number of commodities and better reflect the current commodity distribution.

Assigning commodity codes is a simple exercise where the commodity is clearly visible, e.g. logging trucks. However, many trucks have covered sides making positive identification impossible. Where this occurred, the commodity was inferred either from the vehicle's livery or from knowledge of the trucking company's operation. Irrespective of these clues, it was inevitable that some commodities could not be identified, or that some would be inferred incorrectly. In addition, when the commodity was not visible the vehicle could have been empty.

No allowance was made for the degree of loading. Therefore, partially laden vehicles were treated in the same manner as fully laden vehicles.

The following sections describe the information collected and summarises the data in terms of the gross weight and ESA for the various commodities with respect to four vehicle classifications, i.e.

- all vehicles;
- number of axles per vehicle;
- Transfund New Zealand Project Evaluation Manual vehicle classifications; and,
- standard classified count classifications.

3.2 Weigh-in-motion (WIM) Data

Table 3.1 shows the number of records obtained from the various WIM sites.

Table 3.1 Breakdown of record numbers by WIM site.

WIM Site	Number of Records
SH 1 Drury	3504
SH 2 Te Puke	1958
SH 1 Tokoroa	1294
SH 1 Waipara	821
TOTAL	**7577**

A fundamental consideration in the analyses was to ensure that the data from each location could be combined so that the sample size was maximised. This would seem to be a reasonable assumption as one would expect, for example, a logging truck observed at the Te Puke site to have similar loading characteristics as a logging truck observed at the Tokoroa site. To test this assumption, the distribution of gross vehicle weights for all vehicles, as well as the five most abundant commodities have been plotted in histogram form. This information is presented in Figure 3.1 (a - f).

A close examination of the gross weight distributions for the various commodities presented in Figure 3.1 shows that there may be one, two or three peaks in the distribution curves. Brief interpretations of the gross weight data are as follows:

All Commodites
Figure 3.1(a) shows that there are three reasonably distinct peaks for the *All Commodities* category, one representing empty or lightly laden vehicles, one representing laden single trucks and one representing laden truck and trailer or articulated units.

No Load Description
Figure 3.1(b) shows that the gross weight distribution for the *No Load Description* category echoes the *All Commodities* data as it is effectively a representative subset containing most of the commodity categories.

Empty or Carrying Trade Tools
Figure 3.1(c) depicts the *Empty or Carrying Trade Tools* category and it shows a single peak in the gross weight distribution on the low side of the weight scale. However the gross weights observed were still reasonably significant with a mean value of the order of about 15 t.

Timber, Logs
Not surprisingly, Figure 3.1(d) shows a single peak distribution on the high side of the weight scale for the *Timber, Logs* category. Clearly this commodity involves high axle loads and there is no doubt regarding whether the vehicle is laden or empty.

Aggregates, Earth, etc

Figure 3.1(e) shows a two peak gross weight distribution for the *Aggregates, Earth, Etc* category. The two peaks would coincide with laden single trucks and laden truck and trailer or articulated units respectively.

Buses

Figure 3.1(f) shows a single peak gross weight distribution for the *Buses* category. This would be expected given that buses have a limited payload weight capacity.

The data presented in Figure 3.1(a - f) show that similar distributions of gross vehicle weights were obtained for the various commodities from the four WIM sites. This provides reasonable justification to consider the combined data as being representative of the general traffic spectrum for New Zealand. On this basis, Table 3.2 shows a breakdown of commodity numbers observed at each site.

Table 3.2 shows that the *No Load Description* commodity category dominates the sample in terms of numbers of observations. Of the remaining commodity categories the next four most numerous are as follows:

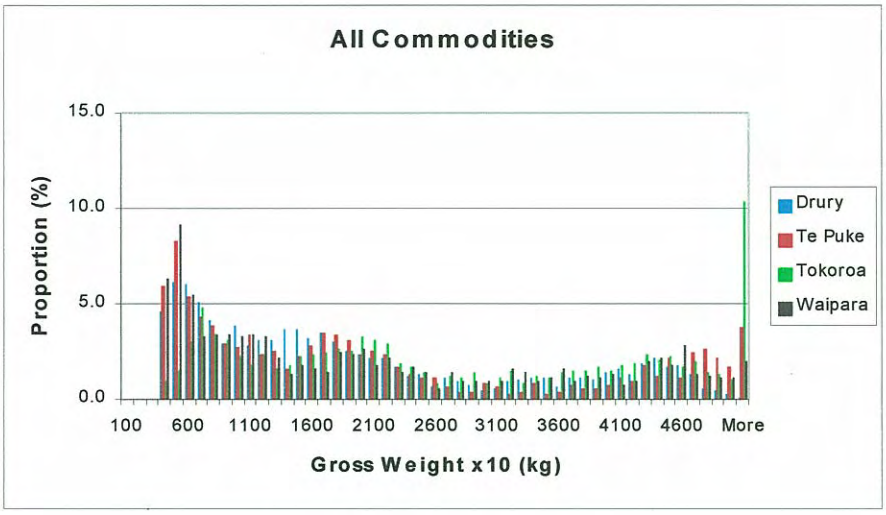
- *Empty or Carrying Trade Tools*
- *Aggregates, Earth, etc*
- *Timber, Logs*
- *Buses*

3.3 Mean ESA and Traffic Distribution Design Factors

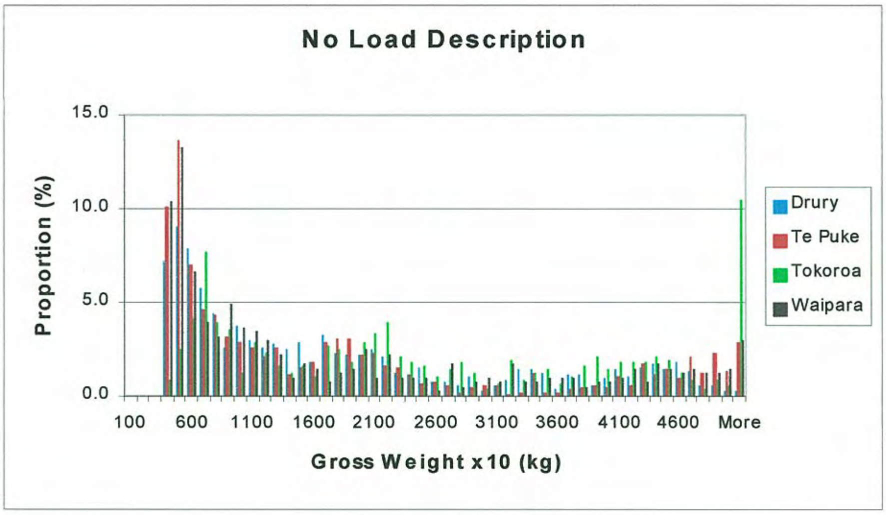
The WIM data for all vehicle observations has been processed with respect to ESA values incorporating 4^{th}, 5^{th}, 7^{th} and 12^{th} powers (ESA^4, ESA^5, ESA^7, ESA^{12}). The detailed results for each commodity are shown in Table B1 (see Appendix B). Table 3.3 shows a summary of ESA data with respect to WIM location and the corresponding TDDF values.

Table 3.3 shows that the mean ESA^4 values for each site are somewhat higher than the corresponding values reported by Bartley Consultants Ltd (1996). The Tokoroa WIM site recorded the highest mean ESA values while the corresponding data from the other three sites was lower and reasonably consistent. The relatively high volume of logging and milk tanker traffic in the Tokoroa area would have been responsible for this result (see Table B1). A similar trend was observed for the TDDF values, with the Tokoroa site showing the highest values, particularly for the cemented (12^{th} power) case.

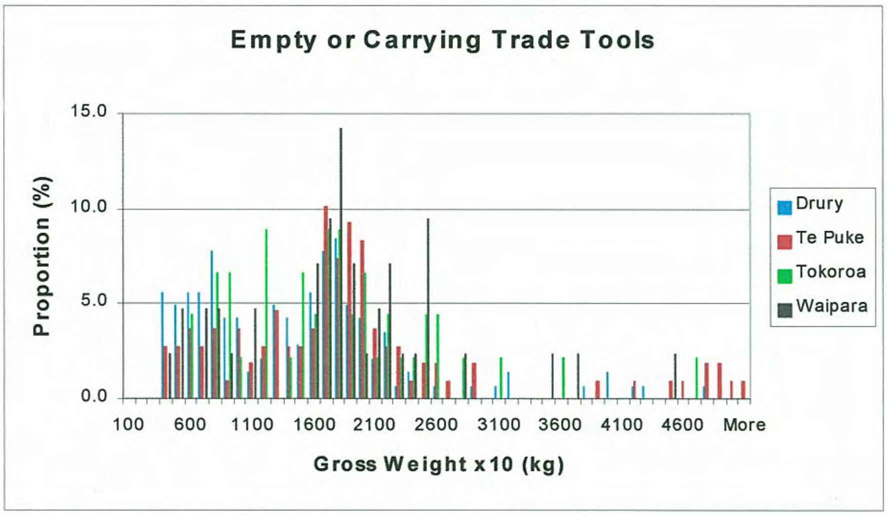
The mean TDDF values shown in Table 3.3 indicate that two levels of TDDF are justified, one for typical urban/rural conditions (*see* Drury, Te Puke, and Waipara data), and one for heavily loaded locations (*see* Tokoroa data). On this basis, recommended TDDF values are shown in Table 3.4



a)

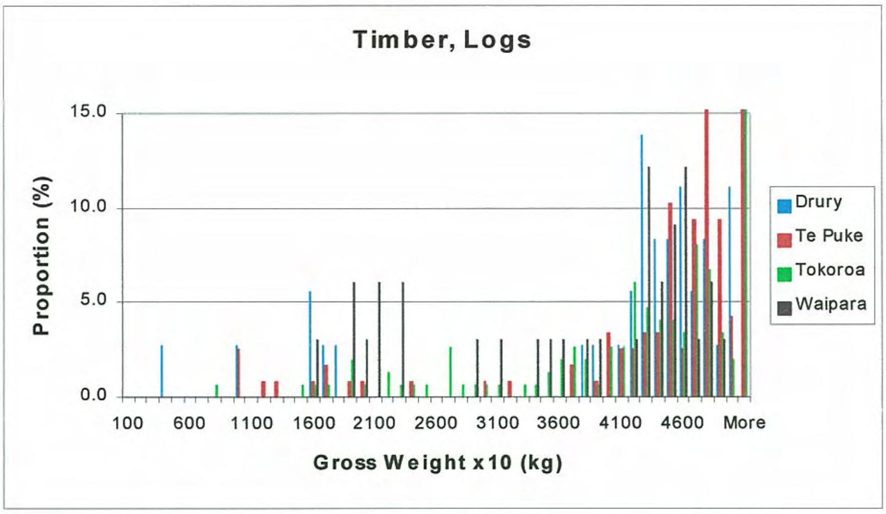


b)

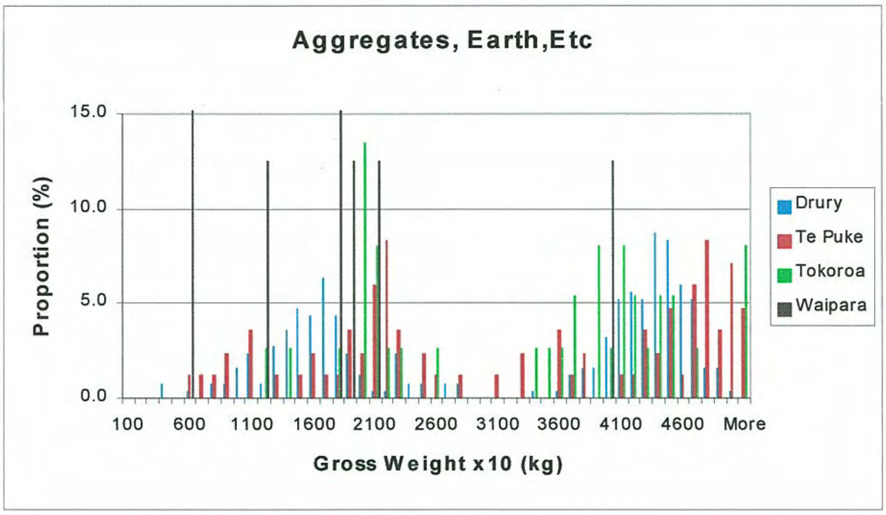


c)

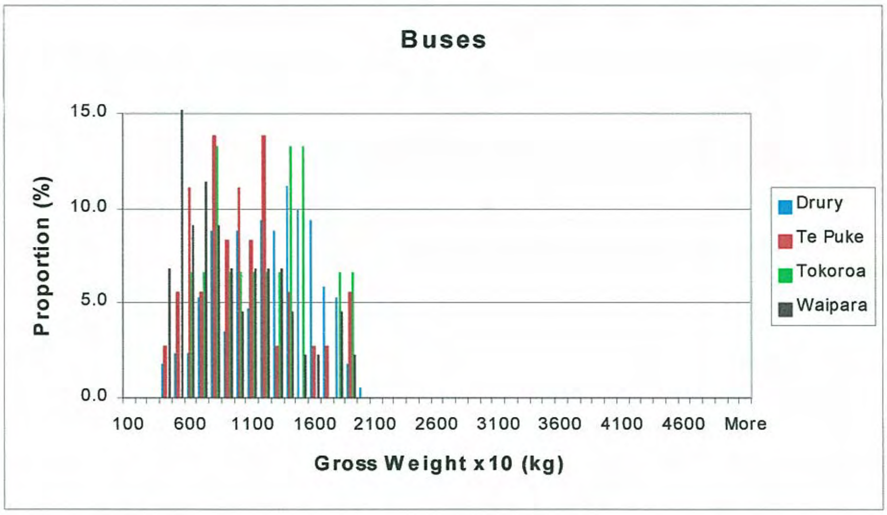
Figure 3.1 Vehicle gross weight distributions by commodity and site.



d)



e)



f)

Figure 3.1 (cont.) Vehicle gross weight distributions by commodity and site.

Table 3.2 Breakdown of commodity observations at each WIM sit

Commodity	Drury	Te Puke	Tokoroa	Waipara	Total
Aggregates, earth, etc	251	84	37	8	**380**
Building materials processed	52	15	19	10	**96**
Buses	170	36	15	44	**265**
Camper vans	41	0	0	6	**47**
Car haulage	102	17	22	11	**152**
Concrete - ready mixed	20	24	2	6	**52**
Construction machinery	39	31	9	3	**82**
Containers	116	21	15	0	**152**
Courier, mail and parcels	38	8	25	4	**75**
Empty or carrying trade tools	142	108	45	42	**337**
Furniture	64	16	8	6	**94**
General freight	81	14	20	15	**130**
Livestock, animals, etc	91	39	37	70	**237**
Logging trucks carrying jinkers	10	56	44	3	**113**
Machinery	54	33	13	9	**109**
Manufactured foodstuffs	87	35	31	24	**177**
Meat, fish and frozen foods	111	47	20	30	**208**
Metals and scrap	45	6	6	1	**58**
Milk	23	22	76	17	**138**
No Load Description	1499	984	562	406	**3451**
Other liquids	178	70	42	25	**315**
Other manufactured products	28	7	1	3	**39**
Paper, pulp and cardboard	7	1	3	2	**13**
Plants, fruit, vegetables, etc	27	16	4	1	**48**
Powdered goods	46	24	12	11	**93**
Prefabricated structural components	21	4	3	1	**29**
Rubbish	33	25	3	10	**71**
Sawdust and wood waste	1	18	15	0	**34**
Stock food, grain, seeds, etc	10	2	2	6	**20**
Timber, logs	36	117	148	33	**334**
Timber, processed	79	77	55	12	**223**
Wool, hides	2	1	0	2	**5**
Total	**3504**	**1958**	**1294**	**821**	**7511**

Table 3.3 ESA and TDDF data with respect to WIM site.

Data	Drury	Te Puke	Tokoroa	Waipara	Total
Number of Records	3504	1958	1294	821	7577
Mean ESA^4	1.20	1.65	3.22	1.38	1.68
Mean ESA^5	1.16	1.74	4.07	1.38	1.83
Mean ESA^7	1.20	2.13	7.80	1.58	2.61
Mean ESA^{12}	2.00	5.42	81.67	4.08	16.71
TDDF Subgrade	1.0	1.2	2.4	1.1	1.6
TDDF Asphalt	1.0	1.1	1.3	1.0	1.1
TDDF Cemented	2.0	3.3	25.4	3.0	9.9

Table 3.4 Recommended TDDFs.

Pavement Component	Traffic Distribution Design Factor	
	Normal Loading	Heavy Loading[(1)]
Subgrade	1.1	2.4
Asphalt Layer	1.1	1.3
Cemented Layer	3.0	25

Note (1) A Heavy Loading situation would include a relatively large proportion of heavy commodities such as logs and bulk tankers where overloading is a distinct possibility.

The current AUSTROADS TDDF values for subgrade, asphalt and cemented materials are 1.1, 1.1 and 10.0 respectively (AUSTROADS 1992). These values compare well with the calculated TDDFs for subgrade and asphalt layers, however the cemented layer TDDFs tend to be quite well above or below the currently used value of 10.0 depending on the loading situation.

The TDDF values shown in Table 3.4 lie within the bounds of the corresponding data determined for various Australian locations by Koniditsiotis (1998).

3.4 ESA Per Commodity for Vehicle Classifications

3.4.1 All vehicles

While the detailed ESA^4, ESA^5, ESA^7 and ESA^{12} results for each commodity are presented in Table B1 (see Appendix B), the overall results are summarised as follows:

- Mean ESA^4 : 1.68
- Mean ESA^5 : 1.83
- Mean ESA^7 : 2.61
- Mean ESA^{12} : 16.70

A histogram plot for the distribution of ESA^4 values for the *All Commodities* category is presented in Figure 3.2. Further histograms for the five most abundant commodities are presented in Figure B1 ((a - f) see Appendix B). Histograms for ESA^5, ESA^7 and ESA^{12} distributions have not been plotted, however the higher powers generally tend to extend the relevant ESA values to upper or lower extremes to an extent depending on the ESA^4s proximity to the value 1.0. Brief interpretations of the ESA^4 distributions are as follows:

All Commodities and No Load Distribution

The histogram plot for *All Commodities* (Figure 3.2) shows that a relatively high proportion of the overall traffic distribution has an ESA^4 value less than approximately 0.1. The proportion of ESA^4 values then flatten off in the range approximately 0.1 to 0.7 before decreasing to a reasonably constant distribution at an ESA^4 value of 1.5+. More than 5% of the traffic distribution has an ESA^4 value in excess of 5. A similar distribution of ESA^4 values was obtained for the *No Load Description* commodity category (Figure B1 (a)). This would be expected given that this category dominates the total sample.

Empty or Carrying Trade Tools

The *Empty or Carrying Trade Tools* commodity category showed a reasonably constant distribution of ESA^4 values up to a value of approximately 1 (Figure B1 (b)). This is somewhat surprising given that empty vehicles may have been expected to have a lower damaging effect.

Aggregates, Earth, etc.

The ESA^4 distribution for the *Aggregates, Earth, Etc* commodity category has two distinct peaks (Figure B1 (c)). The first peak, centred around a value of approximately 0.6 would typically correspond to single trucks which may or may not be partially laden or perhaps empty. Conversely, the second peak, centred around approximately 4 ESA would correspond to very heavily laden single trucks as well as laden truck and trailer or articulated units.

Timber, Logs

The *Timber, Logs* commodity category has the widest distribution of ESA^4 values of all the categories observed (Figure B1 (d) - note the extended ESA^4 axis scale in the histogram plot). The majority of the ESA^4 values lie in the range approximately 2 to 7, although there are also a number of very heavily laden vehicles with ESA^4 values in excess of 10. Somewhat surprisingly there are a reasonable number of very lightly laden vehicles.

Buses

As could be expected, the distribution of ESA^4 values for the *Buses* category is relatively constant up to an ESA^4 value of approximately 1.7 (Figure B1(e)).

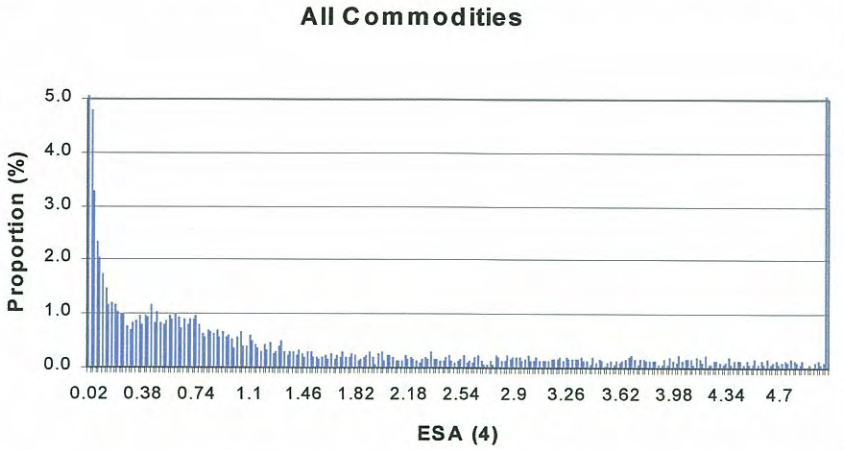


Figure 3.2 Distribution of ESA^4 data for all commodities and all vehicles.

3.4.2 Number of axles

In this section the WIM information has been processed to produce ESA^4, ESA^5, ESA^7 and ESA^{12} data with respect to the number of axles on the observed vehicles and the commodities being carried. The detailed results for each commodity are shown in Table C1 (Appendix C). A summary is presented in Table 3.5.

Table 3.5 Summary of ESA data with respect to axle numbers.

Axles	Count	Mean ESA^4	Mean ESA^5	Mean ESA^7	Mean ESA^{12}
2	2179	0.31	0.27	0.28	1.13
3	954	1.09	1.13	1.42	5.18
4	599	0.89	0.91	1.26	7.76
5	251	1.66	1.75	2.39	12.66
6	1119	2.41	2.67	4.02	42.57
7	1217	3.54	4.11	6.39	39.25
8	1227	2.45	2.58	3.30	12.70
9	31	2.31	2.58	3.71	13.62

Figure 3.3 shows the distribution of the number of axles per vehicle for *All Commodities* as well as for the five most abundant commodity categories. In terms of the overall data, the five-axle and nine-axle vehicles have the least number of observations. The number of observations for two, three and four-axle vehicles decreases steadily with increasing axle numbers while there is a relatively constant proportion of six, seven and eight-axle vehicles.

In terms of specific commodity categories, the *Timber, Logs* category (Code 45) comprises predominantly seven and eight-axle vehicles, while the *Aggregates, Earth,* *Etc* category (Code 40) is dominated by seven-axle and to a lesser extent six-axle vehicles. As expected, *Buses* (Code 95) are limited to two and three-axle categories. The other commodity categories shown are *Empty or Carrying Trade Tools* (Code 00) and *No Load Description* (Code 02).

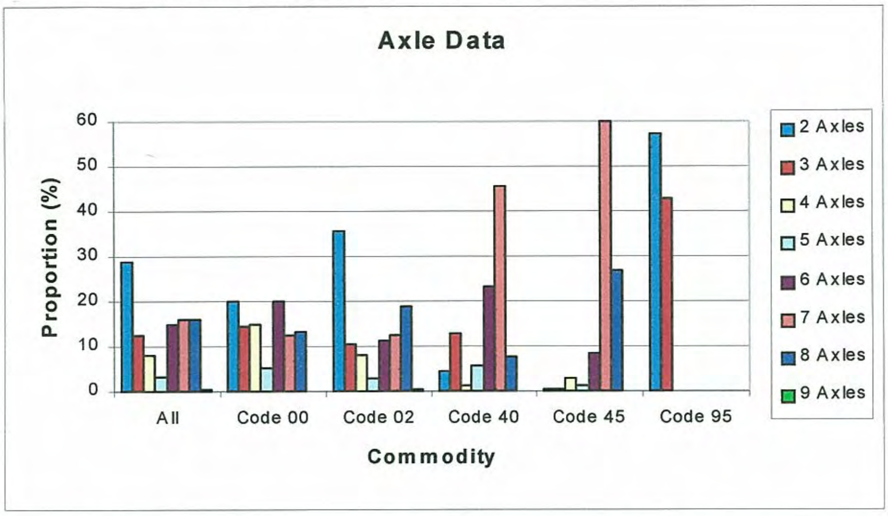


Figure 3.3 Proportion of axle numbers for various commodity categories.

A histogram plot showing the distribution of ESA^4 values against axle numbers for *All Commodities* is shown in Figure 3.4. Similar plots for the five most abundant commodities are presented in Figure C1 (a - e, see Appendix C). Histograms for ESA^5, ESA^7 and ESA^{12} distributions have not been plotted; however, the higher powers generally tend to extend the relevant ESA values to upper or lower extremes.

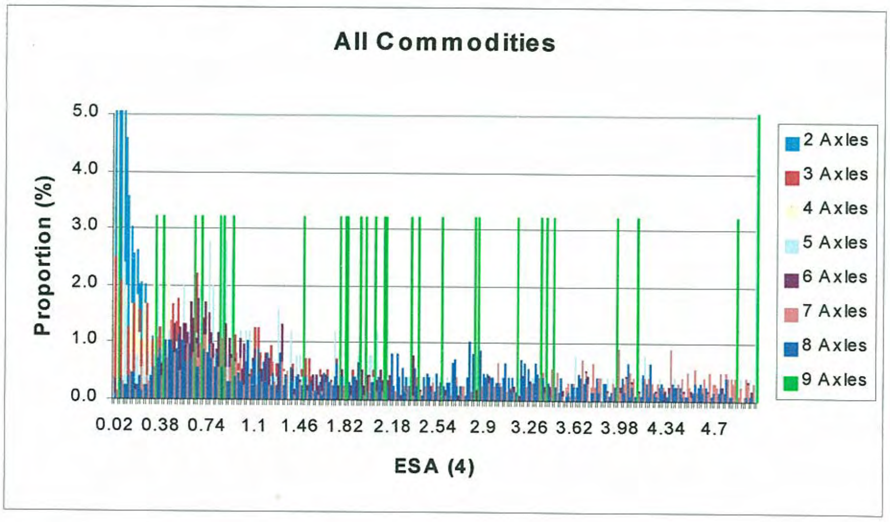


Figure 3.4 Proportion of ESA^4 values for all commodity categories *v* axel numbers.

Examination of the ESA data suggests that the overall data set can be consolidated into three representative groups of vehicles with respect to axle numbers. These groups are:

- 2-axle vehicles;
- 3, 4 and 5-axle vehicles; and,
- 6 plus-axle vehicles.

The ESA^4 distribution for the two-axle vehicle group is relatively low and somewhat variable. This is not surprising given that two-axle trucks tend to be very numerous and their usage is quite varied. Their relatively low running cost means that they may be used well below their maximum weight where necessary.

Conversely, the six plus-axle vehicle category is particularly uniform with respect to ESA values. This reflects the fact that these large truck and trailer or articulated units are relatively expensive to operate and therefore they would generally run at, or close to their maximum legal loading.

The 3, 4 and 5-axle vehicle category represents an intermediate category between the relatively low ESA, but quite varied two-axle vehicle category and the higher ESA and more consistent six plus-axle vehicle category. The 3, 4 and 5 axle category represents the least numerous category of the three categories identified.

Table C2 (Appendix D) shows detailed ESA^4, ESA^5, ESA^7 and ESA^{12} results for the revised vehicle categories. The data is summarised in Table 3.6.

Table 3.6 Summary of ESA data with respect to the revised vehicle categories.

Axles	**Count**	**Mean ESA^4**	**Mean ESA^5**	**Mean ESA^7**	**Mean ESA^{12}**
2	2179	0.31	0.27	0.28	1.13
3,4,5	1804	1.10	1.14	1.51	7.08
6+	3594	2.80	3.12	4.57	30.97

Figure 3.5 shows a histogram of ESA^4 values for the revised vehicle groupings for *All Commodity* categories.

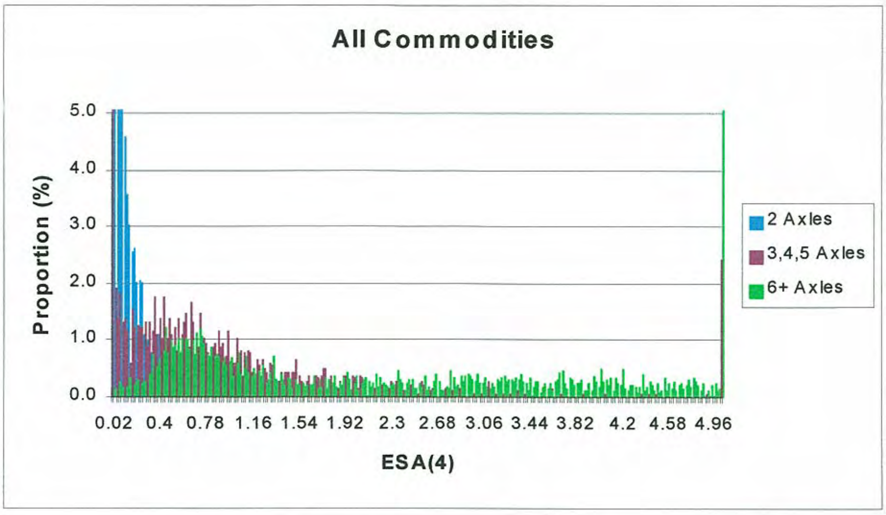


Figure 3.5 Proportion of ESA[4] values for all commodity categories with respect to the (revised) number of axles.

3.4.3 Transit New Zealand Project Evaluation Manual Vehicle Categories

In this section the WIM information has been processed to produce ESA^4, ESA^5, ESA^7 and ESA^{12} data with respect to the vehicle categories described in the Tranfund New Zealand Project Evaluation Manual (PEM) (Transfund New Zealand 1997). The vehicle definitions given in the PEM are as shown in Table 3.7.

Table 3.7 PEM vehicle category definitions.

Vehicle Category	Definition	Comments
Passenger Cars	Cars & station wagons with a wheelbase of 3 m or less.	Not relevant to this study.
Light Commercial Vehicles (LCV)	Vans, utilities & light trucks up to 3.5t gross laden weight.	Not relevant to this study.
Medium Commercial Vehicles (MCV)	Two-axle heavy trucks without a trailer, over 3.5t gross laden weight.	Included in this study.
Heavy Commercial Vehicles Type I (HCV-I)	Rigid trucks with or without trailers or articulated vehicles with three or four axles in total.	Included in this study.
Heavy Commercial Vehicles Type II (HCV-II)	Trucks and trailers or articulated vehicles with or without trailers with five or more axles in total.	Included in this study.
Buses	Buses, excluding minibuses	Included in this study.

The PEM vehicle categories are similar to the revised categories based on axle numbers identified in Section 3.4.2, i.e. 2-axle vehicles, 3, 4 and 5-axle vehicles, and 6+ axle vehicles. The PEM categories are effectively 2-axle vehicles, 3 and 4-axle vehicles and 5+ axle vehicles with a specific category for buses. The *Passenger Car* and *Light Commercial Vehicle* categories are not relevant to this study.

vehicles and 5+ axle vehicles with a specific category for buses. The *Passenger Car* and *Light Commercial Vehicle* categories are not relevant to this study.

Figure 3.6 shows the distribution of the proportion of vehicles in each PEM category for all commodities, as well as for the five most abundant commodity categories. In terms of the overall data, the HCV-II category has the greatest proportion of observations. The MCV and HCV-I categories have a similar proportion of observations.

In terms of specific commodity categories, the *Timber, Logs* category (Code 45) and the *Aggregates, Earth, Etc* category (Code 40) are virtually dominated by HCV-II vehicles.

The detailed ESA^4, ESA^5, ESA^7 and ESA^{12} results for each commodity with respect to PEM vehicle categories are shown in Table E1 (Appendix E). A summary of the results is presented in Table 3.8.

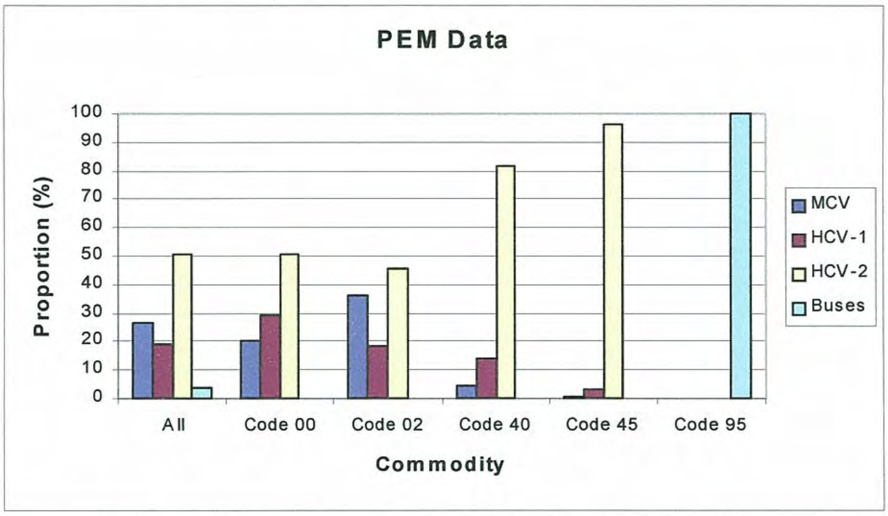


Figure 3.6 Distribution of PEM vehicle classifications for various commodities.

Table 3.8 Summary of ESA data with respect to PEM vehicle classifications.

Category	Count	Mean ESA^4	Mean ESA^5	Mean ESA^7	Mean ESA^{12}
MCV	2027	0.29	0.25	0.27	1.19
HCV-I	1440	1.00	1.04	1.37	6.52
HCV-II	3845	2.73	3.03	4.43	29.78
Buses	265	0.84	0.77	0.72	0.91

Figure 3.7 shows a histogram of ESA^4 values for the PEM vehicle classifications for *All Commodity* categories. As expected, the mean ESA data shown in Table 3.8 and the distribution of ESA data shown in Figure 3.7 are very similar to the corresponding data determined for the revised axle number vehicle classifications described in Section 3.4.2.

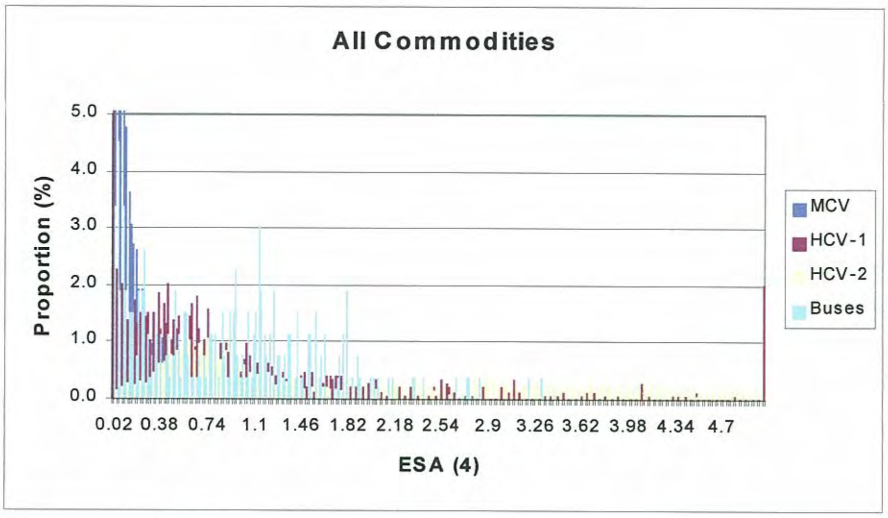


Figure 3.7 Proportion of ESA^4 values for all commodity categories with respect to PEM vehicle classifications.

3.4.4 Classified axle count data

Analysis of the WIM data shows that the vehicle length parameter which is essential for the classified count characterisation was very poorly collected. The raw data showed that approximately one half of the WIM records had no value assigned to the vehicle length field. Given the dominance of the *No Load Description* commodity classification, this leaves little data for the other commodity classifications. The vehicle length cannot be deduced from any other WIM data and therefore it has not been pursued further in this study.

The failure to establish axle load characterisation with respect to classified count vehicle classifications is not considered to be a significant disadvantage. The three previous vehicle classifications are thought to be adequate, and in most cases would be preferred.

3.5 Electronic Massing Unit (EMU) Survey

The EMU survey data has been analysed to establish the distribution of ESA values for heavy vehicles passing the Plimmerton Weighstation site. However, the data has not been included in the main WIM data set because the level of detail that is achieved in an EMU survey is greater than is achievable in typical traffic surveys.

A total of 730 vehicles were surveyed at the Plimmerton site during three separate surveys. Details of the vehicle counts, as well as the ESA^4, ESA^5, ESA^7 and ESA^{12} results are presented in Tables 3.9, 3.10 and 3.11. The three tables show the average ESA results with respect to the following vehicle classifications:

- number of axles (2 to 9),
- revised axles groupings from Section 3.2 (2 axles, 3-5 axles and 6+ axles); and,
- the PEM vehicle classifications (MCV, HCV-I, HCV-11 and Buses).

Table 3.9 Heavy vehicle count and ESA data for the EMU survey with respect to number of axles.

Axles	Count	Mean ESA^4	Mean ESA^5	Mean ESA^7	Mean ESA^{12}
2	264	0.25	0.21	0.19	0.39
3	83	0.92	0.86	0.82	0.97
4	40	0.74	0.65	0.55	0.59
5	42	1.43	1.35	1.31	1.66
6	106	1.96	2.01	2.31	5.76
7	52	2.57	2.57	2.73	4.00
8	142	1.60	1.45	1.27	1.17
9	1	0.85	0.67	0.45	0.20
Total	730	1.10	1.04	1.05	1.73

Table 3.10 Heavy vehicle count and ESA data for the EMU survey with respect to (revised) number of axles.

Axles	Count	Mean ESA^4	Mean ESA^5	Mean ESA^7	Mean ESA^{12}
2	264	0.25	0.21	0.19	0.39
3, 4 or 5	165	1.01	0.93	0.88	1.05
6+	301	1.89	1.84	1.88	3.28
Total	730	1.10	1.04	1.05	1.73

Table 3.11 Heavy vehicle count and ESA data for the EMU survey with respect to PEM vehicle classifications

Axles	Count	Mean ESA^4	Mean ESA^5	Mean ESA^7	Mean ESA^{12}
MCV	246	0.22	0.18	0.17	0.39
HCV-I	112	0.85	0.77	0.71	0.85
HCV-II	342	1.84	1.78	1.82	3.08
Buses	30	0.89	0.80	0.69	0.56
Total	730	1.10	1.04	1.05	1.73

The data presented in Tables 3.9 to 3.11 shows that the EMU survey produced similar, but generally lower ESA^4, ESA^5, ESA^7 and ESA^{12} data than the corresponding survey information obtained from the Drury, Te Puke and Waipara WIM sites. It would appear that there were few very heavily laden axles weighed at the Plimmerton site. This may be attributable to the time of year, or the time of day that the surveys were carried out, or heavily laden trucks may have consciously avoided the Plimmerton site given that the survey was primarily undertaken for axle loading enforcement purposes.

4 Eight hour traffic count factors

4.1 General

A fundamental component of establishing the design traffic parameter is to estimate the ESA loading expected over the first year of the pavement life. The initial year's traffic can then be factored by the number of years required in the design life and any increases or decreases in loading expected over those years to obtain the overall design traffic parameter. Clearly, it is impractical to perform project level traffic surveys for a full year and so a small sample of the traffic distribution can be obtained and the resulting data is factored up to estimate the full year's traffic.

The AUSTROADS Pavement Design Guide (AUSTROADS 1992) does not provide information regarding appropriate factors to transform limited traffic survey data to full year data. The (now superseded) Transit New Zealand State Highway Pavement Design and Rehabilitation Guide (TNZ, 1989) states that daily traffic data should be multiplied by a factor of 300 to provide estimated annual data, however no factors are given for transforming limited period survey data to daily data.

At the time of this study, Transit New Zealand provided screened WIM data from the Te Puke and Waipara sites for the 1998 year. The data has been analysed to determine Daily and Annual Factors in terms of both vehicle numbers and ESA.

4.2 Te Puke WIM Site

Table 4.1 shows a summary of the processed WIM data for the Te Puke site for all records collected in 1998. The data is presented in terms of both heavy traffic counts and ESA. Note that only vehicles with a minimum gross weight of 3.5 t have been recorded.

Table 4.1 Summary of the total 1998 WIM data for the Te Puke site.

Month	**Count**	**ESA**
January	32474	51496.4
February	35342	59797.6
March	39189	63574.9
April	33810	44411.0
May	37012	52370.6
June	35849	50587.3
July	34685	48803.9
August	34999	50346.5
September	38403	59372.5
October	39330	63266.8
November	38239	63133.2
December	38239	62999.5
TOTAL	**436479**	**670160.2**

Table 4.1 shows that the mean load factor (ESA per heavy vehicle) is approximately 1.5. This result is similar to that found for the WIM records summarised in Table 3.3.

The traffic count and ESA data has been determined for each hour of each day of 1998. In particular, three eight hour periods, i.e.

- 7 am to 3 pm;
- 8 am to 4 pm; and,
- 9 am to 5 pm,

have been analysed in detail as they represent eight-hour shifts that could typically be used for manual traffic monitoring. The mean eight-hour count and ESA data for these periods are presented in Tables F1, F2 and F3 respectively (Appendix F).

The factors required to convert the eight-hour data to equivalent mean 24-hour data for each month (Daily Factor) and then to convert the mean 24-hour data to annual data (Annual Factor) are presented in Tables 4.2 to 4.4. Note that a low Daily Factor corresponds to a day of the week with a relatively high proportion of traffic counts or loadings. Similarly, a low Annual Factor corresponds to a month with a relatively high proportion of traffic counts or loadings. Conversely, a high Daily Factor corresponds to a day of the week with a relatively low proportion of traffic counts or loadings and a high Annual Factor corresponds to a month with a relatively low proportion of traffic counts or loadings.

The data presented in Tables 4.2 to 4.4 show that the mean Daily Factors for both traffic counts and ESAs were reasonably consistent from weekday to weekday and from month to month throughout the year. In addition, the mean Daily Factors were relatively consistent for the three eight-hour sample periods. The weekend factors were considerably more inconsistent, and given that it is unlikely that manual traffic monitoring would be undertaken in the weekends, this data has not been considered further in these analyses.

The mean Daily Factors for the full year for heavy traffic counts and ESA were 1.32 and 1.36 respectively. This suggests that an overall Daily Factor of approximately 1.35 is representative of all the 1998 count and ESA data for the Te Puke site. This means that on a typical weekday, an eight-hour traffic survey conducted between the hours of 7 am and 5 pm would identify approximately 74% of the total daily (heavy) traffic in terms of both heavy vehicle numbers and pavement damaging effect.

The Annual Factor varied somewhat by month, especially for the ESA parameter. January provided the highest Annual Factor while December provided the lowest Annual Factor. Mean Annual Factors of 366 and 370 were obtained for the traffic count and ESA parameters respectively.

Table 4.2(a) Daily and Annual Traffic Count Factors for 7 am to 3 pm sampling period at the Te Puke WIM site.

	Eight-Hour Daily Factor - Traffic Count							Annual
Month	**Mon**	**Tues**	**Wed**	**Thurs**	**Fri**	**Sat**	**Sun**	**Factor**
January	1.60	1.48	1.46	1.36	1.39	4.38	4.78	417
February	1.43	1.37	1.35	1.34	1.35	3.77	6.04	346
March	1.41	1.31	1.34	1.32	1.31	3.99	7.85	345
April	1.32	1.23	1.26	1.26	1.30	3.42	6.23	387
May	1.34	1.30	1.23	1.28	1.26	3.88	6.15	366
June	1.34	NR	1.23	NR	1.20	3.70	7.24	365
July	1.34	1.21	1.33	1.43	1.32	3.81	7.51	390
August	1.27	1.21	1.31	1.25	1.22	3.71	7.19	387
September	1.37	1.36	1.38	1.35	1.23	3.62	8.42	340
October	1.23	1.26	1.24	1.27	1.27	4.53	9.76	344
November	1.38	1.19	1.20	1.32	1.31	3.13	10.53	342
December	1.19	1.13	1.15	1.28	1.24	3.03	5.87	364
Full Year	1.35	1.28	1.29	1.31	1.28	3.75	7.30	366

Table 4.2(b) Daily and Annual ESA Factors for 7 am to 3 pm sampling period at the Te Puke WIM site.

	Eight-Hour Daily Factor - ESA							Annual
Month	**Mon**	**Tues**	**Wed**	**Thurs**	**Fri**	**Sat**	**Sun**	**Factor**
January	1.95	1.56	1.55	1.38	1.33	5.28	4.37	403
February	1.57	1.45	1.45	1.42	1.60	4.01	7.68	314
March	1.44	1.34	1.41	1.36	1.37	4.42	9.63	327
April	1.40	1.28	1.27	1.30	1.38	3.41	6.84	453
May	1.38	1.29	1.23	1.27	1.35	4.79	6.90	397
June	1.35	NR	1.26	NR	1.17	4.18	7.81	397
July	1.35	1.30	1.41	1.46	1.37	4.11	9.12	426
August	1.32	1.28	1.43	1.32	1.26	3.73	8.71	413
September	1.47	1.42	1.47	1.38	1.26	3.52	11.89	339
October	1.19	1.30	1.28	1.29	1.30	5.53	14.60	328
November	1.51	1.51	1.42	1.32	1.40	4.12	14.60	318
December	1.15	1.14	1.13	1.29	1.30	3.07	7.05	330
Full Year	1.42	1.35	1.36	1.35	1.34	4.18	9.10	370

Table 4.3(a) Daily and Annual Traffic Count Factors for 8 am to 4 pm sampling period at the Te Puke WIM site.

Month	Eight-Hour Daily Factor - Traffic Count							Annual Factor
	Mon	**Tues**	**Wed**	**Thurs**	**Fri**	**Sat**	**Sun**	
January	1.64	1.48	1.47	1.36	1.46	4.55	4.72	417
February	1.46	1.37	1.37	1.33	1.37	4.08	6.01	346
March	1.39	1.36	1.34	1.32	1.32	4.20	7.62	345
April	1.31	1.20	1.24	1.22	1.27	3.52	5.90	387
May	1.32	1.25	1.20	1.26	1.25	3.94	5.82	366
June	1.31	NR	1.21	NR	1.22	3.89	6.75	365
July	1.33	1.21	1.33	1.43	1.31	4.14	6.99	390
August	1.27	1.20	1.28	1.23	1.22	3.91	6.76	387
September	1.40	1.34	1.38	1.35	1.26	3.87	8.21	340
October	1.27	1.29	1.26	1.29	1.30	4.94	9.33	344
November	1.38	1.24	1.49	1.40	1.29	3.16	9.51	342
December	1.19	1.11	1.19	1.17	1.22	3.41	5.82	364
Full Year	1.36	1.28	1.31	1.31	1.29	3.97	6.95	366

Table 4.3(b) Daily and Annual ESA Factors for 8 am to 4 pm sampling period at the Te Puke WIM site.

Month	Eight-Hour Daily Factor - ESA							Annual Factor
	Mon	**Tues**	**Wed**	**Thurs**	**Fri**	**Sat**	**Sun**	
January	1.94	1.53	1.59	1.32	1.35	5.41	4.46	403
February	1.60	1.48	1.42	1.40	1.47	4.37	7.75	314
March	1.38	1.31	1.37	1.34	1.37	4.74	9.65	327
April	1.38	1.20	1.21	1.27	1.30	3.40	6.15	453
May	1.36	1.27	1.19	1.25	1.32	4.93	6.65	397
June	1.31	NR	1.23	NR	1.17	4.52	7.44	397
July	1.32	1.29	1.39	1.46	1.36	4.60	8.52	426
August	1.32	1.28	1.36	1.28	1.23	3.99	8.11	413
September	1.47	1.39	1.46	1.37	1.28	3.84	11.72	339
October	1.23	1.32	1.27	1.30	1.30	5.88	14.25	328
November	1.52	1.45	1.64	1.48	1.38	3.35	13.51	318
December	1.16	1.11	1.15	1.16	1.28	3.61	7.21	330
Full Year	1.41	1.33	1.36	1.33	1.32	4.39	8.79	370

Table 4.4(a) Daily and Annual Traffic Count Factors for 9 am to 5 pm sampling period at the Te Puke WIM site.

	Eight-Hour Daily Factor - Traffic Count							**Annual**
Month	**Mon**	**Tues**	**Wed**	**Thurs**	**Fri**	**Sat**	**Sun**	**Factor**
January	1.73	1.50	1.52	1.41	1.57	4.81	4.81	417
February	1.48	1.39	1.39	1.35	1.41	4.52	6.34	346
March	1.39	1.32	1.34	1.34	1.35	4.56	7.18	345
April	1.30	1.18	1.24	1.25	1.27	3.66	5.59	387
May	1.33	1.24	1.21	1.28	1.29	4.31	5.66	366
June	1.53	NR	1.24	NR	1.28	4.27	6.49	365
July	1.32	1.25	1.37	1.47	1.35	4.59	7.04	390
August	1.31	1.23	1.33	1.26	1.25	4.31	6.76	387
September	1.45	1.37	1.44	1.37	1.31	4.32	8.42	340
October	1.32	1.37	1.33	1.36	1.38	5.77	9.47	344
November	1.46	1.29	1.53	1.42	1.33	3.56	9.37	342
December	1.24	1.14	1.22	1.20	1.27	4.47	5.42	364
Full Year	1.40	1.30	1.35	1.34	1.34	4.43	6.88	366

Table 4.4(b) Daily and Annual ESA Factors for 9 am to 5 pm sampling period at the Te Puke WIM site.

	Eight-Hour Daily Factor - ESA							**Annual**
Month	**Mon**	**Tues**	**Wed**	**Thurs**	**Fri**	**Sat**	**Sun**	**Factor**
January	2.03	1.52	1.61	1.34	1.44	5.33	4.75	403
February	1.60	1.43	1.43	1.40	1.47	4.86	8.78	314
March	1.34	1.31	1.33	1.34	1.39	5.24	8.65	327
April	1.36	1.17	1.18	1.35	1.28	3.51	6.22	453
May	1.36	1.24	1.18	1.25	1.34	5.45	6.49	397
June	1.37	NR	1.22	NR	1.20	5.13	7.12	397
July	1.33	1.33	1.44	1.50	1.35	7.26	8.47	426
August	1.35	1.28	1.42	1.29	1.25	4.46	8.52	413
September	1.50	1.41	1.48	1.36	1.33	4.19	12.35	339
October	1.25	1.38	1.32	1.36	1.37	6.90	14.30	328
November	1.49	1.37	1.65	1.42	1.38	3.79	12.97	318
December	1.17	1.13	1.16	1.35	1.31	4.24	6.84	330
Full Year	1.43	1.32	1.37	1.36	1.34	5.03	8.79	370

4.3 Waipara WIM Site

Table 4.5 shows a summary of the processed WIM data for the Waipara site for all data collected in 1998. The data is presented in terms of both heavy traffic counts and ESA. Note that only vehicles with a minimum gross weight of 3.5 t have been recorded.

Table 4.5 Summary of the total 1998 WIM data for the Waipara site.

Month	Count	ESA
January	15279	20655.8
February	13351	15677.3
March	14980	18250.6
April	13830	19144.9
May	12627	17651.5
June	11023	14632.0
July	11545	15921.4
August	11769	16530.3
September	13381	19369.8
October	13933	17101.2
November	8976	10665.4
December	10535	14348.6
TOTAL	**151229**	**199948.7**

Table 4.5 shows that the mean load factor for the complete traffic spectrum was approximately 1.3. This result is similar to that found for the WIM records summarised in Table 3.3.

The Waipara traffic count and ESA data has been determined for every hour of every day of 1998. The mean results for the three eight-hour periods are presented in Tables F4, F5 and F6 respectively (Appendix F).

The factors required to convert the eight-hour data to equivalent mean 24-hour data for each month (Daily Factor) and then to convert the mean 24-hour data to annual data (Annual Factor) are presented in Tables 4.6 to 4.8. The data presented in Tables 4.6 to 4.8 shows that the mean Daily Factors for both the traffic count and ESA parameters were somewhat inconsistent with Mondays and Fridays producing higher Daily Factors than Tuesdays, Wednesdays and Thursdays. In addition, the Annual Factors were quite inconsistent from month to month. However, as expected, the mean Daily Factors were relatively consistent for the three eight-hour sample periods.

The mean Daily Factors for the full year for traffic counts and ESA were 1.76 and 1.80 respectively. This suggests that a reasonable overall Daily Factor of approximately 1.8 is representative of all the 1998 data for the Waipara site. This means that on a typical weekday, an eight-hour traffic survey conducted between the hours of 7 am and 5 pm would identify approximately 56% of the total daily (heavy) traffic in terms of both heavy vehicle numbers and pavement damaging effect.

The Annual Factor varied somewhat by month especially for the ESA parameter. Mean Annual Factors of 373 and 375 were obtained for the traffic count and ESA parameters respectively. The highest Annual Factors were found for November and December while January provided the lowest Annual Factor.

Table 4.6(a) Daily and Annual Traffic Count Factors for 7 am to 3 pm sampling period at the Waipara WIM site.

	Eight-Hour Daily Factor - Traffic Count							**Annual**
Month	**Mon**	**Tues**	**Wed**	**Thurs**	**Fri**	**Sat**	**Sun**	**Factor**
January	1.81	1.57	1.62	1.84	2.02	3.77	3.62	307
February	1.93	1.68	1.65	1.73	1.99	4.10	3.55	317
March	1.78	1.65	1.86	1.85	1.95	3.94	2.88	313
April	1.91	1.61	1.54	1.58	2.04	4.17	4.58	328
May	1.67	1.54	1.56	1.53	1.65	3.89	4.83	371
June	1.85	1.72	1.38	1.99	2.27	4.30	5.86	412
July	1.90	1.62	1.74	1.97	1.94	4.57	5.91	406
August	1.94	1.63	1.73	1.65	1.77	3.83	5.77	398
September	1.94	1.72	1.78	1.81	1.71	4.32	4.97	339
October	1.95	1.76	1.69	1.67	1.86	3.98	4.73	337
November	1.86	1.78	1.65	1.67	2.28	3.81	4.84	505
December	2.02	1.65	1.64	1.69	2.32	3.73	3.65	445
Full Year	1.88	1.66	1.65	1.75	1.98	4.03	4.60	373

Table 4.6(b) Daily and Annual ESA Factors for 7 am to 3 pm sampling period at the Waipara WIM site.

	Eight-Hour Daily Factor - ESA							**Annual**
Month	**Mon**	**Tues**	**Wed**	**Thurs**	**Fri**	**Sat**	**Sun**	**Factor**
January	1.70	1.45	1.51	1.84	2.12	5.34	4.43	300
February	1.95	1.56	1.68	1.71	2.09	5.73	4.12	357
March	1.73	1.81	1.74	1.91	1.96	4.78	3.28	340
April	2.09	1.61	1.56	1.63	2.23	5.99	6.35	313
May	1.72	1.42	1.59	1.60	1.81	4.62	5.56	351
June	2.08	1.76	1.48	2.23	2.46	5.72	8.90	410
July	2.12	1.69	1.82	1.95	2.07	7.15	9.19	389
August	1.97	1.66	1.84	1.66	1.83	4.98	8.29	375
September	2.06	1.80	1.83	1.91	1.78	5.56	7.69	310
October	1.99	1.75	1.52	1.53	2.04	5.52	5.34	363
November	1.71	1.97	1.64	1.70	2.64	5.99	5.67	562
December	1.96	1.72	1.52	1.74	2.34	5.98	4.38	432
Full Year	1.92	1.68	1.64	1.78	2.11	5.61	6.10	375

Table 4.7(a) Daily and Annual Traffic Count Factors for 8 am to 4 pm sampling period at the Waipara WIM site.

	Eight-Hour Daily Factor - Traffic Count							Annual
Month	**Mon**	**Tues**	**Wed**	**Thurs**	**Fri**	**Sat**	**Sun**	**Factor**
January	1.74	1.60	1.58	1.91	2.07	3.66	3.42	307
February	1.91	1.71	1.69	1.76	2.05	4.15	3.49	317
March	1.72	1.67	1.81	1.83	1.98	4.20	2.80	313
April	1.83	1.58	1.53	1.51	2.05	4.08	4.21	328
May	1.61	1.50	1.57	1.46	1.66	4.01	4.54	371
June	1.74	1.70	1.37	1.91	2.19	4.14	5.65	412
July	1.87	1.59	1.72	1.92	1.88	4.60	5.30	406
August	1.84	1.55	1.71	1.64	1.71	3.75	5.10	398
September	1.92	1.76	1.76	1.83	1.72	4.32	4.68	339
October	1.89	1.75	1.63	1.64	1.82	4.10	4.42	337
November	1.74	1.74	1.59	1.62	2.26	3.81	3.97	505
December	1.97	1.64	1.58	1.70	2.41	3.80	3.47	445
Full Year	1.82	1.65	1.63	1.73	1.98	4.05	4.25	373

Table 4.7(b) Daily and Annual ESA Factors for 8 am to 4 pm sampling period at the Waipara WIM site.

	Eight-Hour Daily Factor - ESA							Annual
Month	**Mon**	**Tues**	**Wed**	**Thurs**	**Fri**	**Sat**	**Sun**	**Factor**
January	1.66	1.45	1.45	1.95	2.28	5.60	4.20	300
February	1.97	1.61	1.61	1.68	2.21	5.43	3.87	357
March	1.65	1.89	1.71	1.78	2.06	5.18	3.35	340
April	2.04	1.59	1.54	1.52	2.34	6.69	6.26	313
May	1.57	1.36	1.58	1.55	1.85	5.03	5.34	351
June	1.81	1.74	1.41	2.22	2.41	5.26	8.84	410
July	2.08	1.66	1.83	1.98	2.13	7.16	8.36	389
August	1.85	1.56	1.80	1.65	1.78	4.85	7.86	375
September	2.00	1.78	1.77	1.92	1.76	5.65	6.75	310
October	1.89	1.71	1.49	1.50	1.89	5.32	5.17	363
November	1.71	1.92	1.59	1.67	2.79	5.90	4.50	562
December	1.98	1.73	1.52	1.80	2.57	6.24	4.08	432
Full Year	1.85	1.67	1.61	1.77	2.17	5.69	5.71	375

Table 4.8(a) Daily and Annual Traffic Count Factors for 9 am to 5 pm sampling period at the Waipara WIM site.

	Eight-Hour Daily Factor - Traffic Count							Annual
Month	**Mon**	**Tues**	**Wed**	**Thurs**	**Fri**	**Sat**	**Sun**	**Factor**
January	1.74	1.61	1.59	1.90	2.07	3.72	3.13	307
February	1.85	1.68	1.61	1.71	2.04	4.28	3.27	317
March	1.79	1.68	1.74	1.85	1.95	4.50	2.73	313
April	1.81	1.56	1.52	1.48	2.07	4.10	4.05	328
May	1.60	1.45	1.55	1.46	1.71	4.07	4.38	371
June	1.72	1.66	1.41	1.76	1.98	4.30	5.12	412
July	1.85	1.56	1.76	1.83	1.87	4.87	5.03	406
August	1.81	1.58	1.74	1.64	1.69	3.78	4.69	398
September	1.89	1.73	1.75	1.82	1.71	4.42	4.34	339
October	1.94	1.72	1.60	1.65	1.87	4.34	4.17	337
November	1.68	1.62	1.53	1.46	2.22	3.54	3.26	505
December	1.81	1.62	1.61	1.66	2.50	3.78	3.21	445
Full Year	1.79	1.62	1.62	1.69	1.97	4.14	3.95	373

Table 4.8(b) Daily and Annual ESA Factors for 9 am to 5 pm sampling period at the Waipara WIM site.

	Eight-Hour Daily Factor - ESA							Annual
Month	**Mon**	**Tues**	**Wed**	**Thurs**	**Fri**	**Sat**	**Sun**	**Factor**
January	1.71	1.44	1.42	1.86	2.28	5.99	3.99	300
February	1.95	1.54	1.50	1.58	2.19	5.54	3.40	357
March	1.69	1.90	1.61	1.82	2.00	6.19	3.39	340
April	1.98	1.55	1.51	1.48	2.36	7.13	5.91	313
May	1.57	1.32	1.51	1.51	1.91	5.50	5.28	351
June	1.77	1.65	1.37	1.82	2.16	5.31	7.50	410
July	2.03	1.62	1.83	1.95	2.04	8.07	8.06	389
August	1.78	1.57	1.73	1.61	1.75	4.96	8.01	375
September	1.92	1.72	1.71	1.86	1.72	6.10	6.60	310
October	1.96	1.67	1.50	1.49	1.94	5.88	5.28	363
November	1.68	1.76	1.51	1.52	2.80	5.38	3.77	562
December	1.77	1.74	1.53	1.76	2.62	5.87	3.79	432
Full Year	1.82	1.62	1.56	1.69	2.15	5.99	5.41	375

4.4 Interpretation of the Eight Hour Traffic Count Data

Analysis of the WIM data for Te Puke and Waipara has provided a number of issues of interest. The mean Load Factors obtained for both sites (1.5 and 1.3 respectively) were similar to the results obtained from the WIM records analysed in Section 3 of this report, but somewhat higher than the mean Load Factors reported by Bartley Consultants Ltd (BCL, 1996). BCL (1996) reported mean Load Factors in the range 0.8 to 1.2 ESA/heavy vehicle with the Waipara site showing a value of 1.1. The

Waipara data was however based on a partial record of the 1994 year. The Te Puke site was not considered in the BCL (1996) report.

The mean Daily Factors established for the Te Puke (1.35) and Waipara (1.80) sites differ by a reasonable margin. This reflects the fact that more heavy vehicles appear to pass the Waipara WIM site out of the hours of 7 am to 5 pm compared to the Te Puke site.

The Daily Factors for the Te Puke site are quite uniform from weekday to weekday, although there is a slight tendency for Monday's to experience less heavy traffic in terms of vehicle count and damaging effect relative to the other weekdays. The Waipara data shows a similar tendency, not only for Mondays but also Fridays to be relatively quiet, compared with Tuesdays, Wednesdays and Thursdays. Therefore it is reasonable to suggest that the mid-week days are best for carrying out limited period traffic surveys.

The mean weekend traffic at the Te Puke site shows approximately one quarter of the heavy traffic volume and approximately one fifth of the damaging effect of the mean weekday traffic. There is less of a contrast between the weekend and weekday traffic at the Waipara site. There the weekend traffic represents almost one half the weekday traffic in terms of volume and about one third in terms of damaging effect.

The Annual Factors obtained for the two WIM sites are quite inconsistent and difficult to resolve. The Te Puke site shows above average heavy traffic volumes for the months September to December while the January volume is well below average. This seems reasonable considering that January is a popular time for holidays. The Waipara data however shows January to have the highest traffic volumes while the data for the months of November and December are well below average.

The differences between the data obtained from the two WIM sites for which data was available are such that it is not possible to make reliable generalisations regarding Daily and Annual Factors. Rather, the analyses have produced a range of factors which may be consistent with other locations around New Zealand. Further research should be undertaken to focus on this issue.

5 Methods for Determining the Design Traffic Parameter

5.1 General

The procedure that should be used to estimate the design traffic parameter is dependent on a number of variables, e.g.

- the significance of the proposed pavement;
- the availability of past traffic data;
- the location of the site;
- the proximity of WIM or classified count stations;
- the nature of the adjacent land use; and,
- the future plans for the area which may influence traffic flows.

Each variable should be considered when choosing the appropriate method and level of detail to be used.

It must be recognised that any design traffic estimation procedure that incorporates commodity survey data is subject to a number of approximations, not the least being the relatively high proportion of heavy vehicles falling into the *No Load Description* commodity classification. Other sources of fluctuation include, regional bias, axle configurations, seasonal fluctuations, etc. Therefore, it should be stressed that the procedures described in this report are considered to be guidelines only.

5.2 Proposed Procedures for Estimating the Design Traffic Parameter

The level of detail that should be incorporated in the estimation of the design traffic parameter should be dependent on the significance of the proposed pavement. For example, estimating the design traffic for a quiet access road, where the construction traffic represents the bulk of the loading that the pavement will experience does not require a rigorous study of traffic patterns. Conversely, strategic roads such as state highways, for which premature failure could be extremely costly generally require a very detailed traffic investigation.

A number of proposed procedures (with examples of their application) are described in the following paragraphs. They start with the most simple procedure and progressively increase in detail and accuracy. It must be noted that *the procedures developed in this study are applicable to projects where there is an existing traffic stream*, e.g. road rehabilitation projects or minor realignments. Where totally new routes are being designed a detailed traffic study must be undertaken to determine projected traffic numbers from newly generated trips and those scavenged from other routes. This situation is beyond the scope of the current study.

The nature of the WIM equipment is such that there are various limitations regarding the data that can be obtained. As WIM data has been used in this project, the proposed procedures for estimating the design traffic parameter will include these limitations. One important limitation is that the WIM equipment cannot identify super single tyres. Therefore, the proposed procedures should not be used where there is a traffic stream that is expected to have a significant proportion of heavy vehicles equipped with super single tyres.

The WIM data has been obtained from state highway locations, simply because all of the WIM stations are on state highways. This should be kept in mind when using the proposed design traffic estimation procedures as the traffic distribution for other road types may be somewhat different than that for state highways. In addition, there is an implied assumption that the axle loads are generally within the legal limits. If this is not true for a particular location the ESA data could be skewed, especially given that the TDDF values are raised to exponents of up to 12 (for cemented layers).

In each procedure the objective is to determine the total ESAs for the *first year*. The final ESA value is determined by applying a Cumulative Growth Factor which is dependent on the number of years in the design life and the expected growth rate. The design traffic may also need to be adjusted if heavy vehicle loadings are expected change in the future. For example, a nearby forest may start or stop a harvesting operation at some time within the design life of the pavement which would have a significant effect on the design traffic parameter. TDDFs are then applied for each relevant pavement component, i.e. subgrade, asphalt layers and cmented layers.

5.2.1 Procedure one — presumptive data

The lowest level of investigation to determine the design traffic parameter involves adopting a presumptive value based on published data. The use of presumptive data is best suited to very low loading situations where the construction traffic may represent the majority of the total pavement loading.

Presumptive values of design traffic are reported in APRG (1997) for various categories of roads ranging from minor roads with a single traffic lane to collector roads including bus traffic. The designer can quickly determine the loading situation and assign an appropriate design traffic value (see Table 5.1).

Table 5.1 Presumptive (20 year) design traffic values for lightly trafficked flexible pavements (after APRG 1997).

Street Type	**Load Factor**	**Design Traffic (ESA)**
Minor with single lane traffic	0.2	1.5×10^3
Minor with two lane traffic	0.2	2.0×10^3
Local Access with no buses	0.3	2.0×10^4
Local Access with buses	0.4	5.0×10^4
Local Access in industrial area	0.6	7.5×10^4
Collector with no buses	0.5	1.5×10^5
Collector with buses	0.6	3.5×10^5

Example

Available information:

Road type: Local Access with buses

Solution: 20 year design traffic = 5×10^4 ESA (see Table 5.1)

5.2.2 Procedure two — manual traffic counts with load factors

Procedure Two involves undertaking a manual count of the heavy vehicles in the traffic stream. The count should have a duration of eight hours and be carried out between the hours of 7 am to 5 pm on a typical weekday. The eight-hour count can be converted to a 24-hour count by applying a daily factor in the range 1.35 to 1.80 (see Section 4) to account for traffic outside the survey period. The estimated 24-hour count can then be multiplied by an Annual Factor of approximately 370 (see Section 4) to obtain the total estimated heavy vehicles in the first year.

Once the number of heavy vehicles has been established, a load factor can be applied to convert the data to ESA. The data obtained during this project suggests that a mean load factor in the range 1.2 to 3.2 may be appropriate depending on the location.

Example

Available information:
8-hr count : 450 heavy vehicles
Traffic : typical rural

Solution:

Assume Daily Factor of 1.35 & Annual Factor of 370
Assume load factor of 1.2 ESA/HV

First year traffic $= 450 \times 1.35 \times 370 \times 1.2$
$= 2.7 \times 10^5$ ESA

The first year ESA value can be multiplied by a Growth Factor which takes into account the number of years in the design life and the expected annual growth rate. Adjustments may also need to be made to allow for expected changes in land use or traffic routes. TDDFs are then applied for the relevant pavement components.

5.2.3 Procedure three — automated traffic counts with load factors

The next level up in terms of sophistication is similar to that described in Procedure Two except that automated data collection systems are utilised. For example, traffic counts can be established using pneumatic loop counters or by obtaining WIM or classified count data from Transit New Zealand. WIM data is the most accurate to work with because only heavy vehicles activate the record, however there are only a small number of WIM sites and the likelihood that the site in question is in close proximity to a WIM site is quite remote. Traffic counting equipment such as pneumatic loop counters or classified count stations have the advantage of being able to count automatically however they do not necessarily distinguish between heavy and light vehicles. Classified counts can be performed in terms of vehicle length or number of axles but these parameters can be misleading, e.g. a car towing a light trailer could be mistaken as a three axle truck.

If the total traffic stream is recorded the number of heavy vehicles can be estimated by applying a percentage. Heavy vehicle percentages typically range from about 1 to 5% for lightly loaded roads while 7 to 10% heavy vehicles would represent the typical loading on an urban arterial road. Percentages in the range of about 10% to 30% could be appropriate for main freight routes.

Example

Available information:
Daily traffic : 2000 vehicles/day
Traffic : typical urban

Solution:

Assume 10% heavy traffic
Assume load factor of 1.2 ESA/HV, and Annual Factor of 370

First year traffic $= 2000 \times 370 \times 0.1 \times 1.2$
$= 8.9 \times 10^4$ ESA

Once the first year heavy vehicle count has been established the design traffic can be calculated by applying a load factor and cumulative growth factor as described for Procedure Two.

5.2.4 Procedure four — load factors with respect to axle numbers

Procedure Four is slightly more refined than Procedure Three in that the heavy vehicle counts are classified in terms of the number of axles, with three groupings. These are:

- Two-axle heavy vehicles;
- three, four or five-axle vehicles; and,
- six plus axle vehicles.

At sites where the traffic volume is relatively low the counts could be undertaken manually. At busier sites the use of a video camera would be beneficial. The survey should be carried out over an eight-hour period within the hours of 7 am to 5 pm.

Typical load factors for each vehicle classification are given in Table 3.6. The number of vehicles in each classification should be multiplied by the respective load factors and summed to give a total eight-hour ESA value. The appropriate Daily Factor and Annual Factors can then be applied to obtain the total ESA for the first year. Finally, a cumulative growth factor is applied to obtain the final design traffic value.

Example

Available information:
8-hr count data: 100 2-axle trucks
200 3/4/5 axle trucks
50 6+ axle trucks

Solution:

Apply load factors from Table 3.6, i.e.
2-axle : 0.31 ESA/HV
3/4/5 axles : 1.10 ESA/HV
6+ axles : 2.80 ESA/HV
Assume Daily Factor of 1.35, and Annual Factor of 370

First year traffic $= (100 \times 0.31 + 200 \times 1.1 + 50 \times 2.8) \times 1.35 \times 370$
$= 2.0 \times 10^5$ ESA

5.2.5 Procedure five — load factors with respect to PEM classifications

Procedure Five is equivalent to Procedure Four except that Project Evaluation Manual (PEM) vehicle classifications are used instead of the axle number classifications. Typical load factors related to the PEM classifications are presented in Table 3.8.

Example

Available information:
8-hr count data: 150 MCV
200 HCV-I
100 HCV-II
20 Buses

Solution:

Apply load factors from Table 3.8, i.e.
MCV : 0.29 ESA/HV
HCV-I : 1.00 ESA/HV
HCV-II : 2.73 ESA/HV
Buses : 0.84 ESA/HV
Assume Daily Factor of 1.35, and Annual Factor of 370

$$\text{First year traffic} = (150 \times 0.29 + 200 \times 1.0 + 100 \times 2.73 + 20 \times 0.84) \times 1.35 \times 370$$
$$= 2.7 \times 10^5 \text{ ESA}$$

5.2.6 Procedure six — load factors with respect to commodities

Procedure Six involves establishing the distribution of commodities being carried using a video camera to record the traffic for an eight-hour period. The video record should be obtained 0ver an eight-hour period during the hours of 7 am to 5 pm on a typical weekday. The vehicles are classified into the commodity classifications listed in Appendix A and appropriate load factors are applied as presented in Table B1.

Once the eight-hour ESA value has been established, Daily and Annual Factors can be applied to obtain the first year ESA value. A Cumulative Growth Factor is then applied to obtain the final design traffic value.

Example

Available information:
8-hr count data: 50 trucks carrying aggregate
40 trucks carrying logs
30 trucks carrying milk
20 trucks carrying frozen food

Solution:

Apply load factors from Table B1, i.e.
Aggregate : 2.90 ESA/HV
Logs : 5.18 ESA/HV
Milk : 2.65 ESA/HV
Frozen food : 1.32 ESA/HV
Assume Daily Factor of 1.35, and Annual Factor of 370 *(cont. next page)*

First year traffic $= (50 \times 2.90 + 40 \times 5.18 + 30 \times 2.65 + 20 \times 1.32) \times 1.35 \times 370$
$= 2.3 \times 10^5$ ESA

5.2.7 Vehicle axles procedure seven — load factors from commodities and

Procedure Seven is similar to Procedure Six except that the load factors should be applied with respect to both the commodity identified in the traffic survey and the number of axles of each heavy vehicle (2 axles, 3/4/5 axles or 6+ axles). The load factors are presented in Table D1. Care should be taken where the load factors have been established from limited data, i.e. the number of observations in Table D1 should be in the order of 30 or more for the data to be considered to be representative. If 30 observations were not achieved, a conservative estimate from the available load factor data should be adopted.

Once the eight-hour ESA value has been established, Daily and Annual Factors can be applied to obtain the first year ESA value. A Cumulative Growth Factor is then applied to obtain the final design traffic value.

Example

Available information:

8-hr count data: 30 trucks carrying construction machinery - 3 axles
10 trucks carrying construction machinery - 7 axles
20 trucks carrying containers - 7 axles
10 trucks carrying furniture - 2 axles

Solution:

Apply load factors from Table D1, i.e.
Construction machinery - 3/4/5 axles : 1.48 ESA/HV
Construction machinery - 6+ axles : 5.04 ESA/HV
Containers - 6+ axles : 1.53 ESA/HV
Furniture - 2 axles : 0.29 ESA/HV
Assume Daily Factor of 1.35, and Annual Factor of 370

First year traffic $= (30 \times 1.48 + 10 \times 5.04 + 20 \times 1.53 + 10 \times 0.29) \times 1.35 \times 370$
$= 7.7 \times 10^4$ ESA

5.2.8 Procedure eight — load factors from commodities and PEM classification

This procedure is the same as Procedure Seven except that the load factors should be applied with respect to both commodity and PEM vehicle classification. The load factors are presented in Table E1. Care should be taken where the load factors have been established from limited data, i.e. the number of observations in Table E1 should be in the order of 30 or more for the data to be considered to be representative. If 30 observations were not achieved, a conservative estimate from the available load factor data should be adopted.

Once the eight-hour ESA value has been established, Daily and Annual Factors can be applied to obtain the first year ESA value. A Cumulative Growth Factor is then applied to obtain the final design traffic value.

Example

Available information:

8-hr count data: 40 trucks carrying aggregate - HCV-I

30 trucks carrying livestock - HCV-II

10 trucks carrying processed timber - MCV

60 trucks carrying processed timber - HCV-I

Solution:

Apply load factors from Table E1, i.e.

Aggregate - HCV-I : 1.74 ESA/HV

Livestock - HCV-II : 2.69 ESA/HV

Processed timber - MCV : 0.31 ESA/HV

Processed timber - HCV-I : 0.83 ESA/HV

Assume Daily Factor of 1.35, and Annual Factor of 370

First year traffic $= (40 \times 1.74 + 30 \times 2.69 + 10 \times 0.31 + 60 \times 0.83) \times 1.35 \times 370$

$= 1.0 \times 10^5$ ESA

6 Recommendations

The research has identified a number of issues that are worthy of further investigation in the future. These include the following:

- The *No Load Description* commodity category tends to dominate the commodity classifications. It would be beneficial to better characterise this portion of the traffic distribution.

- The data shows that there is some variability in mean ESA values with respect to location. The establishment of further WIM sites would enable this variation to be characterised in a more accurate fashion. This is especially relevant for the TDDF values for cemented materials as their performance criterion involves an exponent of 12 which tends to exaggerate data that may be erroneous or atypical.

- The daily and annual factors calculated in this project have been based on the only screened full-year WIM data that was available at the time. When further data is available it would be desirable to carry out similar analyses to examine any variations with respect to location or year.

- The WIM equipment cannot identify super single tyres. Further studies to determine the distribution of heavy vehicles using super single tyres and their damaging effect would be beneficial.

- The WIM equipment is all located on state highways. Therefore, the state highway traffic characteristics are inherent in the data and the analyses. A study to determine if the state highway traffic distribution is comparable to that for local roads would give more confidence in the general application of the WIM data.

7 Conclusions

This project has involved the performance of a series of traffic surveys and data analyses with the following objectives:

- to develop guidelines for estimating the design traffic parameter with respect to the damaging effect on the subgrade and bound layers using data typically collected in New Zealand; and,
- to determine Traffic Distribution Design (TDD) Factors to take into account the different exponents used in the ESA relationship (4^{th} power) and the AUSTROADS performance criteria (5^{th}, 7^{th} and 12^{th} powers).

The project objectives have been addressed in this report and the main conclusions to be drawn from the study are as follows:

- The process of matching video images of vehicles with the corresponding WIM motion records was successful. Only 2% of the records could not be matched.

- The distribution of vehicle gross weights was relatively consistent from location to location. Therefore, the data from four WIM sites was combined to provide a data set with a population of 7757 records.

- Mean ESA values per heavy vehicle calculated from the WIM records were generally higher than previously reported values. Mean fourth power ESA values of approximately 1.2, 1.7, 3.2 and 1.4 were calculated for the Drury, Te Puke, Tokoroa and Waipara site respectively. This indicates that there is some variation in the mean ESA values with respect to location. The overall mean ESA value was 1.7.

- TDDF values were calculated for each WIM site. The TDDFs for the Tokoroa data were generally higher than those for the other sites. It is suggested that two sets of TDDFs be used, one for "normal" loading conditions and one for "heavy" loading conditions where logging trucks and other heavy commodities that may be prone to overloading make up a significant proportion of the heavy traffic distribution. Under "normal" loading conditions, TDDF values of 1.1, 1.1 and 3.0 are recommended for subgrade, asphalt and cemented materials respectively. Under "heavy" loading conditions, TDDF values of 2.4, 1.3 and 25 are recommended for subgrade, asphalt and cemented materials respectively.

- Commodity survey data has been correlated with ESA data with respect to the number of axles per vehicle and the PEM vehicle classifications. Correlations based on vehicle length have not been achieved because the vehicle length data was not well recorded in the WIM data.

- The *No Load Description* commodity classification dominated the commodity classifications because of the large number of heavy vehicles with covered sides and non-descriptive livery.

- EMU survey data has been analysed, however it has not been included in the main data analyses because it represents a level of detail not typically available to the pavement designer. Notwithstanding this, it was found that the ESA data from the EMU survey was generally lower than that found from the WIM data.

- Daily and Annual Traffic Factors have been established from (1998) WIM data from the Te Puke and Waipara sites. Daily Factors convert typical eight-hour count data to equivalent 24-hour data while Annual Factors convert the 24-hour data to equivalent full year data. Mean weekday Daily Factors of 1.35 and 1.80 were found for Te Puke and Waipara respectively. The mean Annual Factors of approximately 370 were found for both sites.

- Eight procedures have been developed for estimating the design traffic parameter. The procedures range in complexity from simple presumptive values to using commodity surveys with vehicle types being classified with respect to PEM classifications or number of axles. It should be recognised that the proposed procedures are offered as guidelines only, as the WIM data obtained in this project is subject to a number of variations, limitations and approximations.

- The research identified a number of issues that are worthy of further investigation in the future.

8 References

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APPENDIX A

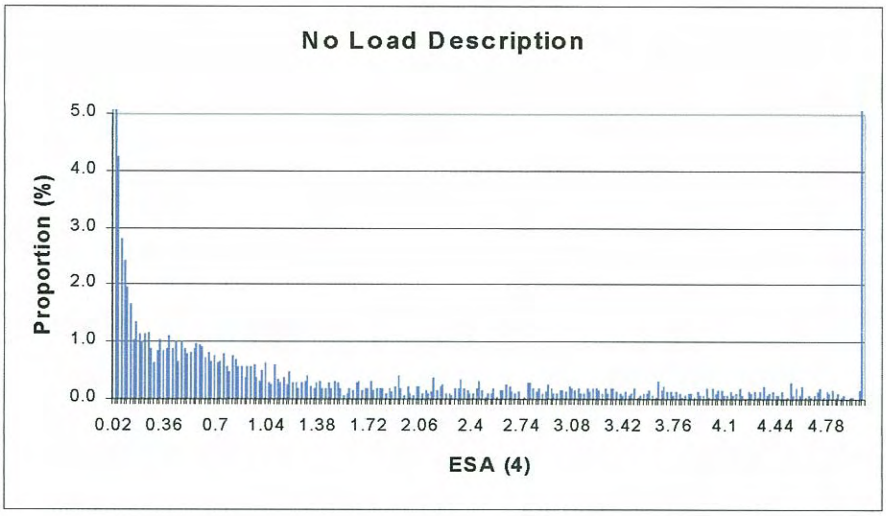
Commodity Codes

Table A1 Commodity codes.

Code	Commodity
0	Empty Or Carrying Tradesmens Tools
1	Maintenance Equipment
2	No Load Description
10	Grain, Seeds
11	Stock Food
12	Fruit and Vegetables
13	Plants
14	Hay
20	Cattle and Horses
21	Sheep, Pigs
22	Poultry
29	Honey
30	Milk and Whey
31	Butter, Cheese and Other Milk Products
32	Meat, Fish and Frozen Foods
33	Wool, Hides
34	Tallow
35	Fertilizer and Powdered Chemicals
40	Aggregates, Earth, Etc
41	Water
45	Timber, Logs
46	Timber, Processed
47	Paper, Pulp and Cardboard
48	Sawdust and Wood Waste
50	Cement and Gypsum
54	Prefabricated Structural Components
55	Building Materials Processed
56	Furniture
60	Solid Fuels
61	Liquid Fuels and Oil
62	Bituminous Products
70	Manufactured Foodstuffs
71	Beer
72	Other Liquids
80	Concrete - Ready Mixed
83	Machinery
84	Construction Machinery
85	Other Manufactured Products
86	General Goods
87	Metals and Scrap
88	Rubbish
90	Mixed Goods
91	Courier, Mail and Parcels
92	Containers
95	Buses
96	Camper Vans
97	Logging Trucks Carrying Jinkers
98	Car Haulage

APPENDIX B

ESA Data With Respect to Commodity For All Vehicles



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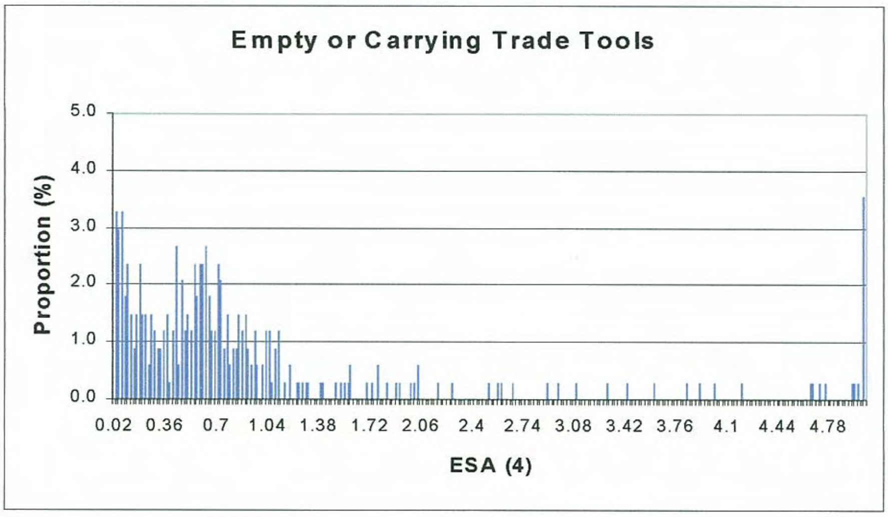

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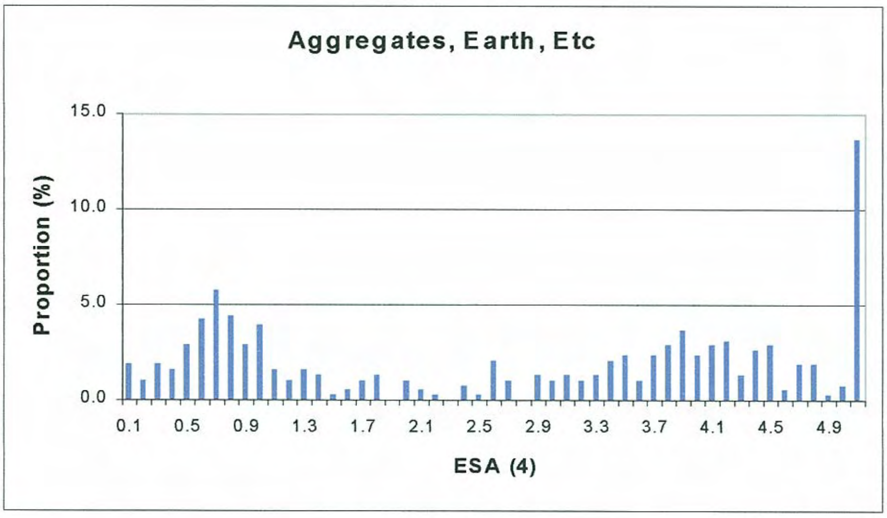
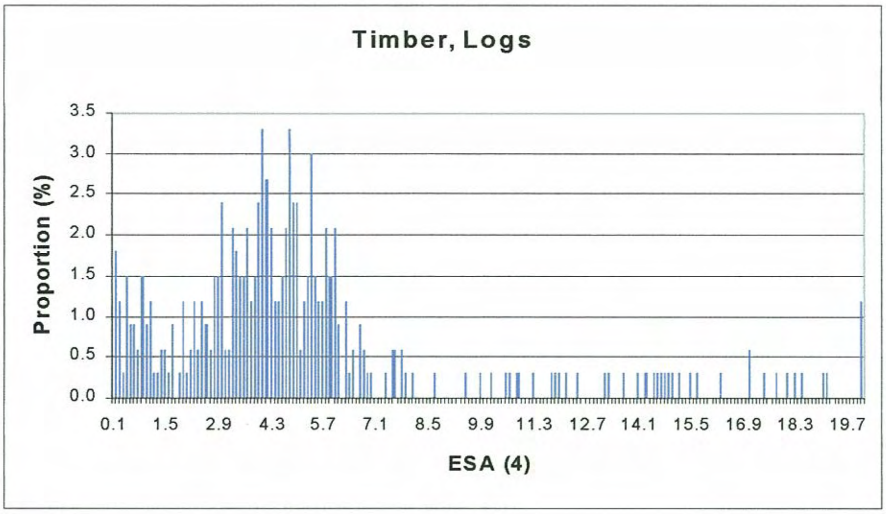


c)

Figure B1 ESA distributions for all vehicles for various commodities.



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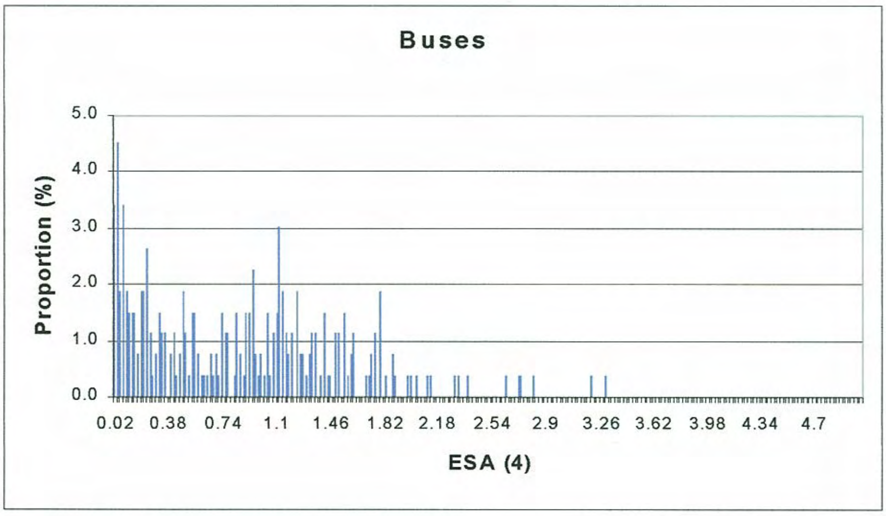


e)

Figure B1 (cont) ESA distributions for all vehicles for various commodities.

Table B1 ESA data with respect to location.

Corrected TNZ Commodity	Data	Site Name Drury	Te Puke	Tokoroa	Waipara	Grand Total
Aggregates, earth, etc	Count of Obsno	251.00	84.00	37.00	8.00	380.00
	Average of ESA4	2.71	3.46	3.25	0.96	2.90
	Average of ESA5	2.80	3.86	3.75	0.90	3.09
	Average of ESA7	3.09	5.10	5.93	0.84	3.77
	Average of ESA12	4.88	13.38	40.08	0.86	10.13
Building materials processed	Count of Obsno	52.00	15.00	19.00	10.00	96.00
	Average of ESA4	0.73	0.63	2.31	1.46	1.10
	Average of ESA5	0.66	0.56	3.48	1.45	1.28
	Average of ESA7	0.58	0.48	9.16	1.65	2.37
	Average of ESA12	0.57	0.45	146.75	4.03	29.84
Buses	Count of Obsno	170.00	36.00	15.00	44.00	265.00
	Average of ESA4	0.94	0.64	0.96	0.54	0.84
	Average of ESA5	0.88	0.56	0.89	0.48	0.77
	Average of ESA7	0.84	0.47	0.80	0.42	0.72
	Average of ESA12	1.13	0.50	0.81	0.40	0.91
Camper vans	Count of Obsno	41.00			6.00	47.00
	Average of ESA4	0.09			0.02	0.08
	Average of ESA5	0.06			0.01	0.05
	Average of ESA7	0.04			0.00	0.03
	Average of ESA12	0.02			0.00	0.02
Car haulage	Count of Obsno	102.00	17.00	22.00	11.00	152.00
	Average of ESA4	0.76	0.72	2.33	0.94	0.99
	Average of ESA5	0.64	0.62	3.04	0.80	1.00
	Average of ESA7	0.52	0.53	6.31	0.61	1.37
	Average of ESA12	0.46	0.48	74.94	0.35	11.31
Concrete - ready mixed	Count of Obsno	20.00	24.00	2.00	6.00	52.00
	Average of ESA4	1.66	1.38	5.13	0.56	1.54
	Average of ESA5	1.72	1.42	7.68	0.47	1.67
	Average of ESA7	2.00	1.66	17.95	0.36	2.27
	Average of ESA12	4.29	3.51	169.28	0.30	9.81
Construction machinery	Count of Obsno	39.00	31.00	9.00	3.00	82.00
	Average of ESA4	1.17	2.62	10.29	1.87	2.75
	Average of ESA5	1.13	3.23	18.12	1.81	3.81
	Average of ESA7	1.13	5.81	69.04	1.80	10.38
	Average of ESA12	1.57	44.10	3140.35	2.05	362.16
Containers	Count of Obsno	116.00	21.00	15.00		152.00
	Average of ESA4	1.26	2.43	1.86		1.48
	Average of ESA5	1.15	2.63	1.92		1.43
	Average of ESA7	1.05	3.45	2.23		1.50
	Average of ESA12	1.06	10.79	4.80		2.78
Courier, mail and parcels	Count of Obsno	38.00	8.00	25.00	4.00	75.00
	Average of ESA4	0.78	0.23	1.00	1.58	0.84
	Average of ESA5	0.72	0.17	0.97	1.52	0.79
	Average of ESA7	0.70	0.10	1.10	1.58	0.81
	Average of ESA12	0.88	0.04	3.18	2.42	1.64

Empty or carrying tradesmans tools	Count of Obsno	142.00	108.00	45.00	42.00	337.00
	Average of ESA4	0.65	1.24	1.53	0.89	0.99
	Average of ESA5	0.56	1.27	1.71	0.81	0.97
	Average of ESA7	0.52	1.48	2.72	0.75	1.15
	Average of ESA12	0.66	3.29	15.80	0.88	3.56
Furniture	Count of Obsno	64.00	16.00	8.00	6.00	94.00
	Average of ESA4	0.43	0.46	0.49	2.25	0.56
	Average of ESA5	0.35	0.39	0.39	2.78	0.52
	Average of ESA7	0.26	0.32	0.27	4.82	0.56
	Average of ESA12	0.19	0.28	0.12	26.66	1.89
General freight	Count of Obsno	81.00	14.00	20.00	15.00	130.00
	Average of ESA4	1.82	1.22	3.80	2.51	2.14
	Average of ESA5	1.81	1.24	4.29	2.67	2.22
	Average of ESA7	1.99	1.47	7.19	3.32	2.88
	Average of ESA12	3.85	3.24	47.49	9.05	11.13
Livestock, animals, etc	Count of Obsno	91.00	39.00	37.00	70.00	237.00
	Average of ESA4	0.94	1.08	2.63	1.82	1.49
	Average of ESA5	0.88	1.03	3.27	1.74	1.52
	Average of ESA7	0.87	1.04	5.94	1.72	1.92
	Average of ESA12	1.19	1.59	42.15	2.30	7.83
Logging trucks carrying jinkers	Count of Obsno	10.00	56.00	44.00	3.00	113.00
	Average of ESA4	1.00	1.15	1.83	1.03	1.40
	Average of ESA5	0.89	1.09	2.13	0.93	1.47
	Average of ESA7	0.76	1.08	3.34	0.82	1.93
	Average of ESA12	0.68	1.67	16.70	0.81	7.41
Machinery	Count of Obsno	54.00	33.00	13.00	9.00	109.00
	Average of ESA4	0.55	0.70	1.36	0.97	0.73
	Average of ESA5	0.47	0.68	1.64	1.00	0.72
	Average of ESA7	0.38	0.74	3.09	1.17	0.88
	Average of ESA12	0.36	1.26	28.49	2.39	4.16
Manufactured foodstuffs	Count of Obsno	87.00	35.00	31.00	24.00	177.00
	Average of ESA4	0.93	0.77	1.74	1.14	1.07
	Average of ESA5	0.86	0.72	2.02	1.11	1.07
	Average of ESA7	0.81	0.70	3.30	1.12	1.27
	Average of ESA12	1.19	0.89	21.42	1.73	4.76
Meat, fish and frozen foods	Count of Obsno	111.00	47.00	20.00	30.00	208.00
	Average of ESA4	0.99	1.36	1.96	2.06	1.32
	Average of ESA5	0.95	1.40	2.32	2.13	1.35
	Average of ESA7	0.98	1.60	4.01	2.44	1.62
	Average of ESA12	1.75	2.96	32.76	4.57	5.41
Metals and scrap	Count of Obsno	45.00	6.00	6.00	1.00	58.00
	Average of ESA4	1.49	1.24	1.39	0.11	1.43
	Average of ESA5	1.48	1.18	1.26	0.05	1.40
	Average of ESA7	1.60	1.18	1.10	0.01	1.48
	Average of ESA12	2.88	1.52	0.97	0.00	2.49
Milk	Count of Obsno	23.00	22.00	76.00	17.00	138.00
	Average of ESA4	2.07	2.85	2.94	1.89	2.65
	Average of ESA5	2.04	2.78	3.30	1.77	2.82
	Average of ESA7	2.15	2.83	4.63	1.63	3.56
	Average of ESA12	3.08	4.09	15.48	1.60	9.89

NO LOAD DESCRIPTION	Count of Obsno	1499.00	984.00	562.00	406.00	3451.00
	Average of ESA4	1.02	1.28	2.95	1.24	1.43
	Average of ESA5	0.97	1.32	3.73	1.24	1.55
	Average of ESA7	0.99	1.58	6.98	1.47	2.18
	Average of ESA12	1.66	3.78	54.42	4.61	11.17
Other liquids	Count of Obsno	178.00	70.00	42.00	25.00	315.00
	Average of ESA4	1.65	1.97	2.73	2.10	1.90
	Average of ESA5	1.67	2.10	3.54	2.31	2.07
	Average of ESA7	1.84	2.56	7.10	2.97	2.79
	Average of ESA12	3.06	5.31	73.70	7.04	13.29
Other manufactured products	Count of Obsno	28.00	7.00	1.00	3.00	39.00
	Average of ESA4	0.30	0.09	0.24	0.10	0.24
	Average of ESA5	0.23	0.04	0.15	0.05	0.18
	Average of ESA7	0.15	0.01	0.05	0.01	0.11
	Average of ESA12	0.09	0.00	0.00	0.00	0.07
Paper, pulp and cardboard	Count of Obsno	7.00	1.00	3.00	2.00	13.00
	Average of ESA4	0.71	0.16	5.96	0.03	1.77
	Average of ESA5	0.65	0.09	8.62	0.01	2.35
	Average of ESA7	0.63	0.03	18.71	0.00	4.66
	Average of ESA12	0.80	0.00	141.91	0.00	33.18
Plants, fruit, vegetables, etc	Count of Obsno	27.00	16.00	4.00	1.00	48.00
	Average of ESA4	1.13	1.31	0.41	0.81	1.12
	Average of ESA5	1.09	1.31	0.32	0.65	1.09
	Average of ESA7	1.12	1.40	0.24	0.44	1.13
	Average of ESA12	1.64	2.12	0.17	0.20	1.65
Powdered goods	Count of Obsno	46.00	24.00	12.00	11.00	93.00
	Average of ESA4	1.67	1.66	3.50	2.18	1.97
	Average of ESA5	1.63	1.63	4.74	2.28	2.11
	Average of ESA7	1.74	1.70	10.04	2.65	2.91
	Average of ESA12	2.73	2.35	101.97	4.92	15.70
Prefabricated structural components	Count of Obsno	21.00	4.00	3.00	1.00	29.00
	Average of ESA4	1.79	0.37	5.01	3.75	2.00
	Average of ESA5	1.71	0.30	6.69	3.86	2.10
	Average of ESA7	1.75	0.23	13.57	4.29	2.85
	Average of ESA12	2.76	0.18	120.00	6.76	14.67
Rubbish	Count of Obsno	33.00	25.00	3.00	10.00	71.00
	Average of ESA4	1.30	1.42	1.75	1.39	1.38
	Average of ESA5	1.27	1.51	1.85	1.63	1.43
	Average of ESA7	1.34	1.89	2.36	2.79	1.78
	Average of ESA12	2.26	4.60	6.10	19.02	5.61
Sawdust and wood waste	Count of Obsno	1.00	18.00	15.00		34.00
	Average of ESA4	0.03	2.74	2.74		2.66
	Average of ESA5	0.01	2.82	2.83		2.74
	Average of ESA7	0.00	3.22	3.23		3.13
	Average of ESA12	0.00	5.62	6.02		5.63
Stock food, grain, seeds, etc	Count of Obsno	10.00	2.00	2.00	6.00	20.00
	Average of ESA4	1.88	0.87	1.81	1.38	1.62
	Average of ESA5	1.89	0.74	1.73	1.36	1.60
	Average of ESA7	2.04	0.58	1.79	1.43	1.69
	Average of ESA12	3.11	0.37	2.87	2.03	2.49

Timber, logs	Count of Obsno	36.00	117.00	148.00	33.00	334.00
	Average of ESA4	3.23	4.54	6.69	2.80	5.18
	Average of ESA5	3.33	5.04	8.88	2.92	6.36
	Average of ESA7	3.75	6.53	18.02	3.41	11.04
	Average of ESA12	6.43	15.75	172.47	6.77	83.53
Timber, processed	Count of Obsno	79.00	77.00	55.00	12.00	223.00
	Average of ESA4	1.60	2.69	4.00	1.09	2.54
	Average of ESA5	1.58	2.86	4.85	1.02	2.80
	Average of ESA7	1.83	3.51	8.11	1.00	3.92
	Average of ESA12	7.12	8.67	48.96	1.46	17.67
Wool, hides	Count of Obsno	2.00	1.00		2.00	5.00
	Average of ESA4	2.07	0.61		0.45	1.13
	Average of ESA5	1.86	0.47		0.35	0.98
	Average of ESA7	1.56	0.28		0.23	0.77
	Average of ESA12	1.26	0.08		0.09	0.56
Total Count of Obsno		3504.00	1958.00	1294.00	821.00	7577.00
Total Average of ESA4		1.20	1.65	3.22	1.38	1.68
Total Average of ESA5		1.16	1.74	4.07	1.38	1.83
Total Average of ESA7		1.20	2.13	7.80	1.58	2.61
Total Average of ESA12		2.00	5.43	81.67	4.08	16.70

APPENDIX C

ESA Data With Respect to Commodities and Number of Axles

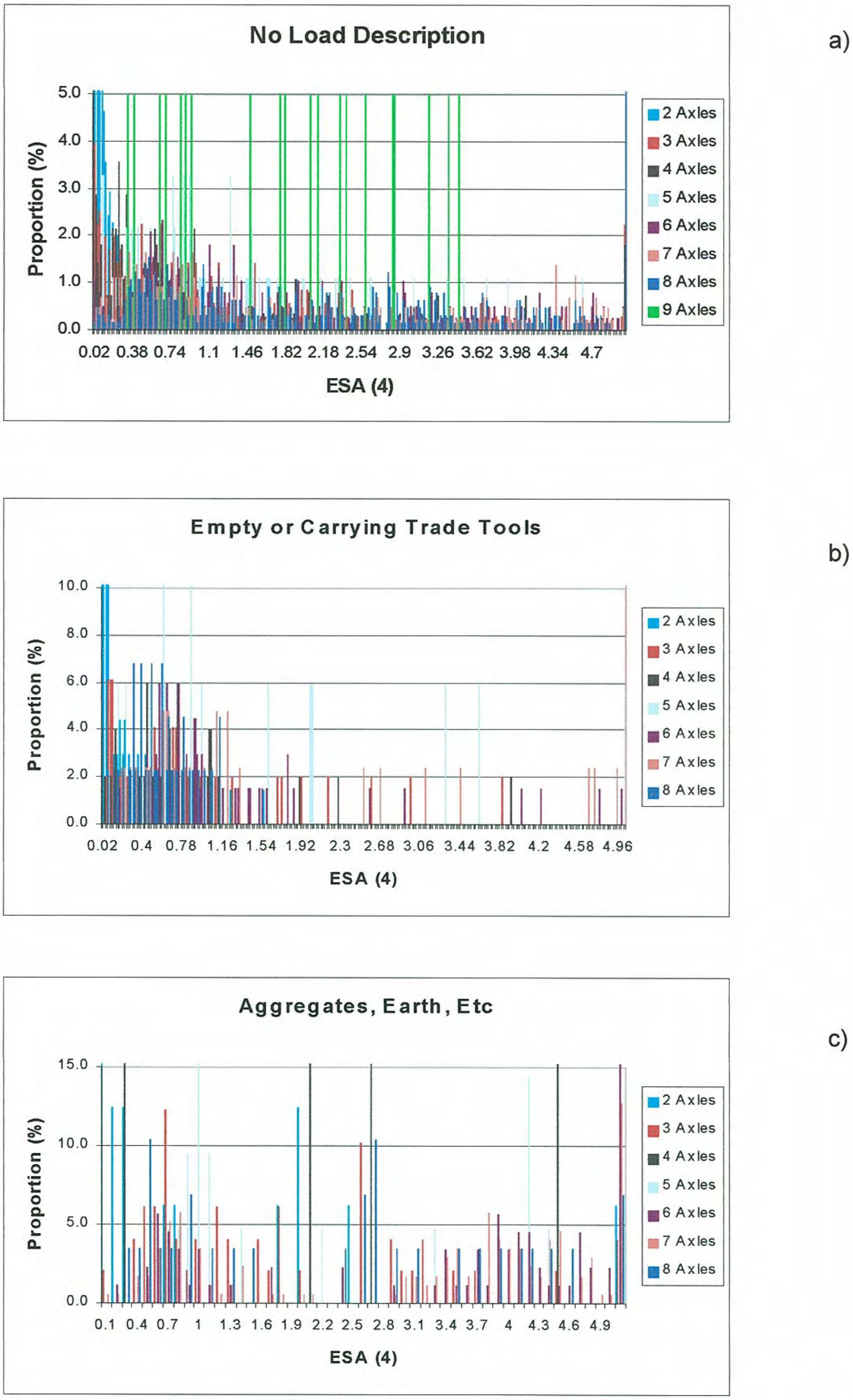
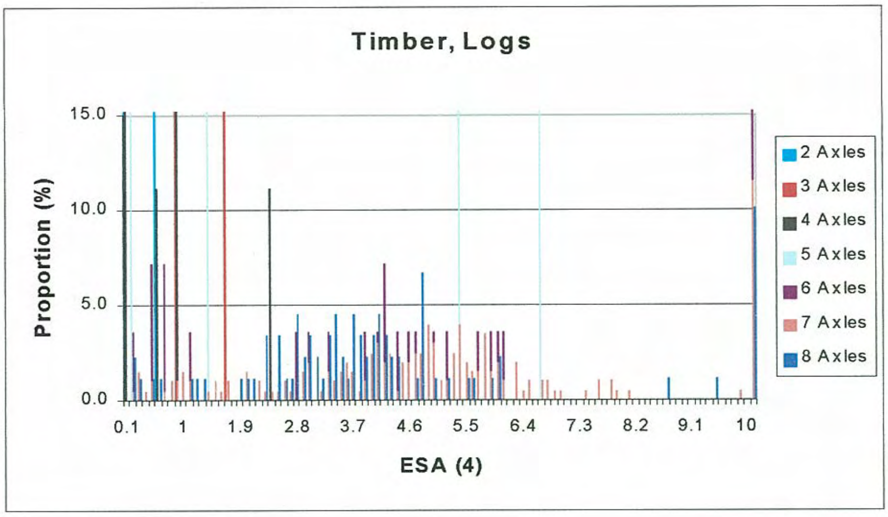


Figure C1 ESA[4] distributions with respect to number of axles for various commodities.



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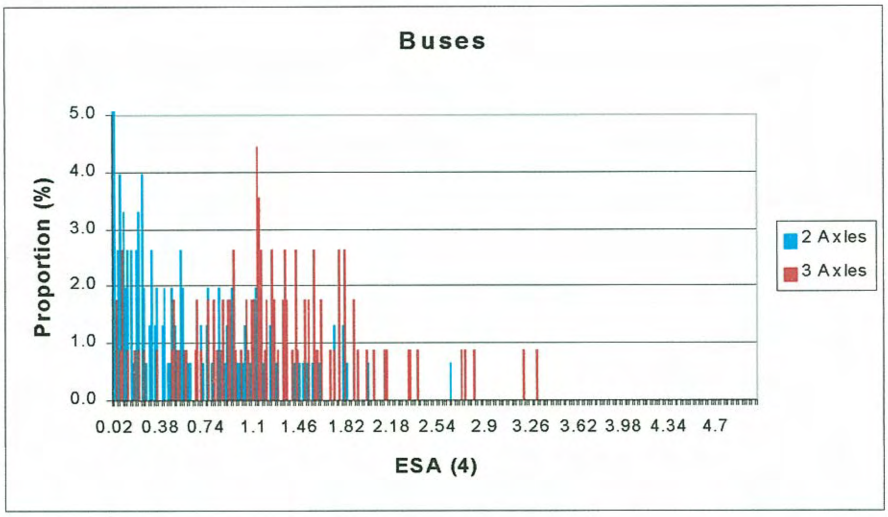

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Figure C1 (cont) ESA[4] distributions with respect to number of axles for various commodities.

Table C1 ESA data with respect to axle numbers.

Corrected TNZ Commodity	Data	Axles								Grand Total
		2	3	4	5	6	7	8	9	
Aggregates, earth, etc	Count of Obsno	16.00	49.00	4.00	21.00	88.00	173.00	29.00		380.00
	Average of ESA4	1.07	1.69	2.37	2.27	3.66	3.19	2.36		2.90
	Average of ESA5	1.19	1.84	2.70	2.37	3.99	3.39	2.33		3.09
	Average of ESA7	1.66	2.39	3.66	2.81	4.86	4.16	2.41		3.77
	Average of ESA12	6.16	6.32	8.64	5.81	9.93	13.35	3.50		10.13
Building materials processed	Count of Obsno	48.00	9.00	9.00	1.00	10.00	8.00	11.00		96.00
	Average of ESA4	0.16	0.93	0.32	1.03	4.49	2.49	1.91		1.10
	Average of ESA5	0.11	0.85	0.23	0.82	6.72	2.45	1.86		1.28
	Average of ESA7	0.06	0.74	0.13	0.57	17.46	2.51	1.98		2.37
	Average of ESA12	0.02	0.66	0.05	0.29	278.61	3.14	4.15		29.84
Buses	Count of Obsno	152.00	113.00							265.00
	Average of ESA4	0.56	1.21							0.84
	Average of ESA5	0.46	1.18							0.77
	Average of ESA7	0.35	1.22							0.72
	Average of ESA12	0.24	1.80							0.91
Camper vans	Count of Obsno	45.00	2.00							47.00
	Average of ESA4	0.05	0.61							0.08
	Average of ESA5	0.03	0.55							0.05
	Average of ESA7	0.01	0.47							0.03
	Average of ESA12	0.00	0.35							0.02
Car haulage	Count of Obsno	32.00	21.00	42.00	29.00	24.00	3.00	1.00		152.00
	Average of ESA4	0.24	0.38	0.92	2.19	1.03	2.79	0.35		0.99
	Average of ESA5	0.17	0.27	0.81	2.66	0.88	2.76	0.22		1.00
	Average of ESA7	0.09	0.16	0.70	5.03	0.74	2.83	0.10		1.37
	Average of ESA12	0.03	0.06	0.81	56.57	0.84	3.69	0.02		11.31
Concrete - ready mixed	Count of Obsno	2.00	35.00	3.00		2.00	10.00			52.00
	Average of ESA4	0.51	1.27	0.68		5.84	2.08			1.54
	Average of ESA5	0.39	1.38	0.60		7.04	2.15			1.67
	Average of ESA7	0.23	2.00	0.50		10.46	2.51			2.27
	Average of ESA12	0.07	11.15	0.41		31.21	5.64			9.81
Construction machinery	Count of Obsno	16.00	11.00	9.00	11.00	27.00	5.00	3.00		82.00
	Average of ESA4	0.17	0.91	1.61	1.95	4.50	7.85	5.25		2.75
	Average of ESA5	0.10	0.98	1.65	2.15	6.99	10.96	5.97		3.81
	Average of ESA7	0.05	1.30	1.86	3.06	23.72	24.12	8.13		10.38
	Average of ESA12	0.01	3.57	3.23	12.62	1046.27	235.31	21.51		362.16
Containers	Count of Obsno	5.00	5.00	5.00	9.00	83.00	10.00	35.00		152.00
	Average of ESA4	0.65	0.83	0.92	1.83	1.71	1.48	1.13		1.48
	Average of ESA5	0.55	0.74	0.84	1.91	1.69	1.41	1.02		1.43

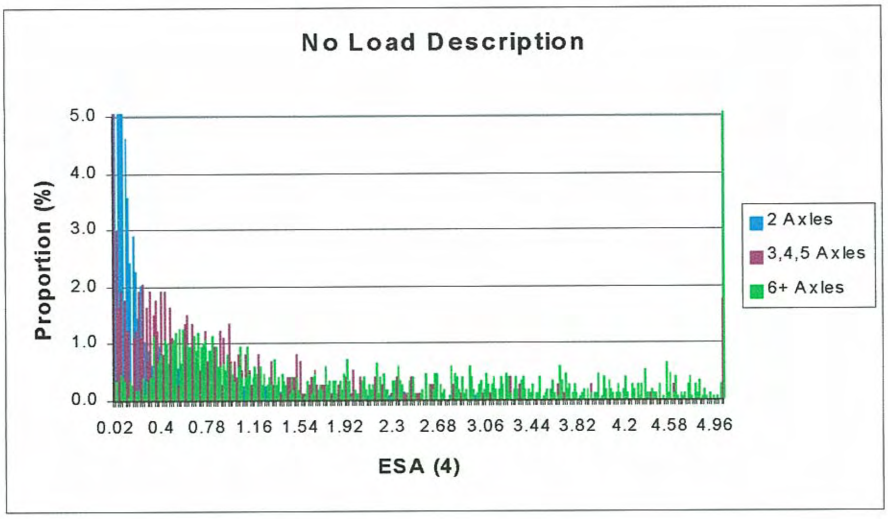
	Average of ESA7	0.43	0.67	0.78	2.36	1.82	1.40	0.89		1.50
	Average of ESA12	0.30	0.81	0.83	6.34	3.72	1.85	0.81		2.78
Courier, mail and parcels	Count of Obsno	28.00	9.00	2.00	2.00	14.00		15.00	5.00	75.00
	Average of ESA4	0.28	0.55	0.24	2.00	1.31		0.96	2.52	0.84
	Average of ESA5	0.22	0.45	0.16	2.10	1.26		0.83	2.87	0.79
	Average of ESA7	0.16	0.32	0.07	2.49	1.25		0.68	4.21	0.81
	Average of ESA12	0.12	0.18	0.01	4.51	1.61		0.58	15.56	1.64
Empty or carrying tradesmans tools	Count of Obsno	68.00	49.00	50.00	17.00	67.00	42.00	44.00		337.00
	Average of ESA4	0.31	0.77	1.04	1.52	1.34	1.95	0.54		0.99
	Average of ESA5	0.28	0.74	1.12	1.65	1.24	2.05	0.45		0.97
	Average of ESA7	0.31	0.74	1.68	2.33	1.30	2.50	0.33		1.15
	Average of ESA12	0.78	1.08	10.62	10.34	2.08	5.61	0.21		3.56
Furniture	Count of Obsno	62.00	12.00	13.00		2.00	1.00	4.00		94.00
	Average of ESA4	0.29	0.81	1.09		1.31	0.80	1.76		0.56
	Average of ESA5	0.22	0.72	1.27		1.26	0.63	1.59		0.52
	Average of ESA7	0.15	0.62	2.12		1.20	0.41	1.35		0.56
	Average of ESA12	0.10	0.57	12.12		1.16	0.14	1.11		1.89
General freight	Count of Obsno	3.00	2.00	7.00		14.00	63.00	41.00		130.00
	Average of ESA4	0.06	2.64	1.44		2.99	2.27	1.90		2.14
	Average of ESA5	0.03	3.21	1.20		3.44	2.32	1.92		2.22
	Average of ESA7	0.01	4.98	1.21		5.48	2.95	2.23		2.88
	Average of ESA12	0.00	16.83	1.45		33.89	10.63	6.07		11.13
Livestock, animals, etc	Count of Obsno	84.00	23.00	29.00	6.00	10.00	16.00	69.00		237.00
	Average of ESA4	0.30	0.60	1.43	1.15	1.97	2.04	3.08		1.49
	Average of ESA5	0.24	0.50	1.64	1.03	1.67	2.09	3.28		1.52
	Average of ESA7	0.20	0.37	2.70	0.90	1.64	2.19	4.28		1.92
	Average of ESA12	0.29	0.24	19.90	0.79	1.95	3.42	16.90		7.83
Logging trucks carrying jinkers	Count of Obsno	1.00	67.00	43.00				2.00		113.00
	Average of ESA4	0.07	1.71	0.95				1.02		1.40
	Average of ESA5	0.03	1.89	0.89				0.81		1.47
	Average of ESA7	0.01	2.65	0.90				0.55		1.93
	Average of ESA12	0.00	11.28	1.90				0.29		7.41
Machinery	Count of Obsno	49.00	21.00	21.00	6.00	8.00	3.00	1.00		109.00
	Average of ESA4	0.52	0.41	0.56	0.95	2.63	1.66	1.91		0.73
	Average of ESA5	0.52	0.34	0.50	0.89	2.82	1.61	2.08		0.72
	Average of ESA7	0.82	0.28	0.47	0.82	3.44	1.67	2.62		0.88
	Average of ESA12	7.38	0.29	0.66	0.79	6.81	2.42	5.11		4.16
Manufactured foodstuffs	Count of Obsno	62.00	23.00	14.00	4.00	42.00	2.00	25.00	5.00	177.00
	Average of ESA4	0.32	0.70	1.74	2.19	1.23	0.93	2.01	3.34	1.07
	Average of ESA5	0.27	0.63	2.05	2.67	1.12	0.74	1.93	4.05	1.07
	Average of ESA7	0.25	0.58	3.62	4.64	1.02	0.50	1.91	6.66	1.27
	Average of ESA12	0.47	0.66	30.80	27.19	1.08	0.22	2.54	29.10	4.76
Meat, fish and frozen foods	Count of Obsno	71.00	30.00	5.00	9.00	84.00	3.00	6.00		208.00

	Average of ESA4	0.41	1.46	0.67	1.16	1.97	2.59	2.53		1.32
	Average of ESA5	0.36	1.71	0.56	1.04	2.01	2.81	2.61		1.35
	Average of ESA7	0.32	2.84	0.42	0.89	2.26	3.73	3.15		1.62
	Average of ESA12	0.43	21.79	0.25	0.73	4.13	11.04	8.92		5.41
Metals and scrap	Count of Obsno	12.00	8.00	8.00	6.00	12.00	5.00	7.00		58.00
	Average of ESA4	0.51	0.97	0.58	1.95	2.15	2.37	2.18		1.43
	Average of ESA5	0.52	0.93	0.44	2.15	2.16	2.30	1.96		1.40
	Average of ESA7	0.68	0.95	0.27	2.87	2.32	2.25	1.62		1.48
	Average of ESA12	2.20	1.37	0.11	7.57	3.43	2.40	1.11		2.49
Milk	Count of Obsno	4.00	1.00		3.00	28.00	81.00	21.00		138.00
	Average of ESA4	0.19	0.83		0.45	2.17	3.19	2.08		2.65
	Average of ESA5	0.11	0.69		0.36	2.31	3.46	1.96		2.82
	Average of ESA7	0.05	0.50		0.25	3.12	4.49	1.85		3.56
	Average of ESA12	0.01	0.25		0.13	11.87	12.23	1.96		9.89
NO LOAD DESCRIPTION	Count of Obsno	1235.00	356.00	281.00	92.00	388.00	432.00	647.00	20.00	3451.00
	Average of ESA4	0.26	0.98	0.72	1.16	2.27	3.52	2.37	1.82	1.43
	Average of ESA5	0.23	1.02	0.73	1.06	2.44	4.20	2.48	1.88	1.55
	Average of ESA7	0.25	1.37	1.03	1.02	3.26	6.99	3.13	2.25	2.18
	Average of ESA12	1.12	5.89	6.76	1.37	13.54	47.44	11.10	4.79	11.17
Other liquids	Count of Obsno	31.00	43.00	21.00	19.00	119.00	49.00	33.00		315.00
	Average of ESA4	0.26	1.43	0.91	1.86	2.65	1.88	2.08		1.90
	Average of ESA5	0.20	1.50	0.88	1.95	3.05	1.93	2.05		2.07
	Average of ESA7	0.15	1.78	0.94	2.40	4.64	2.26	2.15		2.79
	Average of ESA12	0.11	3.64	1.76	6.28	29.73	4.51	3.41		13.29
Other manufactured products	Count of Obsno	30.00	3.00	3.00		1.00	1.00	1.00		39.00
	Average of ESA4	0.15	0.34	0.38		0.41	0.24	2.16		0.24
	Average of ESA5	0.11	0.22	0.26		0.29	0.14	1.87		0.18
	Average of ESA7	0.07	0.10	0.13		0.15	0.05	1.44		0.11
	Average of ESA12	0.06	0.02	0.02		0.04	0.00	0.82		0.07
Paper, pulp and cardboard	Count of Obsno	11.00			1.00		1.00			13.00
	Average of ESA4	0.16	.		17.45		3.82			1.77
	Average of ESA5	0.10			25.61		3.88			2.35
	Average of ESA7	0.04			56.03		4.15			4.66
	Average of ESA12	0.00			425.73		5.58			33.18
Plants, fruit, vegetables, etc	Count of Obsno	19.00	8.00	1.00	3.00	7.00	5.00	5.00		48.00
	Average of ESA4	0.35	0.80	2.28	2.15	1.64	2.69	1.44		1.12
	Average of ESA5	0.30	0.81	2.45	2.23	1.58	2.58	1.39		1.09
	Average of ESA7	0.26	0.98	2.93	2.60	1.58	2.53	1.39		1.13
	Average of ESA12	0.27	2.30	5.18	4.56	2.03	2.76	1.70		1.65
Powdered goods	Count of Obsno	12.00	7.00	6.00	2.00	25.00	27.00	14.00		93.00
	Average of ESA4	0.31	0.98	1.49	2.62	2.74	2.51	1.57		1.97
	Average of ESA5	0.22	1.01	1.34	1.52	3.31	2.65	1.50		2.11
	Average of ESA7	0.12	1.26	1.14	1.44	5.68	3.25	1.48		2.91

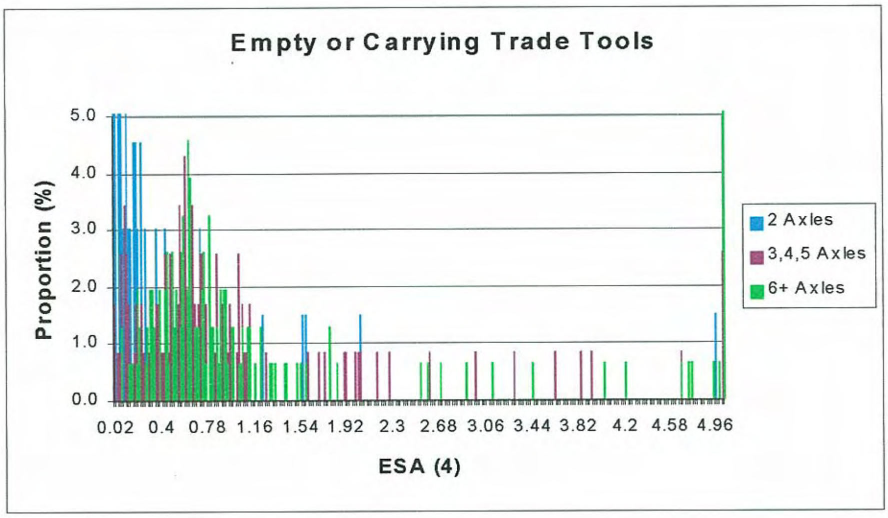
	Average of ESA12	0.04	3.44	0.94	1.34	47.21	8.20	1.80		15.70
Prefabricated structural components	Count of Obsno	3.00	6.00	1.00		3.00	1.00	15.00		29.00
	Average of ESA4	3.42	0.32	0.38		3.65	5.01	1.96		2.00
	Average of ESA5	4.97	0.25	0.30		3.56	5.51	1.87		2.10
	Average of ESA7	11.52	0.18	0.18		4.08	6.94	1.84		2.85
	Average of ESA12	116.49	0.12	0.06		8.43	14.84	2.34		14.67
Rubbish	Count of Obsno	25.00	26.00	3.00	1.00	2.00	6.00	8.00		71.00
	Average of ESA4	0.62	1.47	1.02	0.85	3.82	2.68	2.05		1.38
	Average of ESA5	0.57	1.52	0.93	0.74	5.18	2.91	2.03		1.43
	Average of ESA7	0.58	1.81	0.82	0.62	10.96	3.74	2.14		1.78
	Average of ESA12	1.14	4.04	0.76	0.43	90.78	9.23	3.12		5.61
Sawdust and wood waste	Count of Obsno	2.00	1.00	1.00			21.00	9.00		34.00
	Average of ESA4	0.22	0.03	0.16			2.91	3.18		2.66
	Average of ESA5	0.14	0.01	0.08			3.02	3.27		2.74
	Average of ESA7	0.06	0.00	0.02			3.53	3.59		3.13
	Average of ESA12	0.01	0.00	0.00			6.77	5.47		5.63
Stock food, grain, seeds, etc	Count of Obsno	3.00	2.00		1.00	8.00	1.00	5.00		20.00
	Average of ESA4	0.15	1.44		0.44	1.81	2.29	2.38		1.62
	Average of ESA5	0.08	1.43		0.34	1.80	2.44	2.36		1.60
	Average of ESA7	0.03	1.51		0.21	1.87	2.94	2.51		1.69
	Average of ESA12	0.00	2.15		0.07	2.46	5.50	4.05		2.49
Timber, logs	Count of Obsno	2.00	2.00	9.00	4.00	28.00	200.00	89.00		334.00
	Average of ESA4	0.30	1.26	2.02	3.40	5.48	5.67	4.59		5.18
	Average of ESA5	0.22	1.22	2.82	4.20	7.11	6.99	5.42		6.36
	Average of ESA7	0.13	1.17	6.82	7.18	13.24	12.25	8.70		11.04
	Average of ESA12	0.04	1.11	85.69	40.30	107.61	95.74	54.25		83.53
Timber, processed	Count of Obsno	43.00	10.00	9.00	4.00	23.00	48.00	85.00	1.00	223.00
	Average of ESA4	0.31	1.15	0.47	1.21	2.95	4.17	3.05	5.83	2.54
	Average of ESA5	0.24	1.16	0.36	1.09	3.33	4.83	3.27	7.83	2.80
	Average of ESA7	0.18	1.38	0.23	0.92	4.83	7.35	4.31	15.57	3.92
	Average of ESA12	0.14	3.83	0.10	0.68	24.45	37.25	16.94	103.06	17.67
Wool, hides	Count of Obsno	3.00						2.00		5.00
	Average of ESA4	0.50						2.07		1.13
	Average of ESA5	0.39						1.86		0.98
	Average of ESA7	0.24						1.56		0.77
	Average of ESA12	0.09						1.26		0.56
Total Count of Obsno		2179.00	954.00	599.00	251.00	1119.00	1217.00	1227.00	31.00	7577.00
Total Average of ESA4		0.31	1.09	0.89	1.66	2.41	3.54	2.45	2.31	1.68
Total Average of ESA5		0.27	1.13	0.91	1.75	2.67	4.11	2.58	2.58	1.83
Total Average of ESA7		0.28	1.42	1.26	2.39	4.02	6.39	3.30	3.71	2.61
Total Average of ESA12		1.13	5.18	7.76	12.66	42.57	39.25	12.70	13.62	16.70

Appendix D

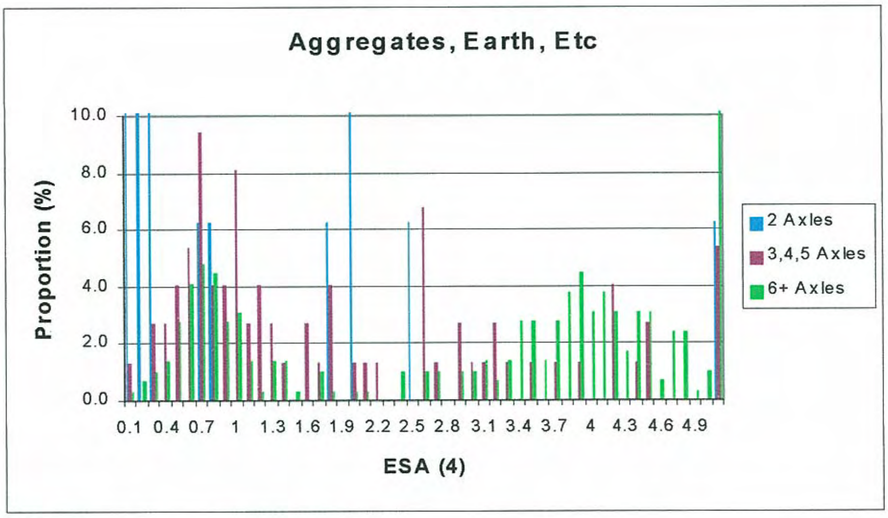
ESA Data With Respect to Commodity and Revised Axle Groupings



a)

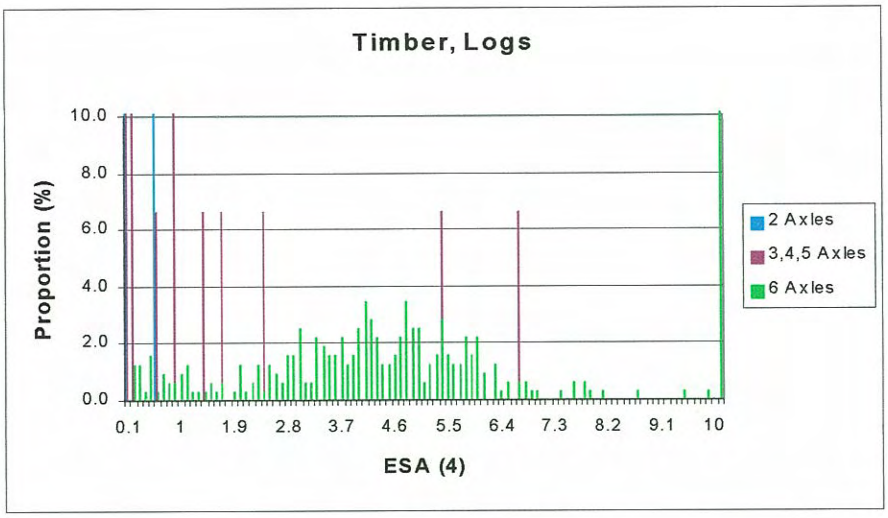


b)

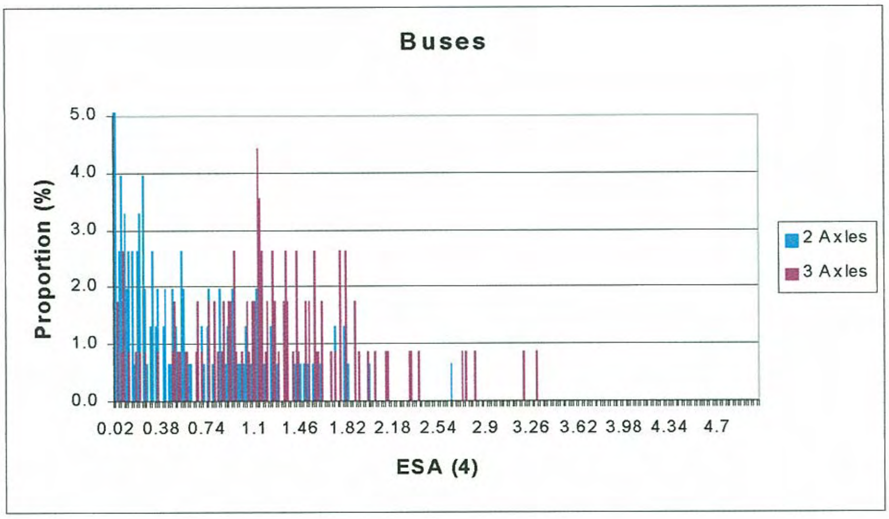


c)

Figure D1 ESA^4 distributions with respect to number of axles for various commodities.



d)



e)

Figure D1 (cont) ESA[4] distributions with respect to number of axles for various commodities.

Table D1 ESA data with respect to (revised) axle numbers.

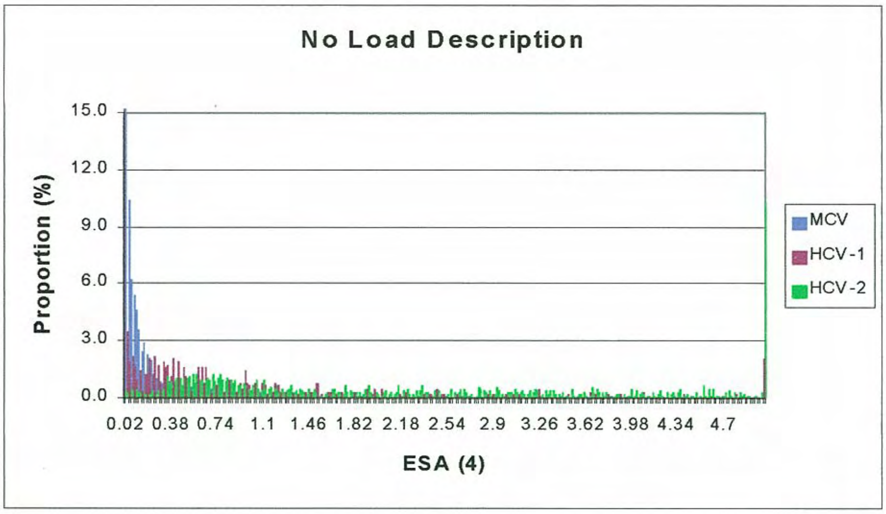
Corrected TNZ Commodity	Data	Revised Axles 2 Axles	3,4,5 Axles	6+ Axles	Grand Total
Aggregates, earth, etc	Count of Obsno	16.00	74.00	290.00	380.00
	Average of ESA4	1.07	1.89	3.25	2.90
	Average of ESA5	1.19	2.04	3.46	3.09
	Average of ESA7	1.66	2.58	4.19	3.77
	Average of ESA12	6.16	6.30	11.34	10.13
Building materials processed	Count of Obsno	48.00	19.00	29.00	96.00
	Average of ESA4	0.16	0.64	2.96	1.10
	Average of ESA5	0.11	0.55	3.70	1.28
	Average of ESA7	0.06	0.45	7.47	2.37
	Average of ESA12	0.02	0.35	98.51	29.84
Buses	Count of Obsno	152.00	113.00		265.00
	Average of ESA4	0.56	1.21		0.84
	Average of ESA5	0.46	1.18		0.77
	Average of ESA7	0.35	1.22		0.72
	Average of ESA12	0.24	1.80		0.91
Camper vans	Count of Obsno	45.00	2.00		47.00
	Average of ESA4	0.05	0.61		0.08
	Average of ESA5	0.03	0.55		0.05
	Average of ESA7	0.01	0.47		0.03
	Average of ESA12	0.00	0.35		0.02
Car haulage	Count of Obsno	32.00	92.00	28.00	152.00
	Average of ESA4	0.24	1.19	1.20	0.99
	Average of ESA5	0.17	1.27	1.06	1.00
	Average of ESA7	0.09	1.95	0.94	1.37
	Average of ESA12	0.03	18.41	1.12	11.31
Concrete - ready mixed	Count of Obsno	2.00	38.00	12.00	52.00
	Average of ESA4	0.51	1.22	2.71	1.54
	Average of ESA5	0.39	1.32	2.97	1.67
	Average of ESA7	0.23	1.88	3.84	2.27
	Average of ESA12	0.07	10.30	9.90	9.81
Construction machinery	Count of Obsno	16.00	31.00	35.00	82.00
	Average of ESA4	0.17	1.48	5.04	2.75
	Average of ESA5	0.10	1.59	7.47	3.81
	Average of ESA7	0.05	2.09	22.44	10.38
	Average of ESA12	0.01	6.68	842.58	362.16
Containers	Count of Obsno	5.00	19.00	128.00	152.00
	Average of ESA4	0.65	1.33	1.53	1.48
	Average of ESA5	0.55	1.32	1.48	1.43
	Average of ESA7	0.43	1.50	1.54	1.50
	Average of ESA12	0.30	3.44	2.78	2.78
Courier, mail and parcels	Count of Obsno	28.00	13.00	34.00	75.00
	Average of ESA4	0.28	0.72	1.33	0.84
	Average of ESA5	0.22	0.66	1.30	0.79
	Average of ESA7	0.16	0.62	1.43	0.81
	Average of ESA12	0.12	0.82	3.20	1.64
Empty or carrying trade tools	Count of Obsno	68.00	116.00	153.00	337.00
	Average of ESA4	0.31	1.00	1.28	0.99
	Average of ESA5	0.28	1.04	1.24	0.97
	Average of ESA7	0.31	1.38	1.35	1.15
	Average of ESA12	0.78	6.60	2.51	3.56
Furniture	Count of Obsno	62.00	25.00	7.00	94.00
	Average of ESA4	0.29	0.95	1.50	0.56
	Average of ESA5	0.22	1.00	1.36	0.52
	Average of ESA7	0.15	1.40	1.17	0.56
	Average of ESA12	0.10	6.58	0.99	1.89

General freight	Count of Obsno	3.00	9.00	118.00	130.00
	Average of ESA4	0.06	1.70	2.23	2.14
	Average of ESA5	0.03	1.70	2.32	2.22
	Average of ESA7	0.01	2.16	3.00	2.88
	Average of ESA12	0.00	5.30	11.81	11.13
Livestock, animals, etc	Count of Obsno	84.00	58.00	95.00	237.00
	Average of ESA4	0.30	1.08	2.79	1.49
	Average of ESA5	0.24	1.12	2.92	1.52
	Average of ESA7	0.20	1.59	3.66	1.92
	Average of ESA12	0.29	10.13	13.16	7.83
Logging trucks carrying jinkers	Count of Obsno	1.00	110.00	2.00	113.00
	Average of ESA4	0.07	1.41	1.02	1.40
	Average of ESA5	0.03	1.50	0.81	1.47
	Average of ESA7	0.01	1.97	0.55	1.93
	Average of ESA12	0.00	7.61	0.29	7.41
Machinery	Count of Obsno	49.00	48.00	12.00	109.00
	Average of ESA4	0.52	0.54	2.33	0.73
	Average of ESA5	0.52	0.48	2.45	0.72
	Average of ESA7	0.82	0.43	2.93	0.88
	Average of ESA12	7.38	0.51	5.57	4.16
Manufactured foodstuffs	Count of Obsno	62.00	41.00	74.00	177.00
	Average of ESA4	0.32	1.20	1.63	1.07
	Average of ESA5	0.27	1.32	1.58	1.07
	Average of ESA7	0.25	2.01	1.69	1.27
	Average of ESA12	0.47	13.54	3.44	4.76
Meat, fish and frozen foods	Count of Obsno	71.00	44.00	93.00	208.00
	Average of ESA4	0.41	1.31	2.03	1.32
	Average of ESA5	0.36	1.44	2.07	1.35
	Average of ESA7	0.32	2.17	2.36	1.62
	Average of ESA12	0.43	15.04	4.66	5.41
Metals and scrap	Count of Obsno	12.00	22.00	24.00	58.00
	Average of ESA4	0.51	1.10	2.20	1.43
	Average of ESA5	0.52	1.09	2.13	1.40
	Average of ESA7	0.68	1.23	2.10	1.48
	Average of ESA12	2.20	2.60	2.54	2.49
Milk	Count of Obsno	4.00	4.00	130.00	138.00
	Average of ESA4	0.19	0.55	2.79	2.65
	Average of ESA5	0.11	0.44	2.97	2.82
	Average of ESA7	0.05	0.31	3.77	3.56
	Average of ESA12	0.01	0.16	10.49	9.89
NO LOAD DESCRIPTION	Count of Obsno	1235.00	729.00	1487.00	3451.00
	Average of ESA4	0.26	0.90	2.67	1.43
	Average of ESA5	0.23	0.92	2.96	1.55
	Average of ESA7	0.25	1.20	4.27	2.18
	Average of ESA12	1.12	5.65	22.20	11.17
Other liquids	Count of Obsno	31.00	83.00	201.00	315.00
	Average of ESA4	0.26	1.40	2.36	1.90
	Average of ESA5	0.20	1.44	2.61	2.07
	Average of ESA7	0.15	1.70	3.65	2.79
	Average of ESA12	0.11	3.77	19.26	13.29
Other manufactured products	Count of Obsno	30.00	6.00	3.00	39.00
	Average of ESA4	0.15	0.36	0.93	0.24
	Average of ESA5	0.11	0.24	0.77	0.18
	Average of ESA7	0.07	0.11	0.55	0.11
	Average of ESA12	0.06	0.02	0.29	0.07
Paper, pulp and cardboard	Count of Obsno	11.00	1.00	1.00	13.00
	Average of ESA4	0.16	17.45	3.82	1.77
	Average of ESA5	0.10	25.61	3.88	2.35
	Average of ESA7	0.04	56.03	4.15	4.66
	Average of ESA12	0.00	425.73	5.58	33.18

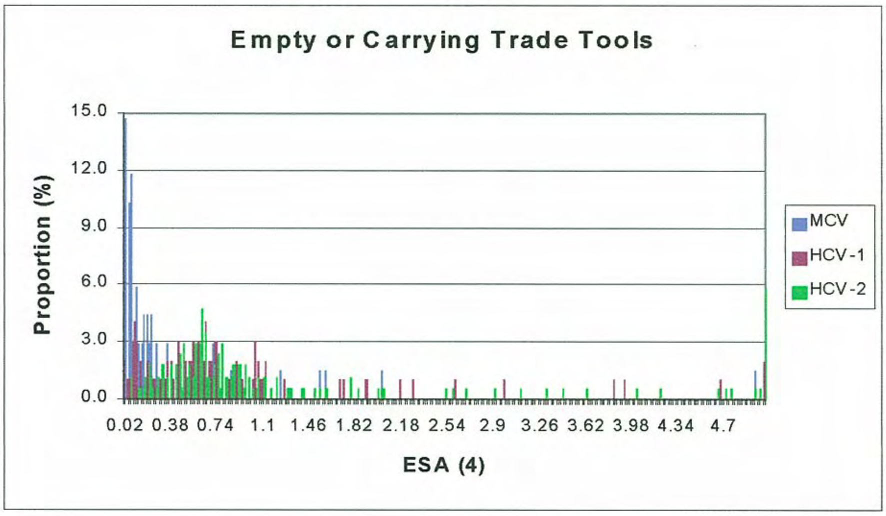
Plants, fruit, vegetables, etc	Count of Obsno	19.00	12.00	17.00	48.00
	Average of ESA4	0.35	1.26	1.89	1.12
	Average of ESA5	0.30	1.31	1.82	1.09
	Average of ESA7	0.26	1.54	1.80	1.13
	Average of ESA12	0.27	3.11	2.15	1.65
Powdered goods	Count of Obsno	12.00	15.00	66.00	93.00
	Average of ESA4	0.31	1.40	2.40	1.97
	Average of ESA5	0.22	1.21	2.66	2.11
	Average of ESA7	0.12	1.24	3.80	2.91
	Average of ESA12	0.04	2.16	21.62	15.70
Prefabricated structural components	Count of Obsno	3.00	7.00	19.00	29.00
	Average of ESA4	3.42	0.32	2.39	2.00
	Average of ESA5	4.97	0.26	2.33	2.10
	Average of ESA7	11.52	0.18	2.46	2.85
	Average of ESA12	116.49	0.11	3.96	14.67
Rubbish	Count of Obsno	25.00	30.00	16.00	71.00
	Average of ESA4	0.62	1.40	2.51	1.38
	Average of ESA5	0.57	1.44	2.75	1.43
	Average of ESA7	0.58	1.67	3.84	1.78
	Average of ESA12	1.14	3.59	16.37	5.61
Sawdust and wood waste	Count of Obsno	2.00	2.00	30.00	34.00
	Average of ESA4	0.22	0.10	2.99	2.66
	Average of ESA5	0.14	0.05	3.09	2.74
	Average of ESA7	0.06	0.01	3.54	3.13
	Average of ESA12	0.01	0.00	6.38	5.63
Stock food, grain, seeds, etc	Count of Obsno	3.00	3.00	14.00	20.00
	Average of ESA4	0.15	1.10	2.05	1.62
	Average of ESA5	0.08	1.07	2.04	1.60
	Average of ESA7	0.03	1.08	2.17	1.69
	Average of ESA12	0.00	1.46	3.24	2.49
Timber, logs	Count of Obsno	2.00	15.00	317.00	334.00
	Average of ESA4	0.30	2.29	5.35	5.18
	Average of ESA5	0.22	2.98	6.56	6.36
	Average of ESA7	0.13	6.16	11.34	11.04
	Average of ESA12	0.04	62.31	85.07	83.53
Timber, processed	Count of Obsno	43.00	23.00	157.00	223.00
	Average of ESA4	0.31	0.89	3.39	2.54
	Average of ESA5	0.24	0.83	3.78	2.80
	Average of ESA7	0.18	0.85	5.39	3.92
	Average of ESA12	0.14	1.82	24.80	17.67
Wool, hides	Count of Obsno	3.00		2.00	5.00
	Average of ESA4	0.50		2.07	1.13
	Average of ESA5	0.39		1.86	0.98
	Average of ESA7	0.24		1.56	0.77
	Average of ESA12	0.09		1.26	0.56
Total Count of Obsno		2179.00	1804.00	3594.00	7577.00
Total Average of ESA4		0.31	1.10	2.80	1.68
Total Average of ESA5		0.27	1.14	3.12	1.83
Total Average of ESA7		0.28	1.51	4.57	2.61
Total Average of ESA12		1.13	7.08	30.97	16.70

Appendix E

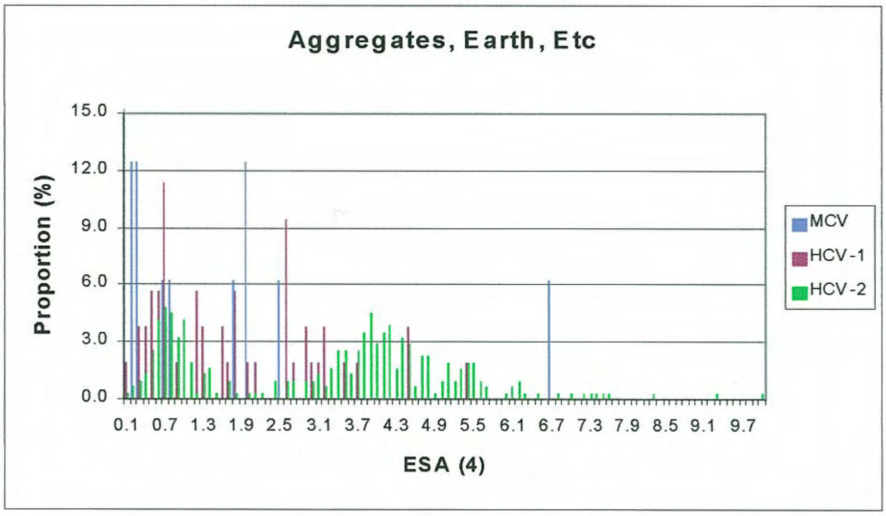
ESA Data With Respect to Commodity and PEM Vehicle Classifications



a)

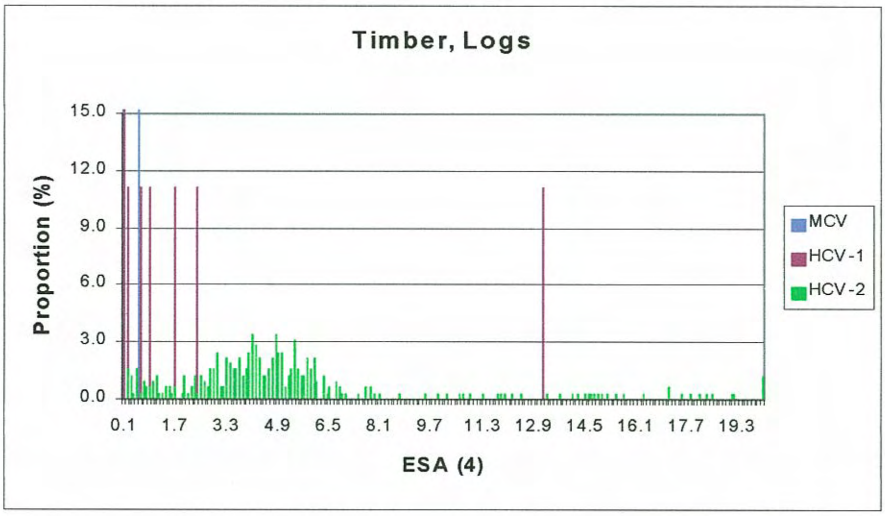


b)

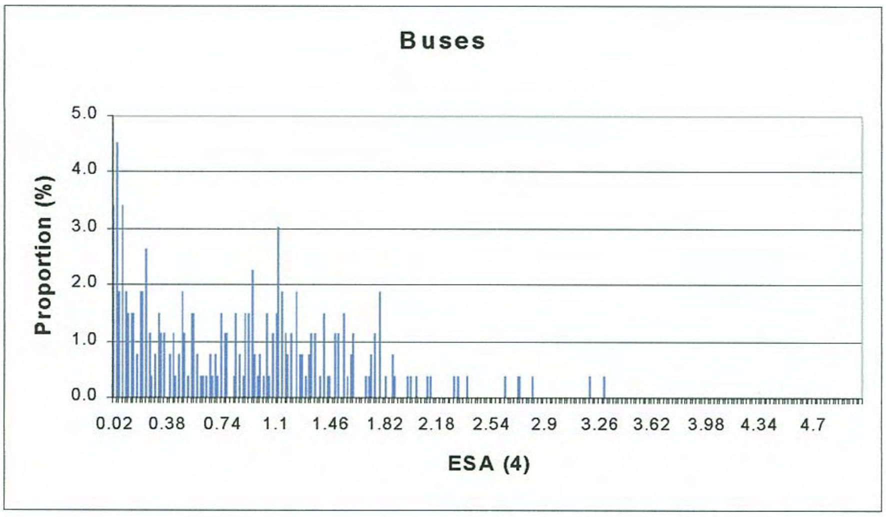


c)

Figure E1 ESA4 distribution with respect to PEM classification for various commodities.



d)



e)

Figure E1 (cont) ESA4 distribution with respect to PEM classification for various commodities.

Table E1 ESA data with respect to PEM vehicle classifications.

Corrected TNZ Commodity	Data	Veh. Class BUS	HCV-I	HCV-II	MCV	Grand Total
Aggregates, earth, etc	Count of Obsno		53.00	311.00	16.00	380.00
	Average of ESA4		1.74	3.19	1.07	2.90
	Average of ESA5		1.91	3.39	1.19	3.09
	Average of ESA7		2.49	4.10	1.66	3.77
	Average of ESA12		6.49	10.96	6.16	10.13
Building materials processed	Count of Obsno		18.00	30.00	48.00	96.00
	Average of ESA4		0.62	2.90	0.16	1.10
	Average of ESA5		0.54	3.60	0.11	1.28
	Average of ESA7		0.44	7.24	0.06	2.37
	Average of ESA12		0.35	95.24	0.02	29.84
Buses	Count of Obsno	265.00				265.00
	Average of ESA4	0.84				0.84
	Average of ESA5	0.77				0.77
	Average of ESA7	0.72				0.72
	Average of ESA12	0.91				0.91
Camper vans	Count of Obsno		2.00		45.00	47.00
	Average of ESA4		0.61		0.05	0.08
	Average of ESA5		0.55		0.03	0.05
	Average of ESA7		0.47		0.01	0.03
	Average of ESA12		0.35		0.00	0.02
Car haulage	Count of Obsno		63.00	57.00	32.00	152.00
	Average of ESA4		0.74	1.70	0.24	0.99
	Average of ESA5		0.63	1.87	0.17	1.00
	Average of ESA7		0.51	3.02	0.09	1.37
	Average of ESA12		0.56	29.33	0.03	11.31
Concrete - ready mixed	Count of Obsno		38.00	12.00	2.00	52.00
	Average of ESA4		1.22	2.71	0.51	1.54
	Average of ESA5		1.32	2.97	0.39	1.67
	Average of ESA7		1.88	3.84	0.23	2.27
	Average of ESA12		10.30	9.90	0.07	9.81
Construction machinery	Count of Obsno		20.00	46.00	16.00	82.00
	Average of ESA4		1.23	4.31	0.17	2.75
	Average of ESA5		1.28	6.20	0.10	3.81
	Average of ESA7		1.55	17.81	0.05	10.38
	Average of ESA12		3.42	644.11	0.01	362.16
Containers	Count of Obsno		10.00	137.00	5.00	152.00
	Average of ESA4		0.88	1.55	0.65	1.48
	Average of ESA5		0.79	1.51	0.55	1.43
	Average of ESA7		0.72	1.59	0.43	1.50
	Average of ESA12		0.82	3.01	0.30	2.78
Courier, mail and parcels	Count of Obsno		11.00	36.00	28.00	75.00
	Average of ESA4		0.49	1.37	0.28	0.84
	Average of ESA5		0.39	1.35	0.22	0.79
	Average of ESA7		0.28	1.49	0.16	0.81
	Average of ESA12		0.15	3.28	0.12	1.64
Empty or carrying tradesmans tools	Count of Obsno		99.00	170.00	68.00	337.00
	Average of ESA4		0.91	1.30	0.31	0.99
	Average of ESA5		0.93	1.28	0.28	0.97
	Average of ESA7		1.22	1.45	0.31	1.15
	Average of ESA12		5.95	3.30	0.78	3.56
Furniture	Count of Obsno		25.00	7.00	62.00	94.00
	Average of ESA4		0.95	1.50	0.29	0.56
	Average of ESA5		1.00	1.36	0.22	0.52
	Average of ESA7		1.40	1.17	0.15	0.56
	Average of ESA12		6.58	0.99	0.10	1.89

General freight	Count of Obsno	9.00	118.00	3.00	130.00
	Average of ESA4	1.70	2.23	0.06	2.14
	Average of ESA5	1.70	2.32	0.03	2.22
	Average of ESA7	2.16	3.00	0.01	2.88
	Average of ESA12	5.30	11.81	0.00	11.13
Livestock, animals, etc	Count of Obsno	52.00	101.00	84.00	237.00
	Average of ESA4	1.07	2.69	0.30	1.49
	Average of ESA5	1.13	2.80	0.24	1.52
	Average of ESA7	1.67	3.50	0.20	1.92
	Average of ESA12	11.21	12.42	0.29	7.83
Logging trucks carrying jinkers	Count of Obsno	110.00	2.00	1.00	113.00
	Average of ESA4	1.41	1.02	0.07	1.40
	Average of ESA5	1.50	0.81	0.03	1.47
	Average of ESA7	1.97	0.55	0.01	1.93
	Average of ESA12	7.61	0.29	0.00	7.41
Machinery	Count of Obsno	42.00	18.00	49.00	109.00
	Average of ESA4	0.48	1.87	0.52	0.73
	Average of ESA5	0.42	1.93	0.52	0.72
	Average of ESA7	0.37	2.22	0.82	0.88
	Average of ESA12	0.47	3.98	7.38	4.16
Manufactured foodstuffs	Count of Obsno	37.00	78.00	62.00	177.00
	Average of ESA4	1.09	1.66	0.32	1.07
	Average of ESA5	1.17	1.64	0.27	1.07
	Average of ESA7	1.73	1.84	0.25	1.27
	Average of ESA12	12.07	4.66	0.47	4.76
Meat, fish and frozen foods	Count of Obsno	35.00	102.00	71.00	208.00
	Average of ESA4	1.35	1.95	0.41	1.32
	Average of ESA5	1.54	1.98	0.36	1.35
	Average of ESA7	2.49	2.23	0.32	1.62
	Average of ESA12	18.72	4.31	0.43	5.41
Metals and scrap	Count of Obsno	16.00	30.00	12.00	58.00
	Average of ESA4	0.78	2.15	0.51	1.43
	Average of ESA5	0.69	2.13	0.52	1.40
	Average of ESA7	0.61	2.26	0.68	1.48
	Average of ESA12	0.74	3.54	2.20	2.49
Milk	Count of Obsno	1.00	133.00	4.00	138.00
	Average of ESA4	0.83	2.74	0.19	2.65
	Average of ESA5	0.69	2.91	0.11	2.82
	Average of ESA7	0.50	3.69	0.05	3.56
	Average of ESA12	0.25	10.26	0.01	9.89
NO LOAD DESCRIPTION	Count of Obsno	637.00	1579.00	1235.00	3451.00
	Average of ESA4	0.86	2.58	0.26	1.43
	Average of ESA5	0.89	2.85	0.23	1.55
	Average of ESA7	1.22	4.08	0.25	2.18
	Average of ESA12	6.27	21.00	1.12	11.17
Other liquids	Count of Obsno	64.00	220.00	31.00	315.00
	Average of ESA4	1.26	2.32	0.26	1.90
	Average of ESA5	1.29	2.55	0.20	2.07
	Average of ESA7	1.50	3.54	0.15	2.79
	Average of ESA12	3.02	18.14	0.11	13.29
Other manufactured products	Count of Obsno	6.00	3.00	30.00	39.00
	Average of ESA4	0.36	0.93	0.15	0.24
	Average of ESA5	0.24	0.77	0.11	0.18
	Average of ESA7	0.11	0.55	0.07	0.11
	Average of ESA12	0.02	0.29	0.06	0.07
Paper, pulp and cardboard	Count of Obsno		2.00	11.00	13.00
	Average of ESA4		10.63	0.16	1.77
	Average of ESA5		14.75	0.10	2.35
	Average of ESA7		30.09	0.04	4.66
	Average of ESA12		215.65	0.00	33.18

Plants, fruit, vegetables, etc	Count of Obsno		9.00	20.00	19.00	48.00
	Average of ESA4		0.96	1.93	0.35	1.12
	Average of ESA5		1.00	1.88	0.30	1.09
	Average of ESA7		1.19	1.92	0.26	1.13
	Average of ESA12		2.62	2.51	0.27	1.65
Powdered goods	Count of Obsno		13.00	68.00	12.00	93.00
	Average of ESA4		1.22	2.40	0.31	1.97
	Average of ESA5		1.16	2.62	0.22	2.11
	Average of ESA7		1.21	3.73	0.12	2.91
	Average of ESA12		2.28	21.02	0.04	15.70
Prefabricated structural components	Count of Obsno		7.00	19.00	3.00	29.00
	Average of ESA4		0.32	2.39	3.42	2.00
	Average of ESA5		0.26	2.33	4.97	2.10
	Average of ESA7		0.18	2.46	11.52	2.85
	Average of ESA12		0.11	3.96	116.49	14.67
Rubbish	Count of Obsno		29.00	17.00	25.00	71.00
	Average of ESA4		1.42	2.41	0.62	1.38
	Average of ESA5		1.46	2.63	0.57	1.43
	Average of ESA7		1.71	3.65	0.58	1.78
	Average of ESA12		3.70	15.43	1.14	5.61
Sawdust and wood waste	Count of Obsno		2.00	30.00	2.00	34.00
	Average of ESA4		0.10	2.99	0.22	2.66
	Average of ESA5		0.05	3.09	0.14	2.74
	Average of ESA7		0.01	3.54	0.06	3.13
	Average of ESA12		0.00	6.38	0.01	5.63
Stock food, grain, seeds, etc	Count of Obsno		2.00	15.00	3.00	20.00
	Average of ESA4		1.44	1.94	0.15	1.62
	Average of ESA5		1.43	1.93	0.08	1.60
	Average of ESA7		1.51	2.04	0.03	1.69
	Average of ESA12		2.15	3.03	0.00	2.49
Timber, logs	Count of Obsno		11.00	321.00	2.00	334.00
	Average of ESA4		1.88	5.33	0.30	5.18
	Average of ESA5		2.53	6.53	0.22	6.36
	Average of ESA7		5.79	11.28	0.13	11.04
	Average of ESA12		70.31	84.51	0.04	83.53
Timber, processed	Count of Obsno		19.00	161.00	43.00	223.00
	Average of ESA4		0.83	3.34	0.31	2.54
	Average of ESA5		0.78	3.72	0.24	2.80
	Average of ESA7		0.83	5.28	0.18	3.92
	Average of ESA12		2.06	24.20	0.14	17.67
Wool, hides	Count of Obsno			2.00	3.00	5.00
	Average of ESA4			2.07	0.50	1.13
	Average of ESA5			1.86	0.39	0.98
	Average of ESA7			1.56	0.24	0.77
	Average of ESA12			1.26	0.09	0.56
Total Count of Obsno		265.00	1440.00	3845.00	2027.00	7577.00
Total Average of ESA4		0.84	1.00	2.73	0.29	1.68
Total Average of ESA5		0.77	1.04	3.03	0.25	1.83
Total Average of ESA7		0.72	1.37	4.43	0.27	2.61
Total Average of ESA12		0.91	6.52	29.78	1.19	16.70

Appendix F

Te Puke and Waipara WIM Site 8-Hour ESA Data

Table F1 Mean count and ESA data for 7 am to 3 pm period at the Te Puke WIM site.

Month	Data	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Weekday	Weekend
January	Mean 8 - Hr Count	656	709	716	772	753	239	219	721	229
	Mean 8 - Hr ESA	852.2	1065.8	1068.6	1201.5	1249.8	314.6	380.2	1087.6	347.4
February	Mean 8 - Hr Count	882	921	937	944	938	335	209	924	272
	Mean 8 - Hr ESA	1360.6	1474.2	1475.8	1499.1	1336.9	532.0	278.1	1429.3	405.1
March	Mean 8 - Hr Count	895	964	945	959	968	317	161	946	239
	Mean 8 - Hr ESA	1421.6	1534.7	1454.9	1513.5	1499.6	464.4	213.0	1484.9	338.7
April	Mean 8 - Hr Count	856	889	865	869	841	319	175	864	247
	Mean 8 - Hr ESA	1060.2	1122.7	1123.8	1100.7	1037.6	420.1	209.5	1089.0	314.8
May	Mean 8 - Hr Count	892	920	971	932	948	308	194	933	251
	Mean 8 - Hr ESA	1224.9	1310.3	1376.6	1325.7	1249.4	352.7	244.8	1297.4	298.8
June	Mean 8 - Hr Count	892	NR	975	NR	996	323	165	954	244
	Mean 8 - Hr ESA	1253.1		1338.3		1438.3	403.6	215.8	1343.2	309.7
July	Mean 8 - Hr Count	838	922	840	780	850	294	149	846	222
	Mean 8 - Hr ESA	1166.1	1209.9	1116.9	1081.7	1148.0	383.2	172.6	1144.5	277.4
August	Mean 8 - Hr Count	891	936	862	902	926	304	157	903	231
	Mean 8 - Hr ESA	1231.4	1265.6	1136.7	1228.1	1290.8	435.8	186.5	1597.4	311.5
September	Mean 8 - Hr Count	931	944	925	948	1039	354	152	957	253
	Mean 8 - Hr ESA	1345.1	1391.7	1343.0	1434.8	1575.6	562.0	166.5	1418.0	364.3
October	Mean 8 - Hr Count	1032	1007	1024	997	997	280	130	1011	205
	Mean 8 - Hr ESA	1713.9	1566.2	1599.9	1579.2	1569.3	369.3	139.8	1605.7	254.6
November	Mean 8 - Hr Count	922	1072	1059	964	973	407	121	998	264
	Mean 8 - Hr ESA	1392.7	1389.1	1484.9	1588.4	1499.9	510.9	144.1	1471.0	327.5
December	Mean 8 - Hr Count	1007	1058	1039	934	965	396	204	1001	300
	Mean 8 - Hr ESA	1772.1	1782.5	1805.4	1571.3	1568.2	663.0	288.2	1699.9	475.6
Full Year	Mean 8 - Hr Count	891	940	930	909	933	323	170	921	247
	Mean 8 - Hr ESA	1316.2	1373.9	1360.4	1374.9	1372.0	451.0	219.9	1359.5	225.5

Table F2 Mean count and ESA data for 8 am to 4 pm period at the Te Puke WIM site.

Month	Data	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Weekday	Weekend
January	Mean 8 - Hr Count	640	709	715	771	718	230	222	711	226
	Mean 8 - Hr ESA	854.3	1085.1	1046.6	1256.2	1227.5	307.1	372.1	1093.9	339.6
February	Mean 8 - Hr Count	863	923	922	952	921	309	210	916	260
	Mean 8 - Hr ESA	1335.6	1441.2	1498.8	1522.3	1454.8	489.2	275.5	1450.5	382.4
March	Mean 8 - Hr Count	907	927	940	958	957	301	166	938	234
	Mean 8 - Hr ESA	1486.1	1560.2	1495.8	1530.8	1501.8	432.4	212.5	1514.9	322.5
April	Mean 8 - Hr Count	863	907	880	896	859	310	185	881	248
	Mean 8 - Hr ESA	1075.1	1196.1	1188.7	1126.3	1101.7	421.0	232.8	1137.6	326.9
May	Mean 8 - Hr Count	904	956	994	949	956	303	205	952	254
	Mean 8 - Hr ESA	1239.6	1325.9	1422.9	1352.3	1283.0	342.6	253.9	1324.7	298.3
June	Mean 8 - Hr Count	910	NR	984	NR	979	307	177	958	242
	Mean 8 - Hr ESA	1289.5		1370.7		1437.6	373.0	226.6	1365.9	299.8
July	Mean 8 - Hr Count	844	927	839	783	856	270	160	850	215
	Mean 8 - Hr ESA	1190.6	1218.1	1136.6	1078.5	1160.3	342.2	184.8	1156.8	263.5
August	Mean 8 - Hr Count	887	944	884	918	928	289	167	912	228
	Mean 8 - Hr ESA	1229.6	1264.8	1190.4	1267.7	1320.0	406.9	200.2	1254.5	303.6
September	Mean 8 - Hr Count	913	955	926	945	1014	331	156	951	244
	Mean 8 - Hr ESA	1350.6	1425.0	1357.6	1446.7	1541.7	514.9	168.9	1424.3	341.9
October	Mean 8 - Hr Count	1002	986	1010	980	975	257	136	991	197
	Mean 8 - Hr ESA	1662.3	1550.0	1611.1	1568.3	1569.1	347.1	143.2	1592.2	245.2
November	Mean 8 - Hr Count	921	1024	855	912	986	404	134	940	269
	Mean 8 - Hr ESA	1388.0	1447.8	1286.2	1424.9	1526.2	628.1	155.8	1414.6	392.0
December	Mean 8 - Hr Count	1003	1079	1006	1023	983	351	206	1019	279
	Mean 8 - Hr ESA	1757.5	1822.7	1768.2	1752.0	1587.4	562.3	281.7	1737.6	422.0
Full Year	Mean 8 - Hr Count	888	940	913	917	928	305	177	917	241
	Mean 8 - Hour ESA	1321.6	1394.3	1364.5	1393.3	1392.6	430.6	225.7	1373.3	328.2

Table F3 Mean count and ESA data for 9 am to 5 pm period at the Te Puke WIM site.

Month	Data	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Weekday	Weekend
January	Mean 8 - Hr Count	607	697	688	743	668	218	218	681	218
	Mean 8 - Hr ESA	817.0	1095.8	1029.4	1237.4	1152.9	311.5	350.0	1066.5	330.8
February	Mean 8 - Hr Count	851	907	908	932	898	279	199	899	239
	Mean 8 - Hr ESA	1332.7	1490.4	1494.4	1526.4	1450.7	439.6	243.1	1258.9	341.4
March	Mean 8 - Hr Count	910	959	940	942	939	277	176	938	227
	Mean 8 - Hr ESA	1528.6	1564.1	1545.1	1529.5	1478.8	391.5	237.1	1529.2	314.3
April	Mean 8 - Hr Count	868	922	878	872	862	298	195	880	247
	Mean 8 - Hr ESA	1091.2	1228.7	1210.8	1058.4	1118.8	407.6	230.5	1141.6	319.7
May	Mean 8 - Hr Count	901	960	986	931	924	277	211	940	244
	Mean 8 - Hr ESA	1244.7	1367.9	1427.0	1353.4	1261.6	310.2	260.5	1330.9	285.4
June	Mean 8 - Hr Count	780	NR	961	NR	936	280	184	892	232
	Mean 8 - Hr ESA	1231.9		1378.9		1404.3	328.5	236.9	1338.4	282.7
July	Mean 8 - Hr Count	847	896	816	763	827	244	159	830	202
	Mean 8 - Hr ESA	1180.3	1180.6	1095.3	1049.3	1164.6	216.8	185.8	1134.0	201.3
August	Mean 8 - Hr Count	862	921	849	893	905	262	167	886	215
	Mean 8 - Hr ESA	1203.9	1271.1	1145.9	1256.1	1297.3	364.0	190.7	1234.9	277.4
September	Mean 8 - Hr Count	881	932	890	934	975	296	152	922	224
	Mean 8 - Hr ESA	1319.7	1404.3	1335.5	1451.2	1493.2	472.3	160.2	1400.8	316.3
October	Mean 8 - Hr Count	960	929	955	933	921	220	134	940	177
	Mean 8 - Hr ESA	1636.7	1479.5	1544.7	1500.1	1494.9	295.8	142.7	1531.2	219.3
November	Mean 8 - Hr Count	873	986	832	897	961	358	136	910	247
	Mean 8 - Hr ESA	1415.6	1531.3	1278.5	1478.0	1523.3	555.8	162.2	1445.3	359.0
December	Mean 8 - Hr Count	969	1049	980	1002	941	268	221	988	245
	Mean 8 - Hr ESA	1730.3	1793.6	1757.4	1499.9	1548.8	479.4	296.9	1666.0	388.2
Full Year	Mean 8 - Hr Count	859	923	890	895	896	273	179	893	226
	Mean 8 - Hr ESA	1311.1	1400.7	1353.6	1358.2	1365.8	381.1	224.7	1357.9	302.9

Table F4 Mean count and ESA data for 7 am to 3 pm period at the Waipara WIM site.

Month	Data	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Weekday	Weekend
January	Mean 8 - Hr Count Mean 8 - Hr ESA	272 391.1	313 458.8	305 442.0	268 362.1	244 314.3	131 124.7	136 150.3	280 393.7	134 137.5
February	Mean 8 - Hr Count Mean 8 - Hr ESA	247 287.5	284 358.4	289 333.5	275 326.8	240 267.5	116 97.7	134 135.9	267 314.7	125 116.8
March	Mean 8 - Hr Count Mean 8 - Hr ESA	272 340.5	293 324.4	259 338.5	262 308.5	248 300.3	123 123.2	168 179.6	267 322.4	145 151.4
April	Mean 8 - Hr Count Mean 8 - Hr ESA	242 304.7	286 395.2	300 409.6	292 390.4	226 286.7	111 106.6	101 100.5	269 357.3	106 103.5
May	Mean 8 - Hr Count Mean 8 - Hr ESA	244 331.6	264 401.1	261 357.9	267 356.7	246 314.7	105 123.3	84 102.4	256 352.4	95 112.8
June	Mean 8 - Hr Count Mean 8 - Hr ESA	198 234.2	214 277.1	267 330.6	185 219.2	162 198.6	86 85.2	63 54.8	205 251.9	74 70.0
July	Mean 8 - Hr Count Mean 8 - Hr ESA	196 242.4	229 304.0	215 282.2	189 263.1	192 248.2	82 71.8	63 55.9	204 268.0	72 63.9
August	Mean 8 - Hr Count Mean 8 - Hr ESA	196 270.8	234 321.6	219 290.0	230 321.0	214 291.7	99 107.0	66 64.3	219 299.0	83 85.7
September	Mean 8 - Hr Count Mean 8 - Hr ESA	230 312.8	259 359.4	251 352.5	246 338.7	261 362.2	103 116.2	90 84.0	249 345.1	97 100.1
October	Mean 8 - Hr Count Mean 8 - Hr ESA	231 277.9	256 315.6	267 362.0	269 360.4	242 271.0	113 100.0	95 103.2	253 317.4	104 101.6
November	Mean 8 - Hr Count Mean 8 - Hr ESA	161 208.3	168 180.1	182 217.0	179 208.7	132 134.9	79 59.4	62 62.7	164 189.8	70 61.0
December	Mean 8 - Hr Count Mean 8 - Hr ESA	168 235.6	206 268.6	208 305.1	201 266.1	147 197.4	91 77.4	93 105.8	186 254.6	92 91.6
Full Year	Mean 8 - Hr Count Mean 8 - Hr ESA	221 286.5	250 330.4	252 335.1	239 310.1	213 265.6	103 99.4	96 99.9	235 305.5	100 99.7

Table F5 Mean count and ESA data for 8 am to 4 pm period at the Waipara WIM site.

Month	Data	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Weekday	Weekend
January	Mean 8 - Hr Count Mean 8 - Hr ESA	283 400.7	309 460.6	312 460.7	258 342.6	238 292.6	135 119.0	144 158.7	280 391.4	140 138.8
February	Mean 8 - Hr Count Mean 8 - Hr ESA	250 284.6	279 347.5	282 346.8	271 333.3	232 252.9	115 103.0	137 144.9	263 313.1	126 123.9
March	Mean 8 - Hr Count Mean 8 - Hr ESA	280 355.8	290 311.9	267 344.5	265 329.8	244 286.4	115 113.7	172 175.9	269 325.7	144 144.8
April	Mean 8 - Hr Count Mean 8 - Hr ESA	252 312.7	292 401.4	300 414.1	305 420.2	225 273.1	113 95.4	110 101.9	275 364.3	111 98.7
May	Mean 8 - Hr Count Mean 8 - Hr ESA	252 361.8	271 418.4	260 360.4	278 368.3	245 307.5	102 113.2	90 106.6	261 363.3	96 109.9
June	Mean 8 - Hr Count Mean 8 - Hr ESA	212 269.6	216 280.5	267 345.9	193 220.1	168 202.2	89 92.8	65 55.1	211 263.7	77 74.0
July	Mean 8 - Hr Count Mean 8 - Hr ESA	200 247.3	234 309.5	217 280.0	194 259.1	198 241.4	81 71.7	70 61.5	209 267.5	76 66.6
August	Mean 8 - Hr Count Mean 8 - Hr ESA	206 287.5	245 341.8	222 296.4	231 322.7	222 300.1	101 110.0	74 67.8	225 309.7	88 88.9
September	Mean 8 - Hr Count Mean 8 - Hr ESA	232 323.0	253 363.2	253 363.9	244 335.5	259 366.3	103 114.2	95 95.7	248 350.4	99 104.9
October	Mean 8 - Hr Count Mean 8 - Hr ESA	238 292.3	257 321.7	276 369.2	274 367.2	248 292.4	110 103.7	102 106.6	259 328.6	106 105.2
November	Mean 8 - Hr Count Mean 8 - Hr ESA	172 208.4	172 185.0	188 223.4	185 212.7	132 127.5	79 60.3	75 79.0	170 191.4	77 69.6
December	Mean 8 - Hr Count Mean 8 - Hr ESA	173 234.3	207 267.8	216 304.6	200 257.8	141 179.9	90 74.1	98 113.3	187 248.9	94 93.7
Full Year	Mean 8 - Hr Count Mean 8 - Hour ESA	228 296.8	251 331.9	254 342.3	242 315.6	214 262.0	103 98.7	103 105.7	238 309.7	103 102.2

Table F6 Mean count and ESA data for 9 am to 5 pm period at the Waipara WIM site.

Month	Data	Mon	Tues	Wed	Thur	Fri	Sat	Sun	Weekday	Weekend
January	Mean 8 - Hr Count	283	307	311	259	239	132	157	280	145
	Mean 8 - Hr ESA	390.5	462.8	470.7	357.3	292.5	111.2	166.9	394.8	139.0
February	Mean 8 - Hr Count	257	283	296	279	234	112	146	270	129
	Mean 8 - Hr ESA	287.2	364.0	372.4	354.2	255.1	101.1	164.7	326.6	132.9
March	Mean 8 - Hr Count	270	288	277	261	248	108	177	269	142
	Mean 8 - Hr ESA	347.5	309.4	365.9	323.3	294.2	95.1	173.9	328.1	134.5
April	Mean 8 - Hr Count	254	295	303	311	223	113	114	277	113
	Mean 8 - Hr ESA	322.5	411.1	422.0	430.1	270.3	89.5	107.9	371.2	98.7
May	Mean 8 - Hr Count	254	281	262	279	238	100	93	263	97
	Mean 8 - Hr ESA	362.5	431.7	377.3	378.2	298.8	103.6	107.9	369.7	105.7
June	Mean 8 - Hr Count	213	222	260	208	185	86	72	218	79
	Mean 8 - Hr ESA	275.4	294.9	356.4	267.8	225.5	91.8	65.0	284.0	78.4
July	Mean 8 - Hr Count	202	238	212	203	199	77	74	211	75
	Mean 8 - Hr ESA	252.9	316.1	281.4	263.0	252.0	63.6	63.8	273.1	63.7
August	Mean 8 - Hr Count	210	241	218	232	225	100	81	225	91
	Mean 8 - Hr ESA	299.7	340.4	308.2	332.1	305.5	107.5	66.6	317.2	87.0
September	Mean 8 - Hr Count	236	258	254	245	262	101	103	251	102
	Mean 8 - Hr ESA	335.7	375.7	377.8	346.3	375.4	105.9	97.8	362.2	101.9
October	Mean 8 - Hr Count	232	262	280	273	240	104	108	257	106
	Mean 8 - Hr ESA	281.5	330.9	368.3	369.2	285.0	93.9	104.5	327.0	99.2
November	Mean 8 - Hr Count	178	185	195	205	135	85	92	180	88
	Mean 8 - Hr ESA	211.0	202.4	235.9	233.4	127.1	66.1	94.3	201.9	80.2
December	Mean 8 - Hr Count	188	209	211	204	136	90	106	190	98
	Mean 8 - Hr ESA	261.7	265.7	303.3	262.7	176.6	78.8	122.0	254.0	100.4
Full Year	Mean 8 - Hr Count	230	255	256	247	215	101	110	241	106
	Mean 8 - Hr ESA	300.9	339.7	352.8	327.4	264.6	93.2	111.2	317.1	102.2