Executive Summary

Project Objectives

The main purpose of this project is to identify appropriate traffic and loading data for use in RAMM, other pavement management systems (PMS) with treatment selection algorithms and for pavement deterioration models (e.g. dTIMS)[1]**.** Also to meet the needs of pavement designers in the estimation of pavement loading over the life of a project, by establishing ESA[2] relationships from a variety of commonly used survey approaches and continuous data sources currently available in New Zealand.

The specific objectives for this research project were as follows:

1. To derive typical relationships between the Transit New Zealand standard telemetry outputs (four Vehicle Length Categories) and other commonly used classification systems in New Zealand such as that adopted by the Transfund Project Evaluation Manual (PEM), i.e. car, LCV, MCV, HCVI, and HCVII.
2. To derive typical percentages of PEM Vehicle Classes for different types of local and State Highway roads, based on a recent survey by LTSA of the vehicle composition across 2,350 roads of all types throughout New Zealand.
3. To derive typical ESA (equivalent standard axle) for the different Vehicle Classes, and determine whether there are any differences on the basis of region, road use, or traffic volume/percentage of heavy vehicles relationship.
4. To derive relationships enabling the ESA determined from short-term surveys to be factored to a week and a year based on the four 'weigh-in-motion' (WIM) sites.

Summary of Outcomes

The outcomes are considered in the order of the objectives listed above.

Objective 1

Relatively poor correlation was found between the four Vehicle Length Categories comprising Transit's standard telemetry outputs and other commonly used classification systems. As a broad generalisation, and in the absence of any other data, the percentage of vehicles from each Transit Vehicle Class (1-13) which can be allocated to each Vehicle Length Category is as follows (ignoring any representation of less than 5%):

Vehicle Length Category 1 (0.0 m -5.5 m)	includes	100% of Vehicle Class 1
Vehicle Length Category 2 (5.5 m - 11.0 m)	includes	100% of Class 2; 75% of Class 3; 70% of Class 4; 40% of Class 5; 70% of Class 6; and 9% of Class 7
Vehicle Length Category 3 (11.0 m - 17.0 m)	includes	8% of Class 3; 30% of Class 4; 40% of Class 5; 25% of Class 6; 70% of Class 7; 70% of Class 8; 25% of Class 9; 30% of Class 10; and 7% of Class 13
Vehicle Length Category 4 (>17 m)	includes	17% of Class 5; 5% of Class 6; 18% of Class 7; 30% of Class 8; 25% of Class 9; 20% of Class 10; 100% of Class 11; and 100% of Class 12

[1] Traffic data required as inputs to dTIMS include AADT, %Cars, %LCV, %MCV, %HCVI, %HCVII and %Bus. NZdTIMS does not have the ability to accept individual axle or axle-group data. Inputs are in ESA/vehicle for each of the vehicle categories.

[2] ESA as defined by the Austroads Pavement Design Guide = $\frac{\text{(Load on Axle Group)}}{\text{Reference Axle Group Load}}$

Accordingly, there is no simple relationship between Transit's Vehicle Class and its Vehicle Length Category. Similarly, there is no useful relationship between Transfund's PEM Classes (i.e. car, LCV, MCV, HCVI and HCVII) and Transit's four Vehicle Length Categories.

Objective 2
Typical percentages of PEM Vehicle Classes for different road types were accurately determined for the weekday interpeak period (09:00 - 16:00) across a wide range of road types throughout New Zealand. Accordingly updated factors are recommended for adoption by Transfund in the PEM manual.

Objective 3
For the convenience of pavement designers, typical ESAs for different Vehicle Classes were established, and reported as ESA4, ESA5, ESA7, and ESA12, for each of the weigh-in-motion sites. As this ESA data is based on a substantially larger sample than previously published data, the new values should be adopted in future. The research identified some differences on State Highways at a regional level, but was unable to identify whether there were any differences in ESA between different road types or between roads carrying different proportions of heavy vehicles.

Objective 4
Relationships were derived from the WIM sites that enable ESA to be calculated from short-term surveys and to be corrected by application of a week factor. However, as the level of accuracy is less than generally accepted, it is recommended that at least 3 years of data from each WIM station be evaluated before confirming whether week and day factors can usefully be used to adjust short-term counts.

Research Stages
The research was undertaken in a series of separate stages, independently addressing various of the objectives. In assessing the manner in which the objectives were met, it is important to understand that the individual stages did not address the various objectives in the order outlined above.

Specifically, Stage 1 addressed Objective #2 and part of #1,
Stages 2 and 3 addressed Objective #1,
Stage 4 addressed Objective #4, and
Stage 5 addressed Objective #3

Stage 1 : Analysis of LTSA Composition Data
The data from 2,350 roads, randomly selected by LTSA from throughout New Zealand, was analysed in terms of vehicle class and road category, then compared with currently adopted relationships.

Stage 2 : Analysis of Transit Weigh-in-Motion Data
Surveys undertaken at the four Transit New Zealand WIM sites in February/March 2000 were analysed with a view to establishing a relationship between Vehicle Length Category, wheelbase and Vehicle Class for application to the Transit continuous telemetry traffic counting sites. The currently adopted Transit relationships between Vehicle Class and the four standard Length Categories, measured at the telemetry, sites are to be reviewed alongside the relationships derived in this research.

It was also intended to review the survey data with a view to identifying, if possible, axle spacing criteria which could be used to distinguish between the main heavy vehicle types classified by routine equipment survey; as opposed to specific visual or commodity surveys. This component produced disappointing results because the commodities were impossible to verify visually. However, the survey did establish a strong correlation between visually recorded truck types and those recorded with the WIM equipment. It was, therefore, decided that a larger sample of WIM data could be reliably used, and would produce more accurate and statistically reliable results.

Stage 3 : Analysis of Comparative Surveys at Selected Telemetry Sites

The data collected by manual means was examined and compared with portable equipment surveys and the telemetry outputs from the count stations at Ohau, Manawatu, and Clareville. Classifiers were used, capable of recording individual vehicles over three-hour periods, analogous to the LTSA survey periods reported in Stage 1. The relationships obtained from these surveys were compared with those derived in Stages 1 and 2.

Stage 4 : Deriving Factors for 3-4 and 8 Hour Visual Surveys

Detailed analysis was carried out, of the data from three of the WIM sites over a full 12-month period. The objective was to develop the multipliers to be used for estimating annual ESA values from short-term surveys of vehicle types.

Stage 5 : Derivation Typical ESA for different Vehicle Classes

Undertaken in parallel with Stage 4, detailed analysis was carried out of the data from the four WIM sites, for the most recent 14-month period up to and including August 2002. The objective being to identify the ESA values for a range of different vehicle classifications, separately for each WIM site. Then, if practicable, to identify variations between different sites with different vehicle characteristics. Also to determine more reliable ESA values for site specific situations that can be related to:

1. Vehicle Length Categories, for which continuous data is collected by Transit NZ from telemetry sites throughout the country, and
2. TNZ Vehicle Classes (1-13), which can be measured by temporary classification equipment (as used in Stage 3).

Results

Stage 1

The results from the analysis of the LTSA survey data generally closely correlated with the relationships adopted by the Project Evaluation Manual and the National Traffic Database. They represent an improved level of accuracy of these relationships, given the large number of roads on which the vehicle classes were sampled and the use of a consistent survey procedure.

Stage 2

The results from Stage 2 give the following outcomes:

- Close correlation between overall vehicle length and wheelbase length.
- No direct relationship between Vehicle Length Category and Vehicle Class; i.e. for any particular Vehicle Class, there is a range of vehicle lengths.
- Some variation in the proportions of the various Vehicle Classes between sites.

Note that the research identified a problem with the Tokoroa WIM site. The data from this site was, therefore, discounted.

Stage 3

The results of Stage 3 showed:

- Close correlation (between 0.996 and 0.998) between overall vehicle length (as recorded at the telemetry stations), and wheelbase (as measured by the temporary classifier) for the heavy vehicle component of the traffic stream.
- Transit Vehicle Classes 2, 3 & 4 generally lie within the same vehicle length band (i.e. 5.5 m – 11 m).
- Transit Vehicle Classes 5-13 show more distinct length ranges, although with considerable overlap.
- Buses cannot be identified separately from other heavy vehicles by either type of classification equipment; they can only be identified visually.
- The PEM HCVII class correlates reasonably well with the Transit Vehicle Classes 8-13, as measured by the temporary classifier.

Stage 4

Interrogation of the data from each of the four WIM sites showed that a full year's reliable data was only obtainable from two of the sites; Drury (on SH1 south of Auckland – 'rural fringe') and Waipara (on SH1 north of Christchurch – 'rural strategic'). Any effects of temperature on the WIM equipment at each of the WIM sites was discounted. Also Vehicle Class (Transit Classes 1 to 13) and site were found to be the key variables with respect to vehicle weights and, by extension, ESA value.

The ESA4 relationships were examined in detail, since they are most commonly used in NZ (i.e. for the design of unbound granular flexible pavements).

The combination of data from the Drury and Waipara WIM sites was used to develop 'Weekly Multipliers' to estimate annual ESA4 from the classified vehicle counts converted to axle groups.

Part Day-of-Week Multipliers were developed for shorter count periods than a full week (3 hours and 8 hours respectively, on any weekday). However, when the relative errors of these ESA4 values were determined, the relative errors varied between about 10% (for the week multiplier) and 18% to 33% (for the three-hour multiplier). The error terms were specifically applicable to the Waipara and Drury sites, and are probably understated for other sites. Accordingly, 3-hour or 8-hour counts are considered to be <u>unsuitable</u> for estimating ESA.

Stage 5

The same data from each of the 4 WIM sites was interrogated with a view to establishing reliable ESA values (raised to the various powers commonly used for mechanistic pavement design - ESA4, ESA5, ESA7 and ESA12), using <u>large</u> continuous samples at each site. For convenience, the 2001 (June-December) and 2002 (January-August) samples were analysed separately, to enable a year to year comparison.

As identified by the detailed statistical analysis in Stage 4, there were some problems with the data collections at the Te Puke and Tokoroa WIM sites. Transit will be addressing these in the future.

Overall ESA values were determined for each site, together with:

- axle group
- TNZ Vehicle Class (3-13), and
- TNZ Vehicle Length Category.

Ignoring the values obtained from the suspect WIM sites, the ESA values for the other two sites are recommended for adoption by pavement designers.

Conclusions

- It is inappropriate to attempt to develop precise relationships between vehicle length and Transit Vehicle Classes, since the variation within and between sites is greater than expected (Stage 2).
- Although it may ultimately be possible to develop an algorithm to predict the detailed composition and ESAs from Length Categories, the usefulness of such an algorithm is considered marginal in relation to the required accuracy needed for current pavement design inputs.
- While the distributions of first axle spacings are not statistically different, a nominal threshold of 3.8 m has been found to differentiate between non-twin-steer truck and trailers (> 3.8 m) and B-trains and semi-trailers (< 3.8 m).
- A-trains cannot be distinguished from truck and trailers based on first axle spacing. Rather, they can be distinguished by their number of axle sets (typically five) as compared with the four axle sets of other 7 and 8 axle vehicles.
- A nominal threshold of 2.2 m has been found to distinguish twin-steer trucks (< 2.2 m) from non-twin-steer trucks (> 2.2 m).
- Commodity surveys cannot be usefully undertaken without stopping the traffic and interviewing each driver as to type and status of load (Stage 2). Visual inspections of moving vehicles are no longer a satisfactory method of commodity survey, and the stopping of vehicles to determine the commodities carried is often impracticable particularly on busy State Highways.
- Manual surveys (person or video) can be used to classify trucks, but are only practicable at sites with overall traffic volumes up to a threshold of around 7,000 vpd (Stage 3).
- Temporary classifier equipment (e.g. Peak ADR used in Stage 3 of this research) is able to identify a more comprehensive range of vehicle types (e.g. Transit Vehicle Classes 1-13) than current telemetry equipment, and accordingly is likely to be more useful for obtaining the necessary ESA values for pavement design purposes.
- Telemetry data is currently limited in its usefulness since the sites are almost all restricted to State Highways, and therefore to ‘rural strategic’ and ‘rural fringe’ road categories.
- The surveys (Stage 3) showed that the variability between survey types (visual, axle groups and length category) within sites was reasonable (with some noted exceptions), but the vehicle class patterns between sites was greater than anticipated. Although an important finding, because the road use category for each site was the same (rural strategic), this outcome contrasts with the findings from Stage 1. Such an outcome is likely a result of the small sample size (3 sites), the duration of surveys (3 hours), and the survey precision.
- It is difficult to determine whether a true seasonal variation or even daily variation exists as the precision of the monitoring equipment could mask any such variability.
- The Stage 4 and 5 results provide useful site specific ESA data by Transit Vehicle Class and Vehicle Length Category. These results are at some variance with previous ESA data published by Transfund that were based on much smaller samples of data. Again, greater accuracy is likely to be obtained if data is available for one or more full calendar years at each site.

Recommendations

- The default values of vehicle composition used by the PEM be updated based on the more extensive survey data now available, as reported in Stage 1.
- The nominal thresholds for axle spacings noted above will be helpful in using machine counts to differentiate between different types of heavy vehicle.
- For pavement design purposes, it may be appropriate to separately redefine road categories based on heavy traffic patterns only, as these are found to be different for the same road categories based on overall (light plus heavy) vehicle traffic patterns.
- Based on the knowledge gained from the detailed statistical analysis undertaken in Stage 4, it is now considered that a minimum of three years continuous and verifiably reliable data for all four WIM sites (preferably more if possible) are necessary to produce meaningful week factors or 3-hour factors. Accordingly, it is recommended that the week factors be reviewed and updated as necessary, once a full 12 months WIM data is available, and subject to rectification of the WIM equipment at the Te Puke and Tokoroa sites.
- It is further recommended that a sensitivity analysis be undertaken to determine the level of accuracy of ESA data required by way of design inputs into current design methods, for a typical range of New Zealand roads.
- That the ESA data developed in this research be publicised to New Zealand pavement designers (Stage 5).

Abstract

In order to identify appropriate traffic and loading data for use in Road Asset Maintenance Management, other pavement management systems, and for pavement deterioration models, data were collected between 2000 and 2002 from 2,350 randomly selected sites throughout New Zealand and from the four Transit New Zealand weigh-in-motion sites.

The data collection and analysis was undertaken in five stages:

1. Typical vehicle composition proportions were obtained for different road categories and compared with previously adopted relationships.

2. Relationships were determined between the various methods of categorising vehicles and quantified to determine the validity of using such relationships to derive Equivalent Standard Axle (ESA) values.

3. Relationships were established between the commonly used Transfund Project Evaluation Manual vehicle classes, length categories and axle groups.

4. Data from short term surveys was used to develop multipliers for use in estimating annual ESA values.

5. ESA values were identified from different vehicle classifications, which can be related to data obtained by continuous collection or by continuous collection equipment.