SYSTEM-WIDE ROAD ACCIDENT ANALYSIS

A STUDY OF ACCIDENT RATES ON ROAD SYSTEMS OF FIVE CITIES IN NEW ZEALAND

(Amended Report 1995)

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AN IMPORTANT NOTE FOR THE READER

The first printing of this report contained errors which have subsequently been amended in this report. Amendments are on pages: 31, 35, 39, 41, 42, 66.

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The primary data source (the accident records) for this study was provided by the New Zealand Ministry of Transport (now Land Transport Safety Authority). Appreciation for this is acknowledged.

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The research was carried out primarily by Dr Tuck Leong Tai, assisted by Grant Smith and Gary Main of Gabites Porter Consultants.

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EXECUTIVE SUMMARY

1. System-wide Road Accident Analysis

System-wide road accident analysis is an analysis of recorded injury road accidents on road network systems. This report records such an analysis of the road accidents in five New Zealand cities: Whangarei, North Shore, Hamilton, Christchurch and Timaru. The research was undertaken between 1989–1991. A computer-based traffic model for each city had been validated against present day (1991) traffic counts. These modelled traffic volumes have been used as measures of exposure to risk which were then compared with actual accident records.

The road classes studied are:

Collector and Arterial
Divided Arterial
Open Road
Local Street, volumes greater than 4000 vehicles per day
Local Street, volumes less than 4000 vehicles per day

Intersection control types are:

Priority X intersection
Priority T intersection
Roundabout
All signals
Signalised X and M (multileg) intersections
Signalised T intersection

2. Estimating Changes in Accident Rates

Relationships that allow estimates of the changes in vehicle accident occurrence resulting from changes made to road and traffic systems were investigated. Significant differences exist between the accident rates on different classes of road and between different intersection control types:

- Local roads have the highest number of accidents per vehicle kilometre travelled.
- Accident rates on low volume local roads do not vary in ways that correlate statistically with traffic volumes and are more likely to be related to traffic environment factors.
- Classes of the road hierarchy that are designed for high traffic volumes and higher speeds have lower accident rates per vehicle kilometre.
- The differences between accident rates at T and X intersections are very marked.

The differences between accident rates of one city and another should be useful areas for further investigation.

The study shows that reasonably reliable estimates of accident changes in accident rates can be made with the following specific conclusions:

- Low volume local roads should be omitted from the analysis.

- Four classes of roads
  - Collector and arterial
  - Divided arterial
  - Open road
  - Local street

  have distinct accident rate characteristics.

- Accident analysis can be carried out for individual cities that have adequately sized accident databases.

- Relationships for these cities should be calibrated individually.

- Accident analyses for smaller centres, with inadequately sized databases, can be carried out using the default values provided in this report.

- Traffic modelling techniques that allow the different road classes and the different intersection types and traffic control types to be identified should be used. This will enhance the reliability of estimates of change.

3. Identifying Outliers

Identification of "outliers", i.e. those locations where the accident rates are significantly higher or lower than are predicted by the formulae, has been achieved.

Instead of defining an accident "black spot" as one where a high number of accidents occur, the techniques reported here compare accident locations having a high number of accidents with traffic volumes and with other accident locations on that road class or at that intersection control type.

Techniques for finding such outliers are tested and sample outlier lists are provided.

These techniques provide powerful tools for locating those places where accident reduction measures may be most effectively employed.

4. Formulae used in Transit New Zealand Project Evaluation Manual

The consequence of the research has been the inclusion in the Transit New Zealand (1991) "Project Evaluation Manual" of formulae that predict the change in vehicle accident rates and allow a cost estimate to be made.

A weighted average cost per accident has been prepared for each road class and intersection type based on the proportion of fatal, serious and minor accidents recorded for each category.

When this cost is used in conjunction with the formulae, the expected cost of accidents can be calculated. Proposals which alter roads to improve safety can thus be evaluated, and incorporated into the economic analysis process.

ABSTRACT

A comparison of the road accident rates between five cities in New Zealand was undertaken between 1989 and 1991. Accident data from these cities were coded onto validated road networks prepared for transportation studies. Accident rates have been calculated using accident data and modelled traffic volumes, and significant differences in accident rates are apparent.

To determine the correlation between traffic volume and accident rate within the road classes and intersection types, detailed regression analyses were applied to the five cities.

The analyses were also used to identify outliers (locations with significantly higher or lower accident rates than usual) and thus identify accident "black spots".

They can be used to estimate costs of accidents for inclusion in economic evaluation of projects, to ensure that proposals to change a traffic or road system, or to employ an accident reduction measure, will be the most economically effective.

1. INTRODUCTION

1. INTRODUCTION

1.1 Background

Transportation studies are used to investigate roading proposals in terms of road network operation and economic evaluation, using system-wide transportation models and accident analysis.

Accident analysis for such studies tends to be left for manual evaluation at the stage of preparing a funding application. However, with the increasing emphasis on providing benefit/cost ratios at the scheme planning stage, provision of a reasonable estimate of accident savings over a whole road network[1] at the same time that the user benefits are required is becoming important.

Changes made to road networks that result in significant shifts of traffic from one road class to another through intersections with different types of control have potential to significantly change the number of accidents that occur in the "before" and "after" situations. Accident analyses of such changes are particularly useful.

This research, undertaken between 1989 and 1991, is based on the hypothesis that accidents can be related to some function of the number of vehicles on a road link, or at an intersection. Such relationships are not normally undertaken as traffic flow statistics are not available over the whole of a city unless a computer model has been developed, and used to estimate traffic on all roads.

The methodology adopted in this study was to take traffic data of cities where validated models exist in consistent formats, and allocate each accident to a link[1] or node (intersection)[1] in the modelled network. As a result, accident rates were able to be calculated, as explained in subsequent sections.

This report contains accident analyses for five cities in New Zealand meeting these requirements, that also represent large and small urban areas, namely:

Whangarei
North Shore
Hamilton
Christchurch
Timaru

Five years of accident data sets from Land Transport Division of Ministry of Transport (LTD MOT) (now Land Transport Safety Authority (LTSA))[2] were matched to the model networks and accident rates calculated for a series of road classes and intersection types.

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1 See Section 1.3 for definitions.

2 For this report, the acronym LTD MOT is retained.

In this context, accident rates are a measure of the "number of accidents per unit of traffic flows". This measure provides a different dimension to the term "black spots" which commonly uses "number of accidents that occur at a site".

Accident rates showed significant differences that needed to be explored. Analytical methods needed to be developed, tested and agreed on, step by step. Different means of disaggregating and analysing the data were explored to develop an appropriate methodology for estimating the changes in accident rates after significant changes have been made to an urban road network.

Analysis of the data showed correlations existing between the models for traffic volume and accident distributions which were considered sufficient to justify the use of predictive formulae in system-wide road accident analysis for other cities in New Zealand.

Originally four reports[3] set out the study process in a very detailed and chronological manner. The four stages of the project and the reports are:

Stage 1	October 1989: Gabites Porter Ltd 1989
Stage 2	December 1990: Gabites Porter Ltd 1990
	January 1991 (extension): Gabites Porter Ltd 1991a
Stage 3	July 1991: Gabites Porter Ltd 1991b; 1991c
Stage 4	September 1991: Gabites Porter Ltd 1991d

For summaries of the study, see Tai et al. (1991a, b).

This report is a summary of the above reports, to record the results of this progressive investigation of the relationships between accidents and traffic volumes for different road classes and intersection types. It contains the critical findings and recommendations, with enough information for practitioners to understand and use the results appropriately, and some additional information, particularly in respect of the "Project Evaluation Manual" (Transit New Zealand 1991).

It should be noted that the progressive nature of the study meant that there were many cases of successive refinement, re-working of data, and re-reporting. Only the final versions have been included in this report.

1.2 Study Objectives

The primary objectives of the study were:

- To explore the reasons for any apparent differences in accident rates across five cities (Christchurch, Hamilton, North Shore, Timaru and Whangarei).

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3 The original reports are available from Transit New Zealand for researchers who intend to follow the research in detail.

- To assess which global statistics are most important to compare networks.

- To determine if a correlation exists between traffic volume and accident rate within each road class or intersection type.

- To develop a database containing information on accident rate relationships for different road classes and intersection types.

- To develop a method of estimating total accident changes when an urban road network is changed.

- To develop a methodology, based on accident analysis, that allows accident savings in a network-wide situation to be incorporated systematically within the procedures of economic evaluation.

- To develop a method by which sites with abnormally high accident rates can be identified.

1.3 Definition of Terms

Several terms have been used in this report that may not be in common usage. Some of these are:

Accident Rate	-	number of accidents/unit of exposure.
Model	-	a mathematical representation of traffic flow.
Network	-	that part of the physical roads represented in the model.
Link	-	the length of road between two intersections.
Intersection	-	junction of two or more roads.
Node	-	an intersection included in the model.
Link Accident	-	accident occurring on a link, unrelated to a node.
Intersection Accident	-	accident occurring at a node (coded as "I" in the LTD MOT accident data).
System	-	the modelled network and traffic flows.
Exposure	-	the number of vehicles on a link or entering an intersection.

1.4 Key Findings

The following relationships were the most important points arising from the study:

- Different road classes and different intersection control types are associated with significantly different accident rates.

  Road classes are:
  - Collector and Arterial
  - Divided Arterial
  - Open Road
  - Local Street, volumes greater than 4000 vehicles per day (vpd)
  - Local Street, volumes less than 4000 vehicles per day (vpd)

  Intersection control types are:
  - Priority X intersection
  - Priority T intersection
  - Roundabout
  - All signals
  - Signalised X and M (multileg) intersections
  - Signalised T intersection

- Link accidents (i.e. occurring between major intersections) were found to correlate best in a linear relationship with traffic volumes.

- Intersection accidents correlated best in a quadratic relationship.

- No satisfactory correlation was found between traffic volumes and accident costs, probably because of an undue influence from the large weighting given to the cost of fatal accidents. This means that:

  - A relatively slight shift in the distribution of fatal accidents could induce large fluctuations in the total cost of accidents for a particular sample.

  - The use of regression formulae in accident cost should therefore be exercised with caution.

  - Only average costs for each road type should be used.

- Accidents were disaggregated by time, to improve the correlation with traffic volumes. However, the results did not favour this procedure. Any future analysis by time should include all injury accidents and 24-hour traffic volumes.

- Low volume local streets (with less than 4000 vpd) had very low correlation between accidents and traffic volumes.

1.5 Factors Limiting Use of Results

The factors which practitioners should keep in mind when using the results of this research include the following:

- The accident records used were those compiled by the LTD MOT from traffic accident reports.

  Only injury accidents were included because non-injury accidents were not available for all the years used for the analysis.

  No adjustments were made for under-reporting rates, except in the final analysis of average accident costs.

- Not all injury accidents are included in the analysis.

  The modelled road networks of the five cities used as the source for traffic volumes did not include all roads. For instance, the percentage of roads included in the networks ranged from 40% to 80% of all roads.

  Only the accidents which occurred on the network roads of the study cities were included. However, these roads accounted for 80% - 85% of all link accidents and 92% - 95% of all intersection accidents.

- The traffic volumes used in this project were produced by traffic models which represent average Monday to Thursday 24-hour flows, and were not based on average annual daily traffic volume (AADT).

  To represent the 24-hour flows as annual volumes, a standard multiplier of 330 was used for all road types.

- Intersection accidents were those coded as "I" (i.e. occurring at an intersection) on the accident record.

  The first analyses that were attempted were based on "I + 30" (i.e. accidents occurring at and within 30m of an intersection), but they were not consistent with other analyses of intersection accidents.

  The "I" convention simplifies decision-making and is consistent with other analyses, but may understate the influence of the intersection in some cases.

- Link accident data include some accidents at minor intersections. Where a road which is coded into a city network intercepts a minor road which has not been coded into the network, the model produces no intersection flow data with which to compare accidents. Consequently, those accidents become included in the link data for the network road.

  Link accidents are therefore more precisely defined as "link and minor intersection accidents", or "link accidents between major intersections". This definition was appropriate in this study because of its emphasis on transportation network analysis, but may give link results which differ slightly from a conventional "mid-block" accident analysis (see Section 2.3.1).

2. STUDY NETWORKS & STATISTICS USED FOR ANALYSES

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2.1 Road and Accident Statistics

The demographic, roading and accident statistics of the five cities are summarised in Table 2.1. Only the injury accident data set was analysed in this study. Non-injury and non-reported accident data could not be included satisfactorily.

Table 2.1 Demographic, roading and accident statistics for the five cities.

Study Area	Population (1986) [1]	Total Length (km) of Road [2]	Total Accidents per Year [3]	Accidents per Year per Thousand People	Accidents per Year per Kilometre
Christchurch	272,000	1654	1351	4.97	0.82
Hamilton	94,500	361	305	3.23	0.84
North Shore	162,000	563	513	3.17	0.91
Timaru	27,600	127	84	3.04	0.66
Whangarei	44,000	213	123	2.80	0.58

Note: [1] NZ Year Book.
[2] Extracted from "Roading Statistics" published by National Roads Board (1989).
[3] Extracted from Ministry of Transport Accident Data. For each city, a minimum of 5 years data was used.

2.2 Adequacy of Data

Christchurch area has by far the longest length of roading of the five cities. It has about three times that of North Shore (the next largest) and 13 times that of Timaru (the smallest). As the sizes of the networks are so disparate, it is important in a comparative study of this kind that the indices or measures of comparison are standardised and made comparable.

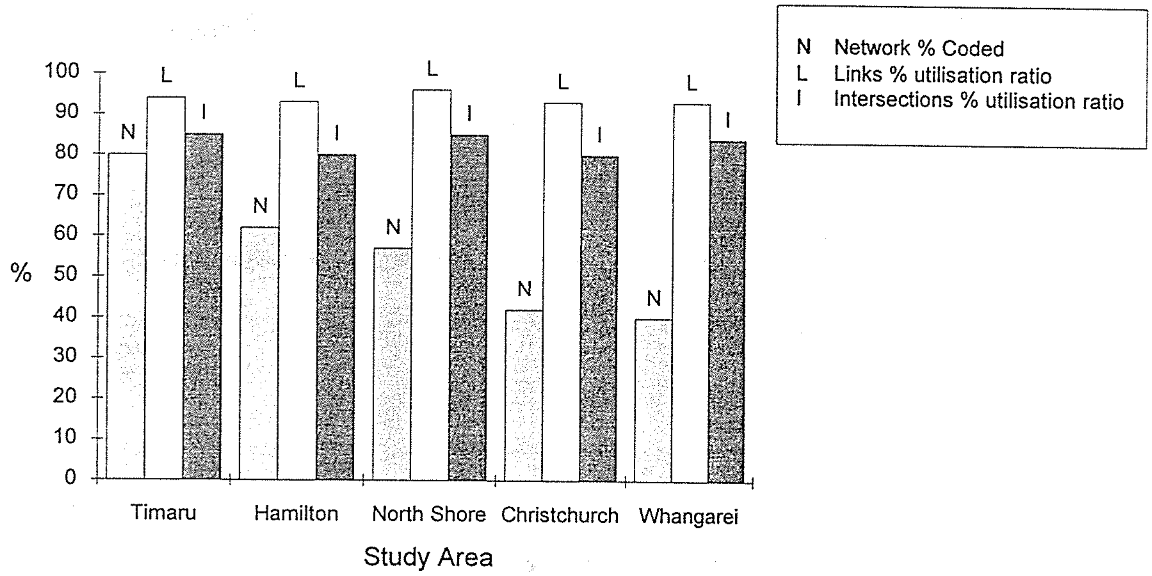
Models can vary enormously in the amount of detail that is included. As shown in Table 2.2, about 80% of the Timaru roads are included in its model, while only 42% of roads are included in the model for Christchurch.

However, because models tend to be set up to include the major roads, and most accidents occur on major roads, more than 90% of all link accidents occur on roads included in the model and more than 80% of all intersection accidents occur at intersections included in the model. The ratio of accidents coded onto the network to the total accidents has been termed the "Utilisation Ratio". These ratios are shown in Table 2.2 and in graphical form as Figure 2.1.

Table 2.2 Network detail and utilisation ratio.

Study Area	Network % Coded	Utilisation Ratio Links (%)	Utilisation Ratio Intersections (%)
Timaru	80	94	85
Hamilton	62	93	80
North Shore	57	96	85
Christchurch	42	93	80
Whangarei	40	93	84

Figure 2.1 Network detail and utilisation ratio.



As the accident-data utilisation ratios are consistently high for these five cities, their coded networks should be adequate for use in a system-wide analysis.

Before beginning a study that is to include accident analysis, the percentage of accidents occurring on the coded network should be checked. If this percentage is less than 80 - 85%, accident data for more links may need to be obtained and the detail of the model adjusted accordingly.

2.3 Disaggregation of Accidents

Disaggregation of accidents according to road class hierarchy, intersection types, or the time of accident can provide more meaningful and, perhaps, more fruitful analyses of road accidents. This is now widely recognised (Chapman 1978 (UK); Dalby 1979 (UK); Humphreys *et al.* 1979 (USA); Andreassen 1983 (Australia)).

2.3.1 Disaggregation by Road Class and Intersection Type

Accidents were disaggregated at two levels. First as either intersection or link accidents, because accident risks at intersections are different from those experienced on links and should be the subject of independent analysis (McGuigan 1981). Then link accidents were classified according to an hierarchy of road classes (Section 3.1), and intersection accidents according to control types (Section 4.1).

Only roads of some traffic significance have been included (coded) in the networks because the traffic models and their associated networks were not intended to address problems which require the consideration of every minor road in the network.

Consequently intersections between coded network roads and non-coded network (minor) roads, called "minor intersections", have not been included. Accidents occurring at such minor intersections have been allocated in the accident record to the relevant network road as a non-intersection, i.e. a link, accident. Link accidents should therefore be more properly termed "link and minor intersection accidents".

This process of accident allocation does not affect data for major intersection types, as virtually all signalised roundabout intersections occur on the network roads. Priority X and T intersections are generally the only types that occur between network roads and minor non-network roads.

2.3.2 Disaggregation by Time

Promising results were shown initially when accidents were disaggregated by time. For both local streets and undivided arterials the weekday business-hours accidents correlated better with volume than did the full accident data. However, when the analysis was repeated for 24-hour modelled flows against four accident groups in later stages of the study, the result was not achieved again. Only T junctions showed an improved correlation as a result of the disaggregation. Therefore disaggregation by time was not pursued further and the results are not included in this report.

2.4 Distribution of Accidents at Links and Intersections

In most countries road users are more likely to be involved in accidents at intersections than at locations remote from intersections (McGuigan 1981). A number of Australian studies (Goonewardene 1983; Hoque 1989) agree with this suggestion, but accident data from the five New Zealand cities appear to suggest otherwise.

Table 2.3 shows that in four of the five New Zealand cities analysed, the number of link accidents exceeded the number of intersection accidents. North Shore and Whangarei showed a considerable bias towards link accidents, Christchurch and Hamilton had only a slight bias, while Timaru was the exception with intersection accidents marginally more dominant.

Table 2.3 Distribution (%) of accidents at intersections and links.

Location	Intersection Accidents (%)	Link Accidents (%)	Total (%)
New Zealand			
North Shore	36	64	100
Whangarei	41	59	100
Christchurch	49	51	100
Hamilton	46	54	100
Timaru	54	46	100
Australia			
Australian Capital Territory (Canberra)[1]	58	42	100
Metropolitan Melbourne[2]	58	42	100

1 Goonewardene (1983)
2 Hoque (1989)

Because definitions between Australia and New Zealand were different, an early task of the research was to re-define "intersection accident" to include all those accidents occurring within 30m of an intersection. Results from Table 2.2 were re-calculated to include these accidents and are shown in Table 2.3.

Table 2.4 Distribution (%) of accidents at intersections (within 30m of intersection) and links.

Location	Intersection Accidents (I+30m) (%)	Link Accidents (%)	Total (%)
North Shore	48	52	100
Whangarei	52	48	100
Christchurch	58	42	100
Hamilton	65	35	100
Timaru	65	35	100

The LTD MOT standardised definition of intersection accident (i.e. accident occurring at a node, coded as "I" in LTD MOT accident data), has been used for this study to retain consistency. Using this revised definition of "intersection accident", the distribution of intersection and link accidents in the cities are now in better agreement with the findings of McGuigan (1981, 1982), Goonewardene (1983), and Hoque (1989).

Tables 2.3 and 2.4 illustrate the importance of having standard definitions for intersection and link accidents, particularly when making comparisons across cities or between countries.

2.5 Comparison of Accident Rates for the Five Cities

2.5.1 Physical Indices

The first level of comparison was to compare accident rates according to the physical characteristics, that is without reference to traffic volumes:

Intersection Accidents
Rate = Intersection accidents per year per intersection.

Link Accidents
Rate = Link accidents per year per kilometre of road.

Both rates are expressed in "accidents per year", the total number of accidents averaged over the time (in years) that accident records are available.

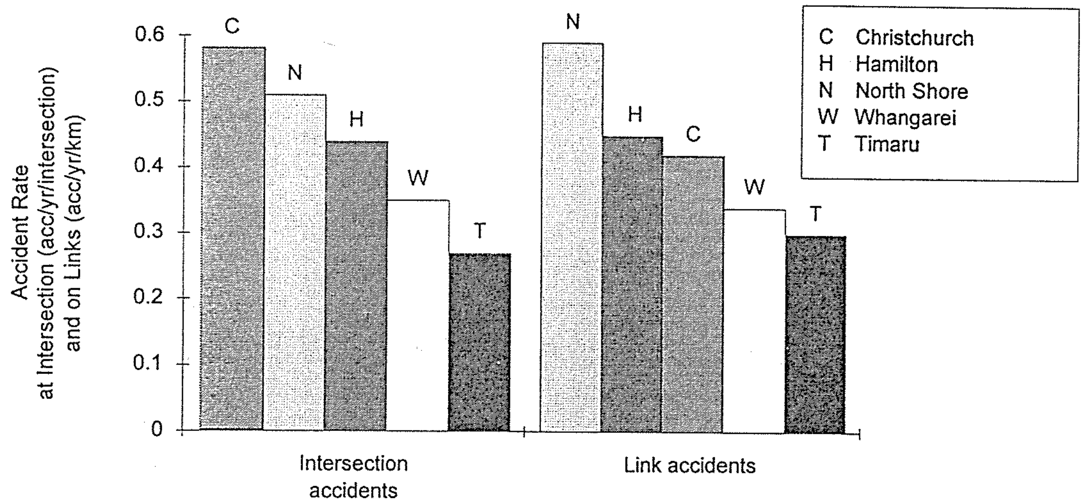
Figure 2.2 compares the intersection and link accident rates in the five cities with the use of the above indices, while Table 2.5 tabulates these rates in descending order.

Table 2.5 Comparison of accident rates for the five cities (Physical Index).

Study Area	Intersection Accident Rate (acc/yr/intersection)	Study Area	Link Accident Rate (acc/yr/km)
Christchurch	0.58	North Shore	0.59
North Shore	0.51	Hamilton	0.45
Hamilton	0.44	Christchurch	0.42
Whangarei	0.35	Whangarei	0.34
Timaru	0.27	Timaru	0.30

Accident rates for intersections and links are clearly different. Accident rates for Christchurch, North Shore and Hamilton, when measured with the above indices, are of a different and higher order than those for Whangarei and Timaru.

Figure 2.2 Comparison of accident rates for the five cities.



2.5.2 Exposure Related Indices

A second level of comparison used accident rates calculated to relate the number of accidents to traffic volume. The two indices developed were:

Intersection Accidents

Rate = Intersection accidents divided by annual volume of traffic entering intersection.

The rate is expressed in "accidents per year per 100 million (M) vehicles (veh)".

Link Accidents

Rate = Link accidents divided by link length and annual volume of traffic using the link.

The rate is expressed in "accidents per year per 100 million (M) vehicle-kilometres (veh-km)".

Table 2.6 Comparison of accident rates for the five cities (Exposure Related Index).

Study Area	**Intersection Accident Rate (acc/yr/100M veh)**		**Study Area**	**Link Accident Rate (acc/yr/100M veh-km)**	
Christchurch	17.05	(128%)	Christchurch	63.95	(130%)
Hamilton	12.34	(92%)	Timaru	46.19	(94%)
North Shore	9.34	(70%)	North Shore	41.51	(85%)
Whangarei	8.16	(61%)	Hamilton	30.24	(62%)
Timaru	7.87	(59%)	Whangarei	30.10	(61%)
Average	**13.37**		**Average**	**49.10**	

* Values in parentheses : percentage of the average accident rate across the five cities.

Figure 2.3 Link and intersection accident rates expressed by Exposure Index, for the five cities.

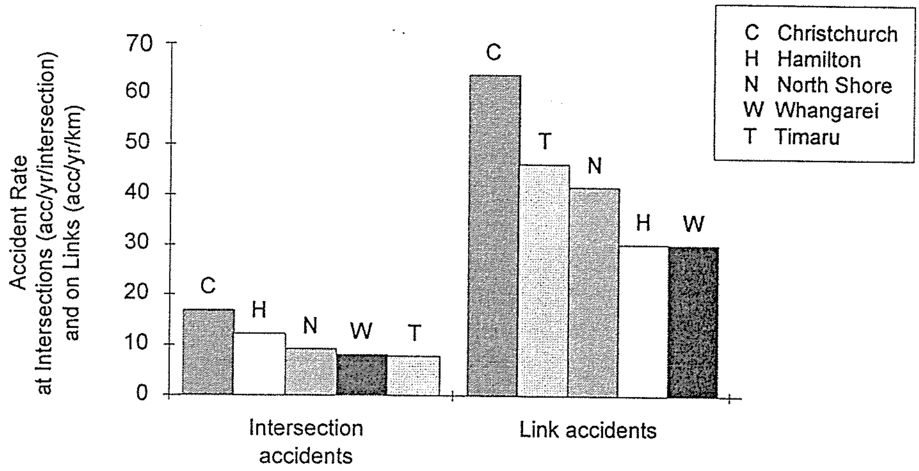


Table 2.6 and Figure 2.3 show that accident rates in Christchurch are about 30% higher than the average across the five cities, for both intersection and link accidents.

The analyses show that the accident rates for the other four cities are below the average, and that the distinctly and significantly higher accident rates in Christchurch are a cause for concern.

2.6 Cluster Analysis

2.6.1 Definition

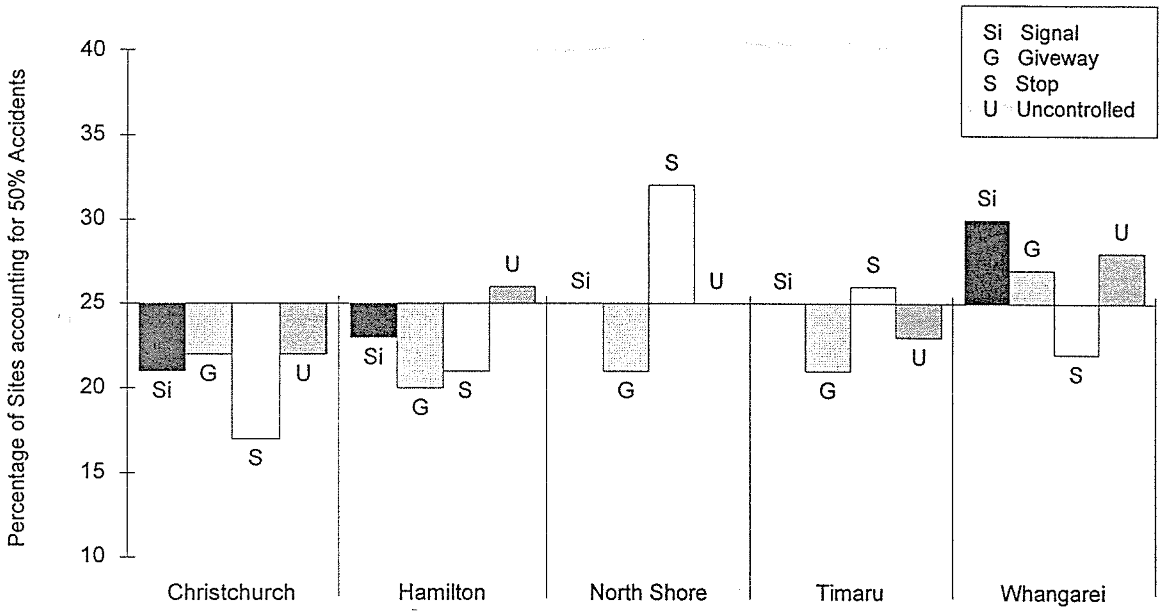
Cluster analysis was first used by Andreassen and Hoque (1987) to describe *"the situation when a few sites (say 25%) account for a large proportion (say 50%) of a particular accident type"*. It is a measure of the level of concentration of accidents in a small proportion of sites. The levels of concentration are "clustered" or "non-clustered". In their study, Andreassen and Hoque's convention of 25% sites for 50% accidents was adopted as the base line from which to assess the phenomenon of clustering.

This base line was applied to this study to establish the level of clustering across the five cities, and to determine how accidents were distributed on the road networks of the five cities. As clustering for each city differed significantly from the others, explanations for the differences were sought.

However, defining clusters of accidents on roads has problems and so only intersection accidents were analysed for clustering as a trial. Link accidents were not analysed for clustering.

Accident clusters were compared for each intersection control type for all five cities by calculating the percentage of sites accounting for 50% of the accidents in each control type. The results are shown in Figure 2.4.

Figure 2.4 Cluster analysis of intersection accidents for the five cities.



2.6.2 Results of Cluster Analysis

Results of the cluster analysis for all the five cities show Christchurch to have the most severe level of clustering for accident distribution for all the intersection control types. The percentages of accident sites accounting for 50% of the accidents for the original four intersection types - signal, give way, stop, uncontrolled - are 21%, 22%, 18% and 22% respectively. The next most severe case of clustering occurs in Hamilton, with corresponding percentages of accident sites of 23%, 20%, 21% and 26%, respectively.

Whangarei has the highest level of non-clustering. Only one control type - the stop control - shows a level of clustering more severe than the base level of 25% (Figure 2.4). Values for the other three control types range between 27% and 30%.

North Shore shows that accidents at give-way intersections are the most clustered with 21% of the sites accounting for 50% of the accidents. Clustering at traffic signal and uncontrolled intersections are relatively less severe with both just reaching the 25% base level. Distribution of accidents at stop-controlled intersections, in contrast to the Hamilton case, appears to be quite evenly spread with 33% of the sites accounting for 50% of the accidents.

Timaru data indicate the existence of clustering at the give-way and uncontrolled intersection types (with corresponding values for the accident site percentages of 21% and 23% respectively). Accidents at signalised intersections in Timaru were not tested for clustering because of the small sample size available.

2.6.3 Implications of Severe Clustering

Severe clustering implies an unreasonable level of accident concentration at a small number of sites.

If the problem occurs across all intersection types in the area, as recorded in Christchurch, the clusters should be investigated to establish whether they relate to traffic volume, i.e. if the clusters correlate strongly with high traffic volume levels, or to the physical environment, i.e. if they correlate more with physical characteristics such as weather or topography.

If they are related to traffic volume, analyses relating accidents with traffic volumes should then be further disaggregated by volume range. In that case, disaggregation by volume range should be applied to both intersection and link accidents. This was trialled in later stages of the study but results were not encouraging and were not pursued further.

3. CORRELATING LINK ACCIDENTS WITH TRAFFIC VOLUMES

3. CORRELATING LINK ACCIDENTS WITH TRAFFIC VOLUMES

3.1 Statistics

Statistics related to accidents on links and at minor intersections in the five cities sampled are given in Table 3.1.

Link accidents were classified according to an hierarchy of road classes.
The first hierarchy that was used (and illustrated in Figure 3.1) was as follows:

Collector	undivided, urban
Arterial	undivided, urban, rural
Open Road /Arterial	divided, urban, rural
Open Road	undivided, rural
Local Street	undivided, urban

These classes related to the codings adopted by the local authorities for the road networks and they correlated in only general terms with the definitions used in the District Schemes of that time.

Later in the project, a further disaggregation of link accidents was made according to the following hierarchy of road classes:

Collector and Arterial	undivided, urban
Divided Arterial	divided, urban
Open Road	undivided, rural
Local Street	volumes greater than 4000 vpd
Local Street	volumes less than 4000 vpd

Link accidents include all the accidents occurring between network and non-network roads, and thus include accidents at minor intersections.

Results recorded in this report are generally those obtained for the later hierarchy but it is useful to report a little of the earlier work.

Table 3.1 Accidents on links and at minor intersections, for the five cities.

Road Class	Accident Sample Size	Length of Road (km)	Vehicle Travel (Mveh-km/yr)	Accidents per Year	Accident Rate (acc/100M veh-km/yr)
Collector	1285	520	829.62	432	52.1
Arterial	662	390	738.61	346	46.9
Divided Arterial	124	52	231.89	72	31.0
Open Road	291	267	404.01	118	29.2
Local Street	641	154	102.98	91	89.2
Total	**3003**	**863**	**2307.11**	**1059**	**45.9**

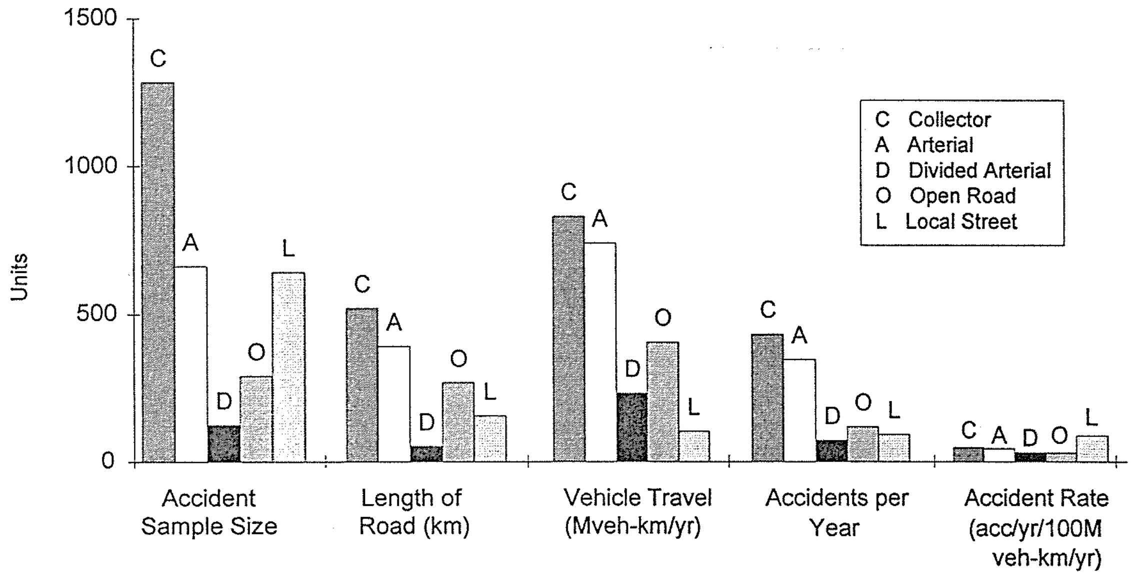


Figure 3.1 Percentage share (%) of vehicle travel and accidents per year, for the five road classes used in the early stages of the project.

3.2 Selection of Model Form

Regression using two model forms for link accidents were tested:

(A) Linear Model $Y = a + bX$

(B) Quadratic Model $Y = a + bX + cX^2$

where Y is the dependent variable, in accidents/year and X is the independent variable, in million veh-km (sum of two way volumes, all lanes).

The comparisons in Table 3.2 show that the simpler linear model is preferred because the coefficient for the X^2 term in the quadratic model is consistently not significant at the $\alpha = 0.01$ level. (An α of 0.01 means a 0.01 chance that the outcome was a result of random error.)

The significance test indicates how significant the correlation is between the dependent variable Y and its predictors X and X^2.

The linear model was thus adopted for correlating link accidents with traffic flows on the five road classes in all later work.

Table 3.2 Comparison of linear and quadratic models for link accidents on five road classes.

Road Class	**Model Form**	**R^2**	**Significance of Coefficient at $\alpha = 0.01$ level**	
			bX	***cX^2***
Collector	Linear	0.362	sig.	-
	Quadratic	0.363	sig.	not sig.
Arterial	Linear	0.454	sig.	-
	Quadratic	0.459	sig.	not sig.
Divided Arterial	Linear	0.407	sig.	-
	Quadratic	0.403	sig.	not sig.
Open Road	Linear	0.407	sig.	-
	Quadratic	0.344	sig.	not sig.
Local Street	Linear	0.303	sig.	-
	Quadratic	0.309	sig.	not sig.

sig. = significant
not sig. = not significant

3.3 Development of Equations

3.3.1 Explanation of Regression Results

R^2 measures the proportion of variance explained by the predictor (in this case, the amount of vehicle travel) in the proposed model. It ranged between 0.30 and 0.45.

A major reason for this range might be that some relevant variables, that are closely associated with the immediate road environment (such as road geometry and land-use frontage, e.g commercial, residential, industrial or rural), were not included in the model. The inclusion of such variables as additional predictors would probably improve the explanatory power and the R^2 value of the model.

Further investigation of the suitability of the proposed models was also carried out using their respective residual plots. These showed a discernible horizontal residual band, indicating that they are indeed predictive models.

The estimated injury accident rate, represented by the slope of the regression line, is one of the most important statistics derived from the regression results. The size of its standard error or of its associated confidence interval band, which gives a measure of the uncertainty in the estimated rate, is within 4 - 10% for the five road classes.

The ranges of accident rates for the 95% confidence interval bands (i.e. the spread between upper and lower values) are given in Table 3.4. The confidence intervals show three distinct confidence interval bands which do not overlap: Local Street band, Collector-Arterial band, and Divided Arterial-Open Road band.

3.3.2 Test for Equality of Slopes

Confirmation that these bands are distinct was carried out using a statistical test for equality of slopes (Draper and Smith 1981, pp. 59-60). Results of the test for equality of slopes of the regression lines are presented in Table 3.3.

The test for equality of slopes between Undivided and Divided Arterials is of particular significance. The statistical test has firmly rejected the hypothesis that the regression lines for the two classes of urban Arterials (Divided and Undivided) are equal. The results indicate instead that they are different and thus their injury accident rates are statistically different from one another.

Table 3.3 Results of test for equality of regression line slopes.

Test	**Outcome on Hypothesis of Equality of Slopes ($\alpha = 0.01$)**	**Remarks concerning Accident Rates**
Local v Collector Local v Arterial	Rejected Rejected	Significantly different for Local Street than for Collector and Arterial
Collector v Arterial	Accepted	Statistically not different on Collector and Arterial
Collector v Divided Arterial Collector v Open Road Arterial v Divided Arterial Arterial v Open Road	Rejected Rejected Rejected Rejected	Significantly different on Collector and Arterial than for Divided Arterial and Open Road
Divided Arterial v Open Road	Accepted	Statistically not different on Divided Arterial and Open Road

As a result of the testing, the road classifications were grouped as:

Collector and Arterial
Divided Arterial
Open Road
Local Street, volumes greater than 4000vpd
Local Street, volumes less than 4000vpd

3.4 Analysis of Combined Data of Five Cities

The regression equations for the combined accident data of all five cities for the grouped road classes used for link accident analysis are summarised in Table 3.4.

Table 3.4 Results for regression analysis of combined accident data by road class, for the five cities.

Road Class	Equation of Model* $Y = a + bX$	95% Confidence Interval of Coefficient *b* (slope)		R^2	Model through Origin $Y = bX$
		Lower	Upper		
Arterial and Collector	$Y = 0.011 + 0.503X$	0.481	0.525	0.56	$Y = 0.509X$
Divided Arterial	$Y = -0.065 + 0.359X$	0.292	0.426	0.55	$Y = 0.334X$
Open Road	$Y = 0.076 + 0.285X$	0.252	0.318	0.52	$Y = 0.308X$
Local Street (>4000vpd)	$Y = -0.027 + 0.814X$	0.657	0.971	0.48	$Y = 0.790X$
Local Street (<4000vpd)	*little correlation*	-	-	0.05	-

* Y = Link accidents/year
X = Vehicle travel in million vehicle-kilometres/year (Mveh-km/yr)
vpd = Vehicles per day
$>$ = greater than $<$ = less than

Local Streets with traffic volume of less than 4000 vpd show very little correlation between accidents and traffic volume. This suggests that, at low traffic volume, accident occurrences are less dependent on traffic and that other factors (geometry, land-use frontage) might be more important.

Erratum: Table corrected and page substituted August 1995

3.5 Analysis of Data of Individual Cities

Results for regression analysis of the five individual cities by road class are shown in Table 3.5. Note that simplified equations forced through the origin have also been derived.

Table 3.5 Results of regression analysis by road class, for the five individual cities.

a. Road Class : Collector and Arterial

City	Equation of Model $Y = a+bX$	95% Confidence Interval of Coefficient b (slope)		R^2	Model through Origin $Y = bX$
		Lower	Upper		
Christchurch	$Y = 0.038 + 0.573X$	0.534	0.612	0.51	Y = 0.593X
Hamilton	$Y = 0.041 + 0.388X$	0.339	0.437	0.47	Y = 0.420X
North Shore	$Y = -0.076 + 0.483X$	0.450	0.516	0.70	Y = 0.453X
Timaru*	$Y = 0.003 + 0.401X$	0.321	0.481	0.35	Y = 0.408X
Whangarei	$Y = 0.012 + 0.284X$	0.343	0.425	0.67	Y = 0.388X
All 5 Cities	$\mathbf{Y = 0.011 + 0.503X}$	**0.481**	**0.525**	**0.56**	$\mathbf{Y = 0.509X}$

* Because of the nature of the sample, the model is statistically unsatisfactory.

b. Road Class : Divided Arterial

City	Equation of Model $Y = a + bX$	95% Confidence Interval of Coefficient b (slope)		R^2	Model through Origin $Y = bX$
		Lower	Upper		
Christchurch	$Y = -0.180 + 0.403X$	0.285	0.521	0.49	$Y = 0.339X$
Hamilton	$Y = 0.062 + 0.313X$	0.164	0.462	0.47	$Y = 0.336X$
North Shore*	–	–	–	–	–
Timaru*	–	–	–	–	–
Whangarei*	–	–	–	–	–
All 5 Cities	$\mathbf{Y = -0.065 + 0.359X}$	**0.292**	**0.426**	**0.55**	$\mathbf{Y = 0.334X}$

* Sample too small to be statistically significant.

c. Road Class : Open Road

City	Equation of Model $Y = a + bX$	95% Confidence Interval of Coefficient b (slope) Lower	Upper	R^2	Model through Origin $Y = bX$
Christchurch	$Y = 0.183 + 0.293X$	0.234	0.352	0.58	$Y = 0.341X$
Hamilton	$Y = -0.024 + 0.404X$	0.279	0.529	0.58	$Y = 0.396X$
North Shore	$Y = 0.030 + 0.243X$	0.190	0.296	0.45	$Y = 0.251X$
Timaru	$Y = 0.027 + 0.303X$	0.232	0.374	0.59	$Y = 0.321X$
Whangarei*	–	–	–	–	–
All 5 Cities	$\mathbf{Y = 0.076 + 0.285X}$	**0.252**	**0.318**	**0.52**	$\mathbf{Y = 0.308X}$

* Sample too small to be statistically significant.

d. Road Class : Local Street (volumes greater than 4000 vpd)

City	Equation of Model $Y = a + bX$	95% Confidence Interval of Coefficient b (slope) Lower	Upper	R^2	Model through Origin $Y = bX$
Christchurch	$Y = 0.099 + 0.862X$	0.609	1.115	0.43	$Y = 0.946X$
Hamilton	$Y = 0.000 + 0.692X$	0.518	0.866	0.83	$Y = 0.692X$
North Shore	$Y = -0.136 + 0.501X$	0.381	0.621	0.77	$Y = 0.374X$
Timaru*	–	–	–	–	–
Whangarei	$Y = -0.102 + 0.682X$	0.557	0.807	0.88	$Y = 0.458X$
All 5 Cities	$\mathbf{Y = -0.027 + 0.814X}$	**0.657**	**0.971**	**0.48**	$\mathbf{Y = 0.790X}$

* Sample too small to be statistically significant.

e. ***Road Class : Local Street (volumes less than 4000 vpd)***

City	Equation of Model $Y = a + bX$	95% Confidence Interval of Coefficient b (slope) Lower	Upper	R^2	Model through Origin $Y = bX$
Christchurch	*little correlation*	–	–	0.009	*n.a.*
Hamilton	*little correlation*	–	–	0.000	*n.a.*
North Shore	*little correlation*	–	–	0.038	*n.a.*
Timaru	*little correlation*	–	–	0.080	*n.a.*
Whangarei	*little correlation*	–	–	0.000	*n.a.*
All 5 Cities	***little correlation***	**–**	**–**	**0.046**	***n.a.***

n.a. = not applicable

3.6 Tests for Equality of Slopes and Comparisons Between Cities

Accident rates by road class, estimated from the regression models for the individual cities, were compared using statistical tests for equality of slopes.

The results suggest that accident rates on the arterial roads in Christchurch and North Shore are of similar order but are higher than those in Hamilton and Whangarei. However the estimated rate from the combined data is statistically different from, and hence is not representative of, the individual cities.

North Shore City appears to have significantly lower accident rates on collectors than have the other cities. Thus, with the exception of North Shore City, the estimated regression model from the combined data for collectors may be used to represent the other four cities.

3.7 Volume/Capacity Bands

To determine whether the correlation between accidents on links and minor intersections and traffic volumes for a particular road class is better represented by a series of straight lines rather than by one single linear regression line, analyses of the accident data were carried out for bands defined by different volume/capacity (v/c) ratios.

Three v/c bands, defined by the v/c ratio ranges 0.00 - 0.33, 0.33 - 0.67 and 0.67 - 1.00, were proposed. Given the road classification used in this study, a standard capacity has been assumed for each of the five road classes. Within each road class, different v/c bands could then be approximated by their corresponding traffic volume bands.

The division of the level of vehicle travel into volume bands for a particular road class offered, in general, less meaningful models than a model from a single regression line. The R^2 values from the regression models associated with the volume bands were found to be very low, lying mainly within the range of 0.00 and 0.16.

Models with such low R^2 values are inappropriate for any evaluation purposes and the analyses were not continued.

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4. CORRELATING INTERSECTION ACCIDENTS WITH TRAFFIC VOLUMES

4. CORRELATING INTERSECTION ACCIDENTS WITH TRAFFIC VOLUMES

4.1 Statistics

Statistics related to accidents at intersections in the five study cities are given in Table 4.1.

Intersection accidents were at first classified according to control type as follows:

Signal
Give Way (Priority)
Stop (Priority)
Uncontrolled

Later in the project, intersection accidents were disaggregated according to control type and geometry as follows:

Priority X intersection
Priority T intersection
Roundabout
All Signals
Signalised X and M (multileg) intersections
Signalised T intersection

Intersections between coded network roads and non-coded network (minor) roads, called "minor intersections", have not been included in the analysis. Accidents occurring at such minor intersections have been allocated in the accident record as non-intersection or link accidents.

This process of allocating accidents occurring at minor intersections to link accidents of a network road does not affect the data for major intersection types, as virtually all signal and roundabout intersections occur on network roads. Priority X and T intersections are the only types that occur between network and minor (non-network) roads.

Table 4.1 Accidents at intersections for the five cities.

Intersection Control Type	Accident Sample Size	Traffic Volume (Mveh/yr)	Accidents /Year	Accident Rate (acc/Mveh/yr)
Priority X	113	405	69	17.03
Priority T	260	1000	112	11.20
Roundabout	37	213	39	18.31
All Signals	253	1722	341	19.80
Total	**663**	**3340**	**561**	**16.79**

At this global level, priority T intersections seem to provide the most favourable statistics from a safety view point. Signalised intersections fare worst, being high both in traffic volume and accident counts.

4.2 Selection of Model Form

As for link accidents, regression of the following two model forms for intersection accidents were tested and comparisons are shown in Table 4.2:

(A) Linear Model $Y = a + bX$
(B) Quadratic Model $Y = a + bX + cX^2$

where Y, the dependent variable, is accident occurrences per year and X, the independent variable, is traffic volume in million vehicles per year.

Table 4.2 Comparison of linear and quadratic models for intersection accidents at four intersection control types.

Intersection Control Type	Model Form	R^2	Significance of Coefficient at $\alpha = 0.01$ bX	cX^2
Priority X	Linear	0.420	sig.	–
	Quadratic	0.442	not sig.	not sig.
Priority T	Linear	0.389	sig.	–
	Quadratic	0.402	not sig.	sig.
Roundabout	Linear	0.374	sig.	–
	Quadratic	0.424	not sig.	not sig.
All Signals	Linear	0.356	sig.	–
	Quadratic	0.380	not sig.	sig.

sig. = significant; not sig. = not significant

These tests show the following points:

1. The quadratic model consistently showed a better explanatory power in terms of its R^2 value than the linear form.

2. The correlation between Y and X in the quadratic model was consistently non-significant, as revealed by the significance test on the b coefficient.

3. The correlation between Y and the X^2 term in the quadratic model was found to be significant for half of the cases (i.e. Priority T and Signal).

As a result, a quadratic model without the X term of the form:

(C) $Y = a + cX^2$

was added for testing.

4.3 Regression Analysis of Intersection Accidents by Intersection Type

The results of the regression analysis for the three model forms by intersection type are given in Table 4.3.

Table 4.3 Results of regression analysis for three model forms by intersection control type.

Intersection Control Type	Equation of Model (A) $Y = a+bX$ (B) $Y = a+bX+cX^2$ (C) $Y = a+cX^2$	R^2	Standard Error of Coefficient			Significance Test ($\alpha = 0.01$)	
			a	*b*	*c*	*b*	*c*
Priority X	$Y = -0.230+0.251X$	0.420	0.094	0.028	-	sig.	-
	$Y = 0.084+0.018X\ 0.034X^2$	0.442	0.165	0.105	0.015	not sig.	not sig.
	$Y = 0.111+0.036X^2$	0.446	0.060	-	0.004	-	sig.
Priority T	$Y=-0.090+0.134X$	0.389	0.043	0.010	-	sig.	-
	$Y = 0.054+0.041X+0.011X^2$	0.402	0.070	0.037	0.040	not sig.	sig.
	$Y = 0.123+0.016X^2$	0.402	0.029	-	0.001	-	sig.
Roundabout	$Y = -0.182+0.215X$	0.374	0.262	0.045	-	sig.	sig.
	$Y =-0.610-0.095X+0.026X^2$	0.424	0.468	0.160	0.013	not sig.	-
	$Y = 0.348+0.018X^2$	0.435	0.150	-	0.003	-	not sig.
All Signals	$Y = -0.281+0.239X$	0.356	0.139	0.020	-	sig.	sig.
	$Y = 0.618-0.059+0.022X^2$	0.380	0.308	0.093	0.007	not sig.	-
	$Y = 0.431+0.018X^2$	0.382	0.082	-	0.001	-	sig.

sig. = significant not sig. = not significant

Comparison of the regression results suggests that the model of the form $Y=a+cX^2$ gives the best fit of the three models tested, both in terms of its R^2 value and the magnitude of the standard error of its coefficients. Examination of the residual plots from the quadratic model for the four intersection types also indicates that it is a possible model.

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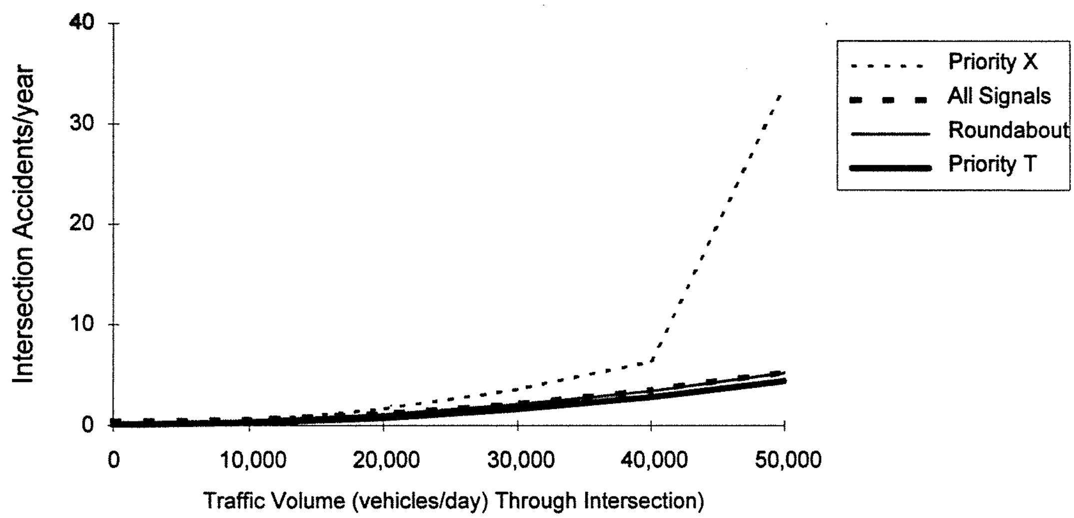
Consequently, the quadratic model (C) $Y = a+cX^2$ is preferred over models (A) and (B). The regression equations estimated for the four intersection types were:

Priority X: $Y = 0.111 + 0.036X^2$
Priority T: $Y = 0.123 + 0.016X^2$
Roundabout: $Y = 0.348 + 0.018X^2$
All Signals: $Y = 0.431 + 0.018X^2$

For ease of comparison, these estimated regression models are displayed together graphically in Figure 4.1 below. Note that this diagram is in vehicles per day, i.e. the number of vehicles per year divided by 330.

Figure 4.1 Estimated regression lines for the four intersection control types.



Within the traffic volume range examined (i.e. 0–50,000 veh/day), the analysis indicates that intersection accidents tend to increase monotonically with intersection traffic volumes.

Priority T intersections appear to exhibit the lowest rate of increase (coefficient $c=0.016$) and are consistently the safest throughout the entire volume range examined.

Roundabout and Signal intersections are estimated to have the same rate of increase ($c=0.018$) which is marginally higher than that for T intersections, but then they were found to operate at higher and wider ranges of traffic volume than both the priority X and T intersection types. Roundabout intersections operate best generally within the 0 – 40,000 veh/day range, and Signal intersections at the 5,000 – 50,000 veh/day range.

Priority X intersections display the highest rate of increase ($c=0.036$) in injury accidents with respect to traffic volume.

4.4 Analysis of Combined Data of Five Cities

Regression results on the combined data from the five cities by the intersection types that were used for later stages of the project are summarised in Table 4.4 and graphically in Figure 4.2. *(It should be noted that the definition of an intersection accident was changed in the later stages of the project from being accidents that happened within 30 m of an intersection to those which occurred at the intersection.)*

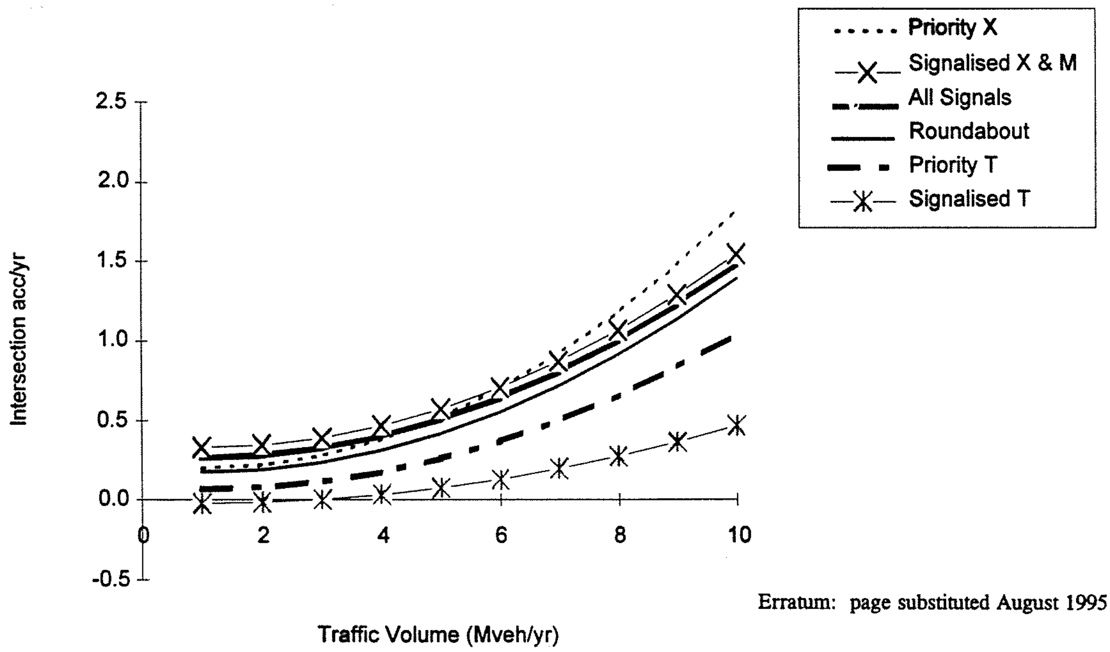
Table 4.4 Results for regression analysis of combined data by intersection control type, for the five cities.

Intersection Control Type	Equation of Model $Y = a + bX^2$	95% Confidence Interval of Coefficient b (slope)		R^2	Model through Origin $Y = bX^2$
		Lower	Upper		
Priority X	$Y = 0.202 + 0.020X^2$	0.016	0.024	0.31	$Y = 0.027X^2$
Priority T	$Y = 0.070 + 0.012X^2$	0.010	0.014	0.34	$Y = 0.014X^2$
Roundabout	$Y = 0.178 + 0.015X^2$	0.011	0.019	0.49	$Y = 0.017X^2$
All Signals	$Y = 0.269 + 0.015X^2$	0.013	0.017	0.36	$Y = 0.018X^2$
Signalised X & M	$Y = 0.332 + 0.015X^2$	0.013	0.017	0.37	$Y = 0.019X^2$
Signalised T	$Y = - 0.019 + 0.006X^2$	0.004	0.008	0.31	$Y = 0.005X^2$

Y = Predicted intersection accidents/year
X = Traffic volume (million vehicles/year)

M = Multileg intersection
X = Cross intersection
T = T intersection

Figure 4.2 Graphical representation of regression results given in Table 4.4.



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A contrast of the difference in the estimated accident rates between intersections of different physical form (X, T and M) and of different control type (unsignalised and signalised) is presented in Table 4.5.

Table 4.5 Contrast in estimated accident rates between intersections of different physical form and different control type.

Physical Form	**Coefficient *b***
Priority X	0.020
Priority T	0.012
Difference	**- 0.008 (- 40%)**
Signalised X, M	0.015
Signalised T	0.006
Difference	**- 0.009 (- 60%)**
Control Type	**Coefficient *b***
Unsignalised X	0.020
Signalised X	0.015
Difference	**- 0.005 (- 25%)**
Unsignalised T	0.012
Signalised T	0.006
Difference	**- 0.006 (- 50%)**

The implications are that, at intersections operating at high traffic levels, e.g. with four million vehicles/year (approximately 12,000 vpd) and above, signals have the potential to reduce the accident rate significantly. As much or even greater reduction could be expected if the physical form of the intersections can be kept to the simpler T layout.

Priority T intersections, whether signalised or non-signalised, appear to have the best safety records.

Congregating approaches into more complicated M or X intersections would not be expected to achieve as great a reduction in accidents.

Erratum: Table corrected and page substituted August 1995

4.5 Analysis of Data of Individual Cities

Regression results for the individual cities are given in Table 4.6, as are the equations when they are forced through the origin.

An equation of form $a + bX^2$ implies a latent risk of accidents even with zero volume through the intersection. The a coefficient may either be termed a miscalibration or, for very low volumes, it could be said to reflect other factors influencing the accident rate not accounted for by the volume. The best fit model through the origin equations have been provided to show the coefficient when based purely on volume.

Table 4.6 Regression results by the six intersection control types, for the five individual cities.

a. ***Intersection Type : Priority X***

City	**Equation of Model** $Y = a + bX^2$	**95% Confidence Interval of Coefficient** b **(slope)**		R^2	**Model through Origin** $Y = bX^2$
		Lower	**Upper**		
Christchurch	$Y = 0.316 + 0.026X^2$	0.018	0.034	0.32	$Y = 0.038X^2$
Hamilton	$Y = 0.121 + 0.024X^2$	0.012	0.036	0.34	$Y = 0.028X^2$
North Shore*	–	–	–	–	–
Timaru	$Y = 0.077 + 0.018X^2$	0.012	0.024	0.43	$Y = 0.022X^2$
Whangarei*	–	–	–	–	–
All 5 Cities	$Y = 0.202 + 0.020X^2$	**0.016**	**0.024**	**0.31**	$Y = 0.027X^2$

* Sample inadequate or too small to be statistically significant.

b. Intersection Type : Priority T

City	Equation of Model $Y = a + bX^2$	95% Confidence Interval of Coefficient b (slope)		R^2	Model through Origin $Y = bX^2$
		Lower	Upper		
Christchurch	$Y = 0.072 + 0.012X^2$	0.010	0.014	0.38	$Y = 0.014X^2$
Hamilton	$Y = 0.068 + 0.014X^2$	0.010	0.018	0.42	$Y = 0.016X^2$
North Shore	$Y = 0.052 + 0.014X^2$	0.010	0.018	0.39	$Y = 0.016X^2$
Timaru	$Y = 0.027 + 0.009X^2$	0.007	0.011	0.47	$Y = 0.010X^2$
Whangarei	$Y = -0.020 + 0.015X^2$	0.009	0.021	0.45	$Y = 0.014X^2$
All 5 Cities	$Y = 0.070 + 0.012X^2$	**0.010**	**0.014**	**0.34**	$Y = 0.014X^2$

c. Intersection Type : Roundabout

City	Equation of Model $Y = a + bX^2$	95% Confidence Interval of Coefficient b (slope)		R^2	Model through Origin $Y = bX^2$
		Lower	Upper		
Christchurch	$Y = 0.182 + 0.020X^2$	0.016	0.024	0.63	$Y = 0.022X^2$
Hamilton*	–	–	–	–	–
North Shore	$Y = 0.085 + 0.008X^2$	0.004	0.012	0.50	$Y = 0.009X^2$
Timaru*	–	–	–	–	–
Whangarei*	–	–	–	–	–
All 5 Cities	$Y = 0.178 + 0.015X^2$	**0.011**	**0.019**	**0.49**	$Y = 0.017X^2$

* Sample size too small to be statistically significant.

d. Intersection Type : Signals (All Intersection Types)

City	Equation of Model $Y = a + bX^2$	95% Confidence Interval of Coefficient b (slope)		R^2	Model through Origin $Y = bX^2$
		Lower	Upper		
Christchurch	$Y = 0.431 + 0.015X^2$	0.011	0.019	0.37	$Y = 0.020X^2$
Hamilton	$Y = -0.150 + 0.024X^2$	0.014	0.034	0.39	$Y = 0.021X^2$
North Shore	$Y = -0.119 + 0.013X^2$	0.007	0.019	0.41	$Y = 0.011X^2$
Timaru*	–	–	–	–	–
Whangarei	$Y = -0.034 + 0.014X^2$	0.004	0.024	0.31	$Y = 0.014X^2$
All 5 Cities	$\mathbf{Y = 0.269 + 0.015X^2}$	**0.013**	**0.017**	**0.36**	$\mathbf{Y = 0.018X^2}$

* Sample size too small to be statistically significant.

e. Intersection Type : Signalised X and M Intersections

City	Equation of Model $Y = a + bX^2$	95% Confidence Interval of Coefficient b (slope)		R^2	Model through Origin $Y = bX^2$
		Lower	Upper		
Christchurch	$Y = 0.494 + 0.015X^2$	0.011	0.019	0.36	$Y = 0.020X^2$
Hamilton	$Y = -0.283 + 0.026X^2$	0.016	0.036	0.47	$Y = 0.021X^2$
North Shore	$Y = -0.050 + 0.011X^2$	0.005	0.017	0.54	$Y = 0.011X^2$
Timaru*	–	–	–	–	–
Whangarei	$Y = -0.033 + 0.014X^2$	0.004	0.024	0.31	$Y = 0.015X^2$
All 5 Cities	$\mathbf{Y = 0.332 + 0.015X^2}$	**0.013**	**0.017**	**0.37**	$\mathbf{Y = 0.019X^2}$

* Sample size too small to be statistically significant.

f. ***Intersection Type : Signalised T Intersections***

City	Equation of Model $Y = a + bX^2$	95% Confidence Interval of Coefficient b (slope)		R^2	Model through Origin $Y = bX^2$
		Lower	Upper		
Christchurch	$Y = 0.053 + 0.007X^2$	0.003	0.011	0.35	$Y = 0.007X^2$
Hamilton*	–	–	–	–	–
North Shore	$Y = -0.125 + 0.006X^2$	0.002	0.010	0.38	$Y = 0.005X^2$
Timaru*	–	–	–	–	–
Whangarei*	–	–	–	–	–
All 5 Cities	$Y = -0.019 + 0.006X^2$	**0.004**	**0.008**	**0.31**	$Y = 0.005X^2$

* Sample size too small to be statistically significant.

4.6 Tests for Equality of Slopes and Comparisons between Cities

As the statistical test for equality of slopes applies only to linear models, a different approach to intersection accidents was needed to assess the representative nature of the combined model and the extent of variation between individual cities.

A regression band of $\pm$ 2 standard errors, i.e. 95% confidence interval, from the combined model is used as a bandwidth. Thus the band is bounded by the two equations which are derived by adding and subtracting two standard errors respectively to the coefficients of the regression model from the combined data.

Any deviation outside the band may then be considered as excessive and likely to be different from the combined model. It is not a statistical test, but it provides a graphical measure of how far one model deviates from the other.

4.6.1 Priority X Intersections

Of the three cities tested for accidents at priority X intersections, results from only Hamilton and Timaru lie within the band. Christchurch had a very high accident rate at priority X intersections which was well above the prescribed band over the full traffic volume range.

4.6.2 Priority T Intersections

For priority T intersections, Hamilton and North Shore show the worst accident rates, followed by Whangarei and Christchurch. Timaru displays the best safety record with accidents at priority T intersections having a rate that is consistently below the prescribed band.

4.6.3 Roundabouts

For roundabouts, only Christchurch and North Shore had large enough samples to warrant meaningful statistical analysis. The analysis revealed a large variation in roundabout accident rate between the two cities, although the rate for Christchurch was more than double that for North Shore at any one point along the traffic range.

4.6.4 Signals - All Intersection Types

Analysis for all signalised intersections showed that Hamilton and Christchurch have the worst accident rates, particularly for intersections operating at high traffic volume range. North Shore and Whangarei provide the best safety records for signalised intersections with their estimated rates lying consistently below the prescribed regression band.

5. ANALYSIS OF OUTLIERS FOR TWO CITIES

5. ANALYSIS OF OUTLIERS FOR TWO CITIES

5.1 Methodology

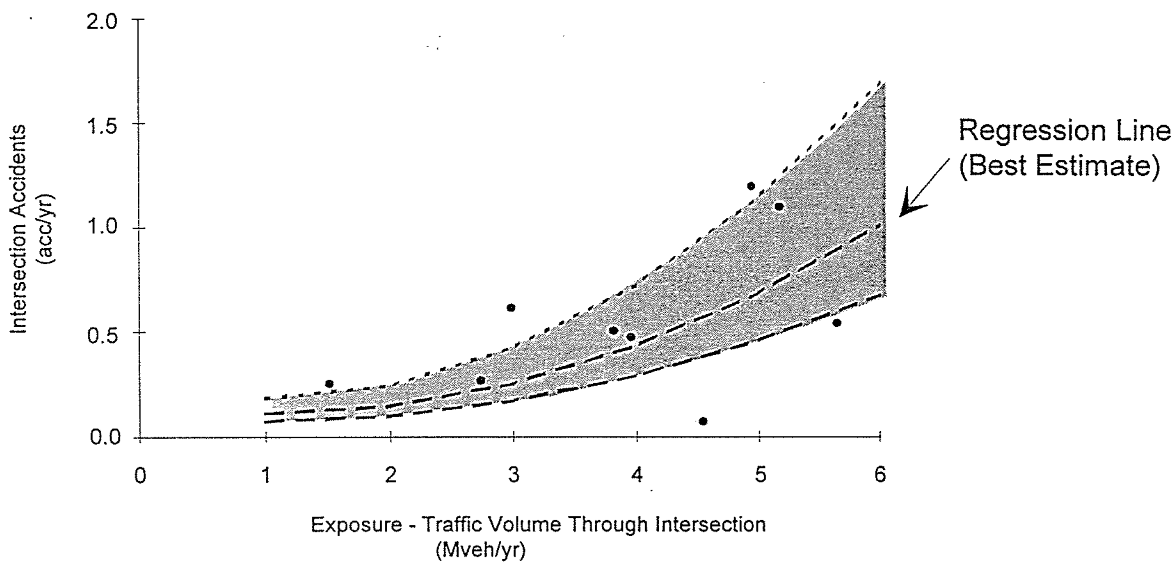
Outliers, or accident "black spots", can be identified in a number of ways, e.g. direct accident counts, clustering, regression bands. Using **direct accident counts** is the most commonly used approach, in which a particular site where the number of accidents exceeds a threshold level may be tagged as a "black spot".

The concept of **clustering** (Section 2.6) is another approach to identify black spots, adopted by Andreassen and Hoque (1987). It is a measure of the level of concentration of accidents in a small proportion of sites but does not relate to traffic volumes.

The problem with most approaches however is their inability to incorporate a measure of exposure in the procedure. A spot with a higher level of traffic exposure is expected to have a higher accident potential and, hence, a higher accident count than another location with a lower exposure. Thus a high accident count does not necessarily make the location a "black spot".

The **regression band** concept is the approach adopted here, in conjunction with the regression analysis to identify outliers. It involves the superimposition of the scattergram plot of a particular accident type onto a prescribed regression band together with the estimated regression line. The concept is shown in Figure 5.1.

Figure 5.1 The regression band approach applied to, for example, a Priority X intersection.



Every data point on the scattergram represents the accident history of a link segment (or an intersection) expressed in terms of its recorded accident rate and its corresponding level of traffic exposure, i.e. vehicle travel or traffic volume.

The estimated regression line represents the average that is specific to the particular city, and how the accident rate is expected to vary with traffic exposure. The band defines the limits outside which a data point may be considered to have deviated excessively from the general trend.

The extent of deviation may be measured with reference to its distance from the regression band as well as by its Studentised residual[4] value from the estimated regression line.

The regression band approach was applied to two cities: Timaru and Whangarei. One road class and one intersection type from the Timaru data are included in this section as examples. The remaining data for Timaru and all for Whangarei are included in the relevant report (i.e. Gabites Porter Ltd 1991b).

5.2 Outlier Analysis of a Selected City

In Timaru, outliers for the only two road classes and two intersection types that had sufficiently large samples for meaningful regression analysis were examined. The roads and intersections are:

Collector
Open Road
Priority X
Priority T

The results of this analysis, for the collector roads and priority X intersections only, are given here.

5.2.1 Outlier Analysis for One Road Class

Eight collector roads deviated excessively (either higher or lower) from the general trend, as indicated by their distances from the regression band and their extreme Studentised residual values. The results are shown on Table 5.1, and expressed graphically on Figure 5.2.

At their particular level of traffic exposure, the significantly higher accident rates for H1 to H5 means that these entries may be considered as outliers to that network, while L1 to L3 are also outliers but they have low accident rates.

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4 Studentised residual is a statistical measure of deviation computed in regression analysis, in which an outlier with greater deviation is more significant.

Figure 5.2 Scattergram plot of accidents on collector roads in Timaru, superimposed onto a prescribed regression band with the estimated regression line.

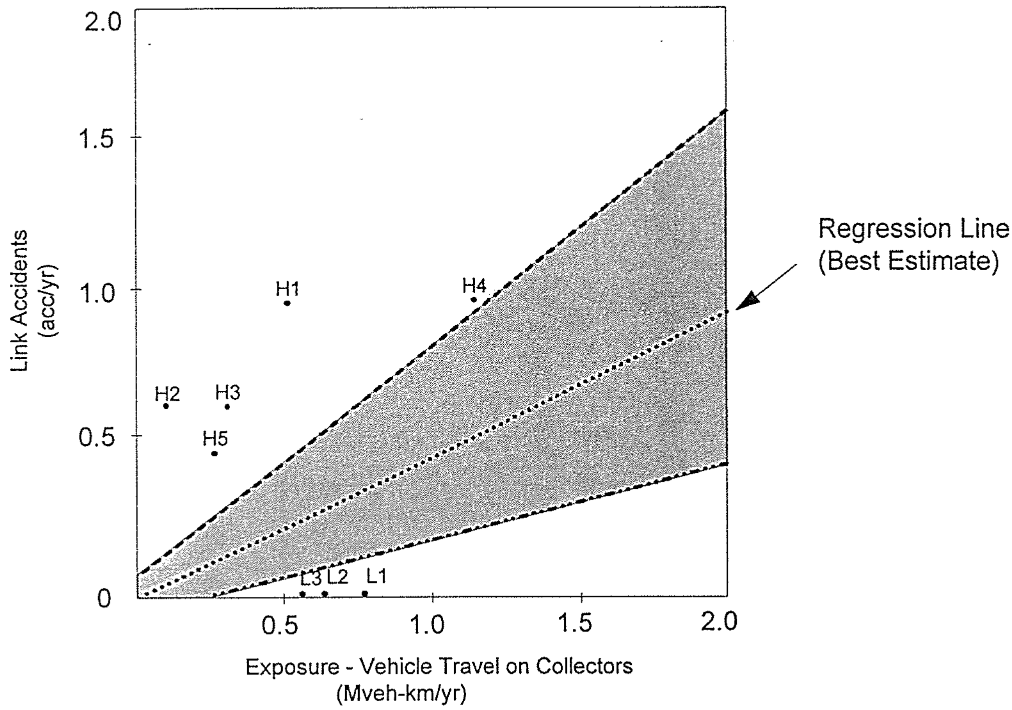

Table 5.1 Attributes of outliers for accidents on collectors in Timaru.

Outlier	Location (between roads)	Deviation (Studentised Residual)	Level of Exposure (Mveh-km/yr)	Recorded Link Accident Rate (acc/yr)	Expected Link Accident Rate (acc/yr)
H1	Waiti Road (Broadway/Kauri)	5.585	0.530	1.000	0.239
H2	Bouverie Street (Grants/Luxmoore)	4.401	0.060	0.670	0.039
H3	Grasmere Street (Selwyn/Evans)	3.639	0.290	0.670	0.137
H4	Waiti Road (Barnes/Broadway)	3.546	1.230	1.000	0.537
H5	Stafford Street (Cliff/North)	2.616	0.220	0.500	0.107
L1	Edward Street (Queen/King)	–2.208	0.730	0.000	0.324
L2	Racecourse Road (SH1/Laughton)	–1.858	0.620	0.000	0.277
L3	Stafford Street (Sarah/Sefton)	–1.705	0.570	0.000	0.256

5.2.2 Outlier Analysis for One Intersection Type

Results from the outlier analysis for intersection accidents at priority X intersections in Timaru are given in Figure 5.3 and Table 5.2.

Figure 5.3 Scattergram plot of accidents at priority X intersections in Timaru, superimposed onto a prescribed regression band with the estimated regression line.

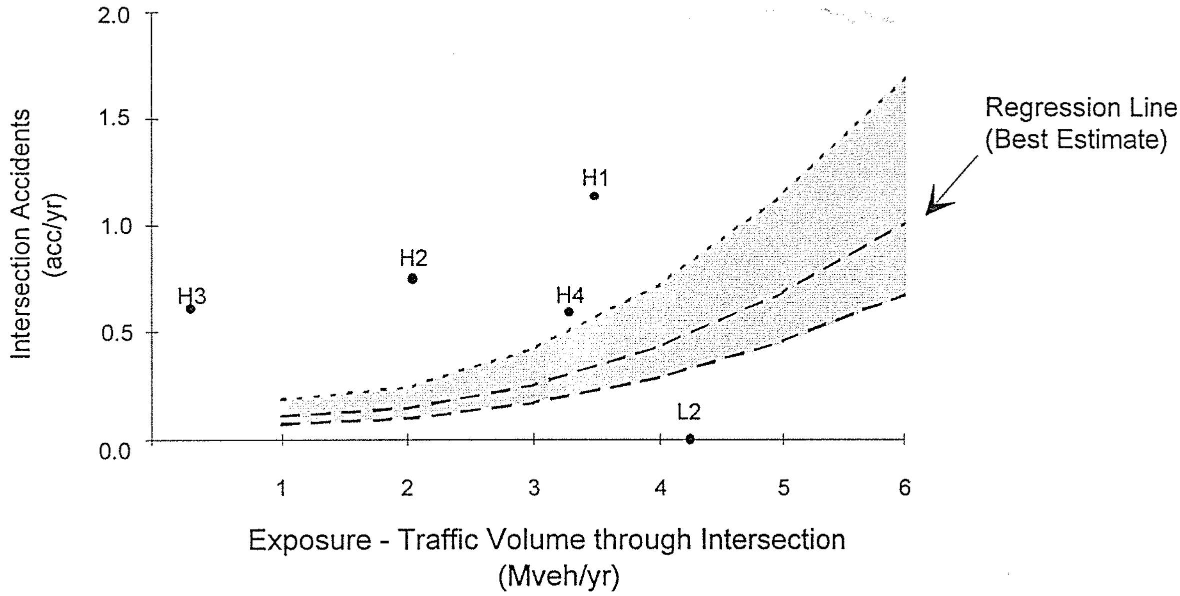

Table 5.2 Attributes of outliers for accidents at priority X intersections in Timaru.

Outlier	Intersection Location	Deviation (Studentised Residual)	Level of Exposure (Mveh/yr)	Recorded Intersection Accident Rate (acc/yr)	Expected Intersection Accident Rate (acc/yr)
H1	Church/Wilson	3.702	3.400	1.170	0.270
H2	Church/Le Cren	2.393	2.380	0.830	0.202
H3	Barnard/Woollcombe	1.991	0.560	0.670	0.141
H4	SH1: (King)/Queen	1.545	3.130	0.670	0.250
L1	Stafford/Heaton	−1.336	4.420	0.000	0.361

5.3 Summary

Using the regression band approach, derived from the regression analyses of road classes and intersection types, any data points that lie outside the regression band are defined as those that have deviated excessively (either higher or lower) from the general trend.

The ability to identify these outliers or black spots has great potential for making our roads safer because the causes for these concentrations of accidents can then be investigated, leading to more productive and efficient strategies for accident prevention.

6. ACCIDENT COSTS

6. ACCIDENT COSTS

6.1 Introduction

Accident costs are an important value to determine as they are used to estimate the cost-effectiveness of a change to a road network that may have been proposed for reducing accident frequency and accident distribution.

Accident costs are estimated according to their severity (minor, serious or fatal), in relation to road class, intersection type and traffic volume. They have been derived from unit costs (in 1990 NZ dollars) and from reporting rates originally given in Road Research Unit (RRU) "Technical Recommendation TR9" (Bone 1986), now superseded by "Project Evaluation Manual" (PEM) (Transit New Zealand 1991).

However, before the average cost of accidents could be determined, the proportions of accidents by severity occurring on the road networks of each of the five cities had to be investigated.

6.2 Proportions of Accidents by Severity

The proportions of accidents by severity for the different road classes (Table 6.1) and intersection types (Table 6.2) of the individual cities are based on the traffic accident reports from the LTD MOT.

6.2.1 Proportions of Accidents by Severity by Road Class

Table 6.1 Proportions of accidents by severity for six road classes for the five cities, and their combined data.

a. ***Road Class : Collector and Arterial***

City	Proportions of Accidents (%)		
	Fatal	**Serious**	**Minor**
Christchurch	2.74	28.79	68.47
Hamilton	3.35	28.55	68.10
North Shore	4.00	33.62	62.38
Timaru	1.63	29.27	69.10
Whangarei	4.20	29.40	66.40
All 5 Cities	**3.17**	**29.79**	**67.04**

b. Road Class : Divided Arterial

City	Proportions of Accidents (%)		
	Fatal	**Serious**	**Minor**
Christchurch	2.55	29.08	68.37
Hamilton	5.82	28.16	66.02
North Shore	3.67	30.27	66.06
Timaru	4.35	26.09	69.56
Whangarei	4.76	23.81	71.43
All 5 Cities	**3.76**	**28.76**	**67.48**

c. Road Class : Open Road

City	Proportions of Accidents (%)		
	Fatal	**Serious**	**Minor**
Christchurch	6.83	40.96	52.21
Hamilton	7.03	25.00	67.97
North Shore	6.00	35.20	58.80
Timaru	3.85	33.33	62.82
Whangarei*	–	–	–
All 5 Cities	**6.24**	**35.18**	**58.58**

* Sample too small to be statistically significant.

d. Road Class : Local Street (volumes greater than 4000 vpd)

City	Proportions of Accidents (%)		
	Fatal	**Serious**	**Minor**
Christchurch	1.22	23.47	75.31
Hamilton	0.00	17.65	82.35
North Shore	3.17	33.33	63.50
Timaru	0.00	26.09	73.91
Whangarei	0.00	21.43	78.57
All 5 Cities	**1.29**	**24.31**	**74.40**

6.2.2 Proportions of Accidents by Severity by Intersection Type

Table 6.2 Proportions of accidents by severity for six intersection control types for the five cities, and their combined data.

a. ***Intersection Type : Priority X***

City	Proportions of Accidents (%)		
	Fatal	**Serious**	**Minor**
Christchurch	2.00	25.28	72.72
Hamilton	1.80	25.68	72.52
North Shore	3.26	30.43	66.31
Timaru	1.16	23.26	75.58
Whangarei	2.13	21.27	76.60
Combined	**2.01**	**25.44**	**72.55**

b. ***Intersection Type : Priority T***

City	Proportions of Accidents (%)		
	Fatal	**Serious**	**Minor**
Christchurch	1.34	25.94	72.72
Hamilton	2.37	30.77	66.86
North Shore	1.39	32.79	65.82
Timaru	1.19	20.24	78.57
Whangarei	1.41	28.87	69.72
Combined	**1.55**	**28.55**	**69.90**

c. ***Intersection Type : Roundabout***

City	Proportions of Accidents (%)		
	Fatal	**Serious**	**Minor**
Christchurch	0.66	18.42	80.92
Hamilton	0.00	28.57	71.43
North Shore	0.00	31.71	68.29
Timaru*	–	–	–
Whangarei*	–	–	–
Combined	**0.43**	**21.79**	**77.78**

* Sample too small to be statistically significant.

d. Intersection Type : All Signals

City	Proportions of Accidents (%)		
	Fatal	Serious	Minor
Christchurch	0.84	24.28	74.88
Hamilton	2.22	25.19	72.59
North Shore	2.34	25.78	71.88
Timaru*	–	–	–
Whangarei	1.22	25.61	73.17
Combined	**1.21**	**24.43**	**74.36**

* Sample too small to be statistically significant.

e. Intersection Type : Signalised X and Multi-Leg

City	Proportions of Accidents (%)		
	Fatal	Serious	Minor
Christchurch	0.94	24.79	74.27
Hamilton	2.21	26.55	71.24
North Shore	2.67	28.00	69.33
Timaru*	–	–	–
Whangarei	1.35	25.68	72.97
Combined	**1.26**	**25.07**	**73.67**

* Sample too small to be statistically significant.

f. Intersection Type : Signalised T

City	Proportions of Accidents (%)		
	Fatal	Serious	Minor
Christchurch	0.00	19.61	80.39
Hamilton	2.33	16.28	81.39
North Shore	2.00	24.00	74.00
Timaru*	–	–	–
Whangarei*	–	–	–
Combined	**1.00**	**20.40**	**78.60**

* Sample too small to be statistically significant.

6.3 Costs of Accidents by Severity for Individual Cities

6.3.1 Average Costs of Accidents

The average cost per accident for each road class or intersection type is given by the formula:

$$C(RI) = X\$M + Y\$S + Z\$F$$

where:

C(RI) is the cost of the accident on a given road class (R) or intersection type (I);

\$M, \$S, \$F are the costs of minor, serious, and fatal accidents respectively, using PEM (1991) methods;

X, Y, Z are constants for proportions of minor, serious and fatal accidents respectively.

Tables 6.3 and 6.4 give the components of the average cost per accident related to the different levels of severity by road class, intersection type, and by city.

The unit costs of accidents used for all road classes and intersection types are:

$2,174,000	fatal accidents
$80,400	serious accidents
$9,300	minor accidents

as given in Table A6.9 of PEM (1991) for urban areas with 50km/h speed limit.

For the open road with 100 km/h speed limit, the unit costs used are:

$2,484,000	fatal accidents
$99,100	serious accidents
$14,700	minor accidents

6.3.2 Accident Costs by Severity for Road Class

The components of the average cost per accident as related to severity, for the six road classes for individual cities, are presented in Table 6.3.

Table 6.3 Components of average cost per accident as related to severity, for the six road classes for individual cities.

a. ***Road Class : Collector and Arterial***

City	Components of Average Accident Cost ($)			
	Fatal	Serious	Minor	Total
Christchurch	59,600	23,100	6,400	89,100
Hamilton	72,800	23,000	6,300	102,100
North Shore	87,000	27,000	5,800	119,800
Timaru	35,500	23,500	6,400	65,400
Whangarei	91,300	23,600	6,200	121,100
Combined	**68,900**	**24,000**	**6,200**	**99,100**

b. ***Road Class : Divided Arterial***

City	Components of Average Accident Cost ($)			
	Fatal	Serious	Minor	Total
Christchurch	55,400	23,400	6,400	85,200
Hamilton	126,500	22,600	6,200	155,300
North Shore	79,800	24,300	6,100	110,200
Timaru	94,600	21,000	6,400	122,000
Whangarei	103,500	19,100	6,600	129,200
Combined	**81,700**	**23,100**	**6,300**	**111,100**

c. ***Road Class : Open Road***

City	Components of Average Accident Cost ($)			
	Fatal	Serious	Minor	Total
Christchurch	169,700	40,600	7,600	217,900
Hamilton	174,600	24,800	10,000	209,400
North Shore	149,000	34,900	8,600	192,500
Timaru	95,600	33,000	9,200	137,800
Whangarei*	–	–	–	–
Combined	**155,000**	**34,900**	**8,600**	**198,500**

* Sample too small to be statistically significant.

d. Road Class : Local Street (all)

City	Components of Average Accident Cost ($)			
	Fatal	**Serious**	**Minor**	**Total**
Christchurch	26,500	18,900	7,000	52,400
Hamilton	0	14,200	7,700	21,900
North Shore	68,900	26,800	5,900	101,600
Timaru	0	21,000	6,900	27,900
Whangarei	0	17,200	7,300	24,500
Combined	**28,000**	**19,600**	**6,900**	**54,500**

6.3.3 Accident Costs by Severity for Intersection Type

The components of the average cost per accident as related to severity, for the six intersection types used later in the project, for individual cities are presented in Table 6.4.

Table 6.4 Components of average cost per accident as related to severity, for the six intersection control types for individual cities.

a. Intersection Type : Priority X

City	Components of Average Accident Cost ($)			
	Fatal	**Serious**	**Minor**	**Total**
Christchurch	43,500	20,300	6,800	70,600
Hamilton	39,100	20,700	6,700	66,500
North Shore	70,900	24,400	6,200	101,500
Timaru	25,200	18,700	7,000	50,900
Whangarei	46,300	17,100	7,100	70,500
Combined	**43,700**	**20,500**	**6,700**	**70,900**

b. Intersection Type : Priority T

City	Components of Average Accident Cost ($)			
	Fatal	Serious	Minor	Total
Christchurch	29,100	20,900	6,800	56,800
Hamilton	51,500	24,800	6,200	82,500
North Shore	30,200	26,400	6,100	62,700
Timaru	25,900	16,300	7,300	49,500
Whangarei	30,700	23,200	6,500	60,400
Combined	**33,700**	**23,000**	**6,500**	**63,200**

c. Intersection Type : Roundabout

City	Components of Average Accident Cost ($)			
	Fatal	Serious	Minor	Total
Christchurch	14,300	14,800	7,500	36,600
Hamilton	0	23,000	6,600	29,600
North Shore	0	25,500	6,300	31,800
Timaru*	–	–	–	–
Whangarei*	–	–	–	–
Combined	**9,400**	**17,500**	**7,200**	**34,100**

* Sample too small to be statistically significant.

d. Intersection Type : All Signals

City	Components of Average Accident Cost ($)			
	Fatal	Serious	Minor	Total
Christchurch	18,300	19,500	7,000	44,700
Hamilton	48,300	20,300	6,700	75,300
North Shore	50,900	20,700	6,700	78,300
Timaru*	–	–	–	–
Whangarei	26,500	20,600	6,800	53,900
Combined	**26,300**	**19,700**	**6,900**	**52,900**

* Sample too small to be statistically significant.

e. ***Intersection Type : Signalised X and Multi-Leg***

City	Components of Average Accident Cost ($)			
	Fatal	**Serious**	**Minor**	**Total**
Christchurch	20,500	19,900	6,900	47,300
Hamilton	48,000	21,400	6,600	76,000
North Shore	58,000	22,500	6,500	87,000
Timaru*	–	–	–	–
Whangarei	29,400	20,600	6,800	56,800
Combined	**27,400**	**20,200**	**6,800**	**54,400**

* Sample too small to be statistically significant.

f. ***Intersection Type : Signalised T***

City	Components of Average Accident Cost ($)			
	Fatal	**Serious**	**Minor**	**Total**
Christchurch	0	15,800	7,500	23,300
Hamilton	50,600	13,100	7,600	71,300
North Shore	43,500	19,300	6,900	69,700
Timaru*	–	–	–	–
Whangarei*	–	–	–	–
Combined	**21,700**	**16,400**	**7,300**	**7300**

* Sample too small to be statistically significant.

6.4 Correlating Accident Costs and Exposure

Once accident costs were established, an attempt was made to check whether there was a relationship between accident cost and exposure, i.e. vehicles or volume for intersections and vehicle-kilometres for links. Christchurch was used to test this exposure.

Correlation between accident costs and exposure for Christchurch is apparently not as strong as that between accident counts and exposure as shown in Tables 6.5 and 6.6.

The R^2 values for accident counts lie mainly in the upper end of the 0.30 - 0.45 range, whereas R^2 values for costs are generally below 0.30.

Table 6.5 Correlation between accident cost on links including minor intersections by road class and exposure for Christchurch.

Road Class	**Equation of Model** $Y = a + bX$	**95% Confidence Interval of Coefficient *b* (slope)**		R^2
		Lower	**Upper**	
Arterial	$Y = 6.992 + 13.419X$	10.533	16.484	0.262
Collector	$Y = 1.554 + 16.494X$	14.495	18.493	0.295
Divided Arterial	$Y = 0.440 + 6.862X$	4.614	9.110	0.363
Open Road	$Y = 7.984 + 15.856X$	11.695	20.017	0.400
Local Street (all)	–	–	–	0.077*

* This extremely low R^2 value indicates very weak or little correlation between accident costs and exposure.

Table 6.6 Correlation between accident cost at intersections by control type and exposure for Christchurch.

Intersection Type	**Equation of Model** $Y = a + bX$	**95% Confidence Interval of Coefficient *b* (slope)**		R^2
		Lower	**Upper**	
Priority X	$Y = -1.482 + 6.797X$	3.153	10.441	0.171
Priority T	$Y = -0.192 + 2.937X$	1.871	4.003	0.216
Roundabout	$Y = 2.691 + 4.675X$	1.465	7.885	0.254
All Signals	$Y = -10.598 + 7.617X$	5.779	9.455	0.285

A fatal accident is considered to have a cost about 27 times that of a serious accident and 233 times that of a minor one. Therefore, accident cost is influenced heavily by the proportion of fatal accidents at the accident location.

Unless a strong correlation exists between accident severity distribution and exposure, attempts to correlate accident cost and exposure would not be expected to obtain good regression results. Thus, regression analysis of accident cost against exposure is at the same time both an analysis of accident occurrences and of severity distribution against exposure.

6.5 Weighted Average Costs

Using the tables in the preceding sections, and values in PEM, weighted average accident costs can be established for each road type and intersection type. These are shown in Table 6.7, while Tables 6.8 and 6.9 summarise the results of the study for use in project economic analysis. The dollar values are in July 1991 dollars, and will need updating before application.

6.6 Examples Using Results of System-wide Road Accident Analysis

The data may be used to allocate average accident rates for each road class and intersection type in a transportation model and to determine changes in accident occurrence and cost as changes are made to a road network.

To do this, the network files need to contain sufficient data fields for the appropriate codes to be included, and for the operating suite to be capable of the analysis, unless "external" analysis, e.g. by spreadsheet, is undertaken.

The data can be used to indicate likely outcomes of specific changes in road networks as shown in the two examples given on pp.69-70.

Table 6.7 Fully adjusted accident costs according to severity and road class or intersection type.

NETWORK CATEGORY	ACCIDENT TYPE																FULLY ADJUSTED TOTAL COST ($)
	FATAL INJURY				SERIOUS INJURY				MINOR INJURY				NON-INJURY				
Road Class	Average Cost ($)	Occ.	UR	Adjusted Cost ($)	Average Cost ($)	Occ.	UR	Adjusted Cost ($)	Average Cost ($)	Occ.	UR	Adjusted Cost ($)	Average Cost ($)	Occ.	UR	Adjusted Cost ($)	
Collector and Arterial	2,174,000	0.0317	1	**68,915**	80,400	0.2979	1.6	**38,321**	9,300	0.6704	2.5	**15,586**	1400	1.75	13	**31,850**	**154,674**
Divided Arterial	2,174,000	0.0376	1	**81,742**	80,400	0.2876	1.6	**36,996**	9,300	0.6748	2.5	**15,586**	1400	1.75	13	**31,850**	**166,17**
Open Road	2,484,000	0.0624	1	**155,001**	99,100	0.3518	2.2	**76,699**	14,700	0.5858	5.0	**43,056**	2400	0.8	35	**67,200**	**341,957**
Local Street (>4000)	2,174,000	0.0192	1	**41,740**	80,400	0.2431	1.6	**31,272**	9,300	0.7440	2.5	**17,298**	1400	1.75	13	**31,850**	**122161**
Intersection Type																	
Priority X	2,174,000	0.0201	1	**43,697**	80,400	0.2544	1.6	**32,726**	9,300	0.7255	2.5	**16,867**	1400	1.75	13	**31,850**	**125,141**
Priority T	2,174,000	0.0155	1	**33,697**	80,400	0.2855	1.6	**36,726**	9,300	0.6990	2.5	**16,251**	1400	1.75	13	**31,850**	**118,525**
Roundabout	2,174,000	0.0043	1	**9,348**	80,400	0.2179	1.6	**28,030**	9,300	0.7778	2.5	**18,083**	1400	1.75	13	**31,850**	**87,312**
All Signals	2,174,000	0.0121	1	**26,305**	80,400	0.2443	1.6	**31,426**	9,300	0.7436	2.5	**17,288**	1400	1.75	13	**31,850**	**106,870**
Signal. X,M	2,174,000	0.0126	1	**27,392**	80,400	0.2507	1.6	**32,250**	9,300	0.7367	2.5	**17,128**	1400	1.75	13	**31,850**	**108,620**
Signal. T	2,174,000	0.0100	1	**21,740**	80,400	0.2040	1.6	**26,242**	9,300	0.7860	2.5	**18,274**	1400	1.75	13	**31,850**	**98,107**

Factors to account for un-reported accidents:
Occ. = Occurrence multiplier
UR = Under Reporting multiplier
$ = $NZ July 1991, to nearest dollar

Adj. = adjusted
Signal. = signalised
M = Multileg intersection
X = Cross intersection
T = T intersection

Erratum: Table corrected and page substituted August 1995

Regression on Combined Data from the Five Cities by Road Class

Table 6.8 Regression equations, factors and costs for accident rates on link roads, by road class.

Accident Type	Fatal	Serious	Minor
Cost at 50 km/h	$2,174,000	$80,400	$9,300
Cost at 100km/h	$2,484,000	$99,100	$14,700

Road Class	Equation of Model $Y=a+bX$	95% Confidence Interval of Coefficient b (slope)		R^2	Model through Origin $Y = bX$	Occurrence Factor for Accident Type			Average Accident Cost ($)
						Fatal	Serious	Minor	
Collector and Arterial	$Y=0.011+0.503X$	0.481	0.525	0.56	$Y = 0.509X$	0.0317	0.2979	0.6704	**154,674**
Divided Arterial	$Y=0.065+0.359X$	0.292	0.426	0.55	$Y = 0.334X$	0.0376	0.2876	0.6748	**166,176**
Open Road	$Y=0.076+0.285X$	0.252	0.318	0.52	$Y = 0.308X$	0.0624	0.3518	0.5858	**341,957**
Local Street (>4000 vpd)	$Y=0.027+0.814X$	0.657	0.971	0.48	$Y = 0.790X$	0.0129	0.2431	0.7440	**122,161**
Local Street (<4000 vpd)	little correlation	–	–	0.05	–	–	–	–	**–**

Y = Link accidents/year
X = Exposure in million vehicle-kilometres/year
vpd = vehicles per day
$ = $NZ July 1991, to nearest dollar

Regression on Combined Data from the Five Cities by Intersection Type

Table 6.9 Regression equations, factors and costs for accident rates at intersections, by intersection control type.

Accident Type	Fatal	Serious	Minor
Cost at 50 km/h	$2,174,000	$80,400	$9,300
Cost at 100km/h	$2,484,000	$99,100	$14,700

Intersection Type	Equation of Model* $Y=a+bX^2$	95% Confidence Interval of Coefficient b (slope)		R^2	Model through Origin $Y = bX^2$	Occurrence Factor for Accident Type			Average Accident Costs ($)
						Fatal	Serious	Minor	
Priority X	$Y = 0.202+0.020X^2$	0.016	0.024	0.31	$Y = 0.027X^2$	0.0201	0.2544	0.7255	**125,141**
Priority T	$Y = 0.070+0.012X^2$	0.010	0.014	0.34	$Y = 0.014X^2$	0.0155	0.2855	0.6990	**118,525**
Roundabout	$Y = 0.178+0.015X^2$	0.011	0.019	0.49	$Y = 0.017X^2$	0.0043	0.2179	0.7778	**87,313**
All signals*	$Y = 0.269+0.015X^2$	0.013	0.017	0.36	$Y = 0.018X^2$	0.0121	0.2443	0.7436	**106,870**
Signalised X, M	$Y = 0.332+0.015X^2$	0.013	0.017	0.37	$Y = 0.019X^2$	0.0126	0.2507	0.7367	**108,621**
Signalised T	$Y = -0.019+0.006X^2$	0.004	0.008	0.31	$Y = 0.005X^2$	0.0100	0.2040	0.7860	**98,107**

Y = Intersection accidents per year
X = Traffic volume in million vehicles per year, i.e. sum of vehicles entering an intersection
$ = $NZ July, to nearest dollar

M = Multileg intersection
X = Cross intersection
T = T intersection
* = T, X, M intersections

6.6.1 Example 1

- A decision is to be made whether to change an existing two-lane arterial or collector road into a four-lane divided arterial road.

- Daily (Mon-Thurs) traffic flow is planned to carry 24,000 vehicles.

- Annual exposure (X) for a 2-km section is 24,000 x 330 x 2
  = 15.84 million vehicle kilometres.

Existing Collector or Arterial:

- Equation for model used (Table 6.8): $Y = bX$ (through origin)
- Reported injury accidents per year (Y) (Table 6.8) = 0.509 x 15.84 = 8.06
- Fully adjusted total cost of an accident (Table 6.8) for Collector and Arterial = $154,674
- Accident costs per year = $1,246,672

Divided Arterial:

- Equation for model used (Table 6.8): $Y = bX$ (through origin)
- Reported injury accidents per year (Y) (Table 6.8) = 0.334 x 15.84 = 5.29
- Fully adjusted total cost of an accident (Table 6.8) for Divided Arterial road = $166,176
- Accident costs per year = $879,071

Summary

This example shows that the advantage of a lower accident rate on the divided arterial road is not significantly reduced by the increase in severity and cost of accidents on that road class.

The benefit of introducing the median would be $367,601 per year.

6.6.2 Example 2

- A decision is to be made whether to convert a priority X intersection to either signalised X or roundabout control.

- Daily (Mon-Thurs) traffic entering the intersection is 17,000 vehicles per day.

- Annual exposure *(X)* is 330 x 17 000 = 5.61 million vehicles per year.

Existing Priority X Control

- Equation for model used (Table 6.9) $Y = bX^2$ (through origin)
- Reported injury accidents per year *(Y)* (Table 6.9) = 0.027 x 5.61^2 = 0.850
- Fully adjusted total cost of an accident (Table 6.9) for Priority X = $125,141
- Accident costs per year = $106,370

Signalised X Control:

- Equation for model used (Table 6.9): $Y = bX^2$ (through origin)
- Reported injury accidents per year *(Y)* (Table 6.9) = 0.019 x 5.61^2 = 0.598
- Fully adjusted total cost of an accident (Table 6.9) for Signalised X= $108,621
- Accident costs per year = $64,955

Roundabout Control:

- Equation for model used (Table 6.9): $Y = bX^2$ (through origin)
- Reported injury accidents per year *(Y)* (Table 6.9) = 0.017 x 5.61^2 = 0.535
- Fully adjusted total cost of an accident (Table 6.9) for Roundabout = $87,313
- Accident costs per year = $46,712

Summary

A number of points can be derived from this example:

- The benefit in converting the intersection to a roundabout is $59,658 per year, and to signals is $41,415.

- Even though there is a similar number of accidents, the roundabout accident costs are less because of the lower severity of roundabout accidents.

- The decision to accept either option will depend also on construction cost, vehicle operating costs and travel time costs.

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