# REVIEW OF ACCIDENT ANALYSIS PROCEDURES FOR PROJECT EVALUATION MANUAL

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## AN IMPORTANT NOTE FOR THE READER

The research detailed in this report was commissioned by Transit New Zealand when it had responsibility for funding roading in New Zealand. This funding is now the responsibility of Transfund New Zealand.

*The material contained in this report is the output of research and should not be construed in any way as policy adopted by Transit New Zealand or Transfund New Zealand but may form the basis of future policy.*

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# EXECUTIVE SUMMARY

The Transit New Zealand Project Evaluation Manual (1996) outlines the procedures to be adopted when evaluating roading projects in New Zealand. In 1996, as part of the periodic updating of these procedures, two aspects of the accident analysis procedures were reviewed. The aspects were:

(a) **Increased severity** - an adjustment in the calculated cost of accidents to reflect the increased severity that results from increases in traffic speed; and

(b) **Curve improvements** - the procedures used to calculate the reductions in accident rates resulting from improvements to horizontal curves. This investigation would also consider whether the accident severity cost adjustment ((a) above) should be applied when making improvements to horizontal curves.

A review of the current (1996) procedures identified that the rationale behind each procedure was sound and in keeping with other literature both in New Zealand and internationally. However, the two procedures were found to have been based on different measures of speed. In particular, the procedures for increased severity were based on an analysis of regulatory speeds which may not be a particularly good indicator of local accident severity.

Further questions were raised regarding the ability to combine procedures which had been developed from different speed and accident data sources. In order to assess the procedures, a common base has been sought for the accident and speed data.

Road geometry data to provide a network-wide measure of advisory speed, which could be related to mean traffic speeds, were used as a common base to investigate the two aspects. Strong predictive relationships between the accident severity, as measured by average accident cost and speed; and between accident rate and the difference between the approach and design speeds of curves were determined.

To do this a network-wide measure of vehicle speed had to be identified. From the state highway road geometry survey undertaken in 1992 using the Australian Road Research Board (ARRB) Road Geometry Data Acquisition System (RGDAS), a speed measure which can be related to mean traffic speed is possible to calculate. RGDAS data have been combined with traffic volumes, road cross-section data, and accident data to provide a common database for use in the analysis.

An analysis of accident data from the Land Transport Safety Authority (LTSA) Crash Investigation System (CIS), traffic volume and cross-sectional data from the National Traffic Database (NTD) and Road Assessment & Maintenance Management system (RAMM), and the RGDAS advisory speed data for New Zealand state highways, has confirmed that:

- the cost of rural accidents, i.e. accidents occurring at 100 km/h regulatory speed, increases at a rate of NZ(1996)$5,828 per accident per 1 km/h increase in mean traffic speed;
- the accident rate for curves is related to the difference ($\Delta$SD) between the approach speed or approach speed environment and the mean curve speed, and is such that the accident rate decreases by $1.025^{\Delta SD}$, i.e. a 2.5% reduction per km/h decrease in speed difference; and
- because the accident severity is related to the speed environment, a curve improvement that does not alter the overall speed environment should not be subject to an adjustment for accident severity increase.

Draft procedures have been presented for adoption for the revision of the Transit New Zealand Project Evaluation Manual.

## ABSTRACT

The Transit New Zealand Project Evaluation Manual (1996) outlines the procedures to be adopted when evaluating roading projects in New Zealand. In 1996, as part of the periodic updating of project evaluation methods, two aspects of the accident analysis procedures were reviewed. The issues addressed were the increased severity of accidents that occur at higher speeds; and the prediction of reduction in accident rates that result from improving curves.

The review first considered the rationale behind the present procedures, the basis from which these had been derived, together with other supporting studies. Both procedures were soundly based, but they were found to have been constructed using different accident and speed data. It was therefore doubtful that the two procedures should be applied together.

An analysis of accident data has confirmed that:

- the cost of rural accidents, i.e. accidents occurring at 100 km/h regulatory speed, increases at a rate of NZ(1996)$5,828 per accident per 1 km/h increase in mean traffic speed;
- the accident rate for curves is related to the difference ($\Delta$SD) between the approach speed or approach speed environment and the mean curve speed, and is such that the accident rate decreases by $1.025^{\Delta SD}$; and
- because the accident severity is related to the speed environment, a curve improvement that does not alter the overall speed environment should not be subject to an adjustment for accident severity increase.

# 1. INTRODUCTION

The Transit New Zealand Project Evaluation Manual (PEM) (Transit New Zealand 1996) outlines the procedures to be adopted when evaluating roading projects in New Zealand. In 1996, as part of the periodic review of these procedures, research into two aspects of the accident analysis procedures were addressed:

(a) **Increased severity** - an adjustment in the calculated cost of accidents to reflect the increase in accident severity that results from increases in traffic speed; and

(b) **Curve improvements** - the procedures used to calculate the accident rate reductions resulting from improvements to curves. This investigation would also consider whether the accident severity adjustment ((a) above) should be applied when making improvements to horizontal curves.

These two procedures, copies of which are provided in Appendix 1, consider the effect of traffic speed on both severity and accident rate. Presently, these procedures are expressed in terms of mean speed. However, the two studies (Bone 1992, Jackett 1992) on which the procedures were based had been undertaken independently and use subtly different measures of speed to form the relationships. This raises doubts about the relationship between the two procedures, and whether or not they should be applied together. When evaluating the accident benefits that result from improving a sub-standard curve, the current procedures at times generate a negative benefit because the increased accident severity is greater than the benefits of a reduced curve accident rate. This result has been questioned by a number of analysts.

This research reviews the present procedures, and their applications, and if necessary develops revised procedures.

To achieve these objectives, Section 2 first outlines the rationale behind the original procedures, how these procedures were derived, and the findings of selected overseas studies. After identifying that the procedures have been developed from potentially incompatible studies, the key elements of an integrated study are then identified.

Section 3 presents the framework for this integrated study to assess the effect of speed on accident severity and accident rate for curves. Section 4 details the methodology adopted, together with the data sources and details of database construction.

The results of the analysis are presented in Sections 5 and 6 which consider the effects of speed on accident severity and accident rates on curves respectively. Section 7 considers the issue of combined procedures and proposes an evaluation framework, and the conclusions are presented in Section 8. Costs are in NZ$ as at 1996, unless stated otherwise.

# 2. PREVIOUS WORK

The two procedures had been developed to answer a recognised weakness within the project evaluation system. For both of the procedures it is useful to consider the rationale behind the procedure; the research on which each of the present procedures is based; and the evidence, supporting or otherwise, of the present procedure. The supplementary issue of whether or not the two procedures should be applied together when undertaking curve realignments is then discussed.

## 2.1 Accident Severity

### 2.1.1 Rationale

The accident severity procedure is based on the finding that the severity of a given type of traffic accident will increase with increased speed. This has been discussed at length by many researchers (Finch et al. 1994, Fieldwick and Brown 1987).

The main argument is that the energy involved in an accident is related to the square of vehicle(s) speed(s) through:

$$E = ½.mv^2 \qquad \text{(Equation 1)}$$

where $E$ = energy ($kg.m^2/s^2$)
$m$ = mass (kg)
$v$ = velocity (m/s)

The greater the speed of a vehicle the more energy it has. Since the principle of conservation of energy applies, the energy (E) of the vehicle(s) before impact must be transformed into the deformation of vehicles and occupants after impact. Consequently the likelihood of a fatality will increase with greater speed. This is reflected in the increases in the estimated average economic cost for minor injury, serious injury and fatal accidents (shown in Table 2.1). The effect of increased speed is therefore a significant economic effect that must be accounted for within the economic evaluation procedures.

Table 2.1 Cost per accident by severity.
(Source: Table 6.9, Transit New Zealand PEM, February 1996)

| **Regulatory Speed Limit (km/h)** | **Total cost per accident (NZ$ July 1994) all movements combined** | | |
|---|---|---|---|
| | **Minor injury** | **Serious injury** | **Fatal** |
| 100 | $21,400 | $236,000 | $2,570,000 |
| 70 | $20,800 | $221,000 | $2,410,000 |
| 50 | $15,100 | $203,000 | $2,280,000 |

### 2.1.2 Basis of Current Procedures

The accident severity cost increase provisions of the present PEM have been derived from consideration of the proportions of the fatal, serious injuries and minor injuries that occur in accidents within the three different speed limits of 50 km/h, 70 km/h and 100 km/h (Bone 1992). The analysis is based on reported injury accidents for the 2½ year period between January 1988 to June 1990. The cost increases reflect that, as speeds increase, the likelihood of an accident resulting in a serious injury or fatality increases. However, the increase may also include an effect related to the differing occupancy levels of vehicles used on urban and rural roads.

Although the research suggested a series of corrections based on the relationship between mean speed and regulatory speed, a simplified procedure was adopted for use in the PEM. Under this procedure the cost of accidents was increased by 2.5% for each 1 km/h increase in mean speed. Another simplification made was that the adjustment for mean speed increases is not applied when this increase is less than 5 km/h.

### 2.1.3 Discussion of Current Procedures

The conclusion that accident severity increases with speed is supported by a number of other studies both in New Zealand and overseas. In New Zealand, a reduction in operating speed of 13 to 16 km/h (8-10 mph) occurred with the implementation of a 80 km/h (50 mph) speed limit during the 1973 "oil crisis". During that time, accidents on urban roads for which the speed limit remained unchanged dropped by 5.9%. However, accidents on rural roads, i.e. those subject to the lower speed limit, dropped by 24% (Frith and Toomath 1982).

In the United States the oil crisis also prompted a reduction in open speed limits. The accompanying reduction in mean speed from 65 mph (104 km/h) to 57 mph (91 km/h) was accompanied by 9,100 fewer fatalities (TRB 1984). Many other studies of speed reductions during the oil crisis period have produced similar reductions in accident numbers, but the effect on accident rates (accidents per 100 million vehicle-km travelled) was seldom discussed. A possible but not quantifiable effect of the oil crisis was a reduction in longer distance travel. This would reduce the amount of travel and would therefore account for the reduction in the number of accidents, but not necessarily mean a reduction in accident rates.

A change in accident severity related to a reduction in mean speed during the oil crisis was, however, confirmed in New Zealand. On rural roads subject to the 80 km/h (50 mph) speed limit, fatal and serious casualties dropped by 29%, while at the same time all casualties dropped by 19% (Toomath 1975).

Following the easing of the oil crisis, a number of countries increased open road speed limits. In the United States fatalities increased by 20 to 30% following mean speed increases from 63.0 mph to 67.1 mph (Freedman and Williams 1992). Given that no dramatic change in the price of fuel had occurred at this time, there is less likelihood that large changes in amount of travel precipitated the change in the number of fatalities.

These studies identify a strong relationship between the regulatory speed and accident severity as well as a relationship between changes in speed limit and changes in mean speed. However, a direct relationship between accident severity and mean speed has not been tested.

The definition of mean speed that is used in such studies needs to be clarified. In New Zealand, open road mean speeds are measured through regular surveys of free unimpeded vehicles undertaken at selected sites where no highway geometry constraints exist. While the definition of the mean speeds referred to in the other studies is often not specified, it is thought to be similar, i.e. that of the mean speed of free vehicles that are not constrained by road geometry.

In each of the above studies the change in open road mean speed has been precipitated by a change in the regulatory speed. The relationship between open road mean speed and speed limit is not, however, consistent. Open road mean speeds tend to increase over time. Before 1973, open road mean speeds in New Zealand were increasing at a rate of 1 km/h/year (MOT 1984). For four rural sites monitored between 1976 and 1984, an average increase of 1 km/h/year was also recorded (MOT 1986), while similar effects have been found in the United States (TRB 1984) and Australia (Sanderson and Cameron 1982).

Whether or not a change in open road mean speed reflects the change in mean speed on specific highway sections, where road geometry and/or traffic volumes are significant, is unknown.

The data of Table 2.2 raise further questions about the use of regulatory speed as a measure of determining the speed on different road types. The regulatory speed increase, in 1985, from 80 km/h to 100 km/h resulted in a speed increase on the roads with high design standard. However, on rural roads of low design standard no change in mean speed was recorded.

Table 2.2 Passenger car speeds recorded by Ministry of Transport (MOT), New Zealand, in surveys based on road standards, for the years 1984 and 1986 (MOT 1986).

| **Road location and standard** | **Speed (km/h)** | | | |
|---|---|---|---|---|
| | **1984** | | **1986** | |
| | **Mean** | **85 %ile** | **Mean** | **85 %ile** |
| Rural high design standard | 99.2 | 113.0 | 102.6 | 116.0 |
| Rural low design standard | 87.1 | 99.0 | 87.2 | 98.0 |
| Urban motorway (Auckland Southern Motorway) | 101.6 | 115.0 | 107.0 | 121.0 |
| Urban 100 km/h roads | 73.3 | 83.3 | 77.3 | 89.0 |
| Urban 50 km/h and 70 km/h | 63.9 | 71.0 | 65.7 | 73.0 |

One reason for this trend is that the speed of an unimpeded vehicle on a particular highway section is thought to be a function of:

- the desired speed of the driver; and,
- the design speed of the road section.

The desired speed is determined by the speed environment which reflects drivers' assessments of the road alignment. For example, the 85th percentile speed of a 400-m radius curve will be higher if the curve is in a 120 km/h environment than if in a 90 km/h speed environment (McLean 1979).

The procedures developed in the PEM are used to assess the effect on accident severity that results from a road improvement at a specific location. The speed measures that are used are location-specific. Therefore the accident severity adjustment should be determined using "local" data rather than aggregate measures such as the regulatory speed or open road mean speed.

While the relationship between accident severity and regulatory speed is strong at an aggregate level, evidence suggests that the regulatory speed may not be a good predictor of mean speed at a particular location, and therefore relating accident severity increases to measures based on regulatory speed must be questioned.

## 2.2 Accident Rates on Curves

### 2.2.1 Rationale

Isolated curves which have a design speed that is inconsistent with the surrounding alignment can "surprise" drivers. The disparity between drivers' expectations and the design of such curves results in a higher accident rate. The design guidelines seek to limit the change in the design speed between road sections by 10-15 km/h (AUSTROADS 1993). This philosophy is based on the Australian finding that the overall speed environment, i.e. the standard of the alignment approaching a curve, will affect the speed at which drivers will negotiate the curve (McLean 1979).

### 2.2.2 Basis of the Current Procedures

The current PEM procedures for predicting accident rates, or reductions in accident rates following improvements in the design speed, were developed from research undertaken by the Land Transport Safety Authority (LTSA) (Jackett 1992). That study considered 900 curves within the Wellington region of the LTSA, which extends from Gisborne across to New Plymouth and to the northern portion of the South Island. The study showed that accident rates were related to the curve speed and the approach speeds to the curves.

The curve speed was measured using a "ball bank" gauge and the approach speed was based on the assessed 85th percentile speed. Curve-related accidents, i.e. those with movement codes B, C and D in the LTSA Crash Investigation System (CIS), were recorded in number only, for the five years preceding 1989. Descriptions of the movement codes are provided in Appendix 2. Accident rates were derived from the Transit New Zealand periodic traffic counts for the highways in question.

Although two different speed measurement systems were used, speeds were converted to the "design speed", which is equal to the 85th percentile of the desired speed. The result was a predictive equation ($R^2 = 0.95$) which relates curve accident rates, measured in accidents per million vehicles entering the curve, to the difference between the approach and curve speeds.

### 2.2.3 Discussion of Current Procedures

The approach adopted by LTSA considers both the overall speed environment of the preceding length of road and that of the curve in question. This approach is consistent with the relationship between approach speed and curve speed (McLean 1979), and supported by other studies (Matthews and Barnes 1988) which found that drivers who are surprised by an isolated sub-standard curve are likely to have a higher accident liability. The study included a large sample and spans a range of speeds. This helps the study overcome variations that may arise from the subjective assessment of the approach speed environment.

## 2.3 Combining the Current Procedures

The present PEM applies the severity adjustment when a curve is improved because the mean speed increases at the accident site. However, it may be argued that those vehicles travelling well in excess of the mean speed are most likely to have accidents on curves. If this were the case, a curve improvement would increase the mean speed but the severity of accidents would not increase because the speed of the faster vehicles with higher accident liabilities would remain unchanged. However, if an increase in mean speed results in an equivalent increase over the whole speed distribution, the argument does not hold. The key issue is the propensity of individual drivers to speed and their individual accident liability.

Accident involvement (rate) has been related to speed variance, and with a U-shaped curve, so that vehicles travelling much faster or slower than the mean speed are more likely to be involved in accidents (TRB 1984). One study found that drivers who travelled in the top 4% of speeds were six times more likely to have an accident (West and Dun 1971), while another study referenced by Finch et al. (1994) found that the accident rate for drivers travelling at speeds considerably different from the mean (±24 km/h) was increased by a factor of 10. If speed variance does not alter with respect to mean speed, then mean speed may be used as a reasonable measure of accident rate and at the same time of accident severity. Evidence on this matter is however conflicting.

In New Zealand speed variance was found to remain constant following changes in the regulatory speed and open road mean speed (MOT 1986). Another New Zealand study (Bennett 1994) specifically considers the effects of road geometry on speed at a particular location rather than on open road mean speed, and found that the standard deviation ($\sigma$) of speeds increases with mean speed ($\mu$) so that:

$$\sigma = 1.73 + 0.12\,\mu \qquad R^2 = 0.56, SE = 1.65 \qquad \text{(Equation 2)}$$

One explanation to account for the different conclusions is that the maximum speed variance is found in the measurement of open road speeds, but the potential for variation is reduced by the constraints that road geometry places on the desire to travel at higher speeds. The formula predicts $\sigma = 13.97$ when $\mu = 102$. This is similar to the variance found in the data from open road mean speed measurement undertaken by the LTSA and supports the explanation.

Other research (Garber and Gadinia 1988) found a non-linear decrease in speed variance with increasing mean speed. The correlation of mean speed, speed variance and design speed, combined with a negative relationship between mean traffic speed and accident rate, led the researchers to conclude that local geometric factors were a significant determinant and the variables did not act independently on accident rates. A further study (Garber and Gadiraju 1991) identified that speed variance decreased as the difference between design and regulatory speed increased.

Although these studies offer differing results with respect to the relationship between mean speed measures and speed variance, they all identify the importance of road geometry on the mean speed of traffic and therefore on the accident potential at a particular location.

## 2.4 Summary

The review of the procedures used to account for increasing accident severity with speed increases and with accident rates for curves, has found that:

- the use of regulatory speed as a determinant of accident severity at a particular location is not intuitively logical;
- the methodology adopted for determining accident rates for curve improvements is supported by other studies;
- the subsequent application of a severity correction which is not related to geometry is not supported.

Furthermore, accident data used in the two studies are from two different time periods, and it is likely that the downward trend in accident rates may have an effect. However this is not seen as a significant problem.

# 3. FRAMEWORK FOR AN INTEGRATED STUDY

## 3.1 Outline

The review of the research underpinning the present procedures identifies the need for an integrated study to re-assess the relationship between:

- accident severity and speed;
- accident rates at isolated curves; and
- the application of both procedures in situations where the realignment of curves is being considered.

Reviewing the basis for the present procedures in the light of the general literature, identifies that:

- a common measure of speed should be used in both procedures; and
- the speed measure used must be capable of differentiating between locations where road geometry affects traffic speed.

The outcome of this research will be revised procedures for the adjustment of accident costs and accident rates. The speed measures selected must be able to be predicted from the data that are commonly available to the project analyst.

One method by which this outcome could be achieved is to select a sample of curves and to measure speeds directly. This approach would provide data on the distribution of speeds at the sites. Although attractive, it is not possible to undertake a study of this type within the available time frame and budget for this present project. The alternative is to seek some other means of obtaining a measure of speed for a large sample of roads.

## 3.2 Speed Measures

Before considering the measures that are available, some terms are defined:

| | |
|---|---|
| Collision speed | the speed of a vehicle(s) at impact. |
| Driving speed | the speed of a vehicle(s) before any "avoidance" action is taken. |
| Regulatory speed | the legal speed limit for the road section. |
| Mean speed | the average speed of traffic at a particular location or over a particular road section. |

| | |
|---|---|
| Speed environment | describes the characteristics of a road section that is reasonably consistent in terrain and geometric standard. It equals the 85th percentile speed of the free speed distribution. |
| 85th percentile speed | the speed which 15% of vehicles exceed. |
| Design speed | the speed applied to individual geometric elements; the speed used to co-ordinate these elements of the road to ensure drivers will not be exposed to an unexpected hazard. It is approximately equal to the 85th percentile speed. |

In terms of the aims of this project, it is the collision speed that directly affects accident severity, while the driving speed of vehicles is related to accident rate. However, obtaining data on these speeds would require considerable resources.

With the exception of regulatory speed, no speed measure is available over a large part of the roading network. However, for the state highway network, road geometry data were collected in 1991 using the Australian Road Research Board (ARRB) Road Geometry Data Acquisition System (RGDAS). RGDAS collects data on:

- horizontal curvature (expressed as 1/radius),
- gradient,
- cross-slope,
- distance (along the highway).

Combining these data with the design value for side friction (f), it is possible to calculate the design speed of road section using the equation:

$$V^2 = 127\,R\,(e + f) \qquad \text{(Equation 3)}$$

where $e$ = superelevation
$f$ = coefficient of side friction
$V$ = design speed (km/h)
$R$ = radius (m)

The design speed is, by definition, equal to the 85th percentile speed, and has been identified as an important variable in the determination of mean speed on a road section. It is therefore a better measure of vehicle speeds at specific locations than the regulatory speed. Such a speed measure would fulfill the requirements identified above.

Although friction data are available for the state highway network, they are in situ data. Research has shown that the value of the coefficient of friction (f) used in the design equation is not a factor that governs traffic speed, but rather an outcome of the speed selected by the driver (Bennett 1994). On this basis, an alternative speed formulation which is independent of friction has been adopted (Wanty et al. 1995). This is the RGDAS advisory speed function (AS) which is defined as:

$$AS = \sqrt{(bk)^2 + 2k\left[a + \frac{X}{100}\right]} - bk \qquad \text{(Equation 4)}$$

where AS = RGDAS Advisory Speed
a = 0.3
b = 0.0017
X = % cross-slope
H = curvature (rad/km)
k = 63,500/H (km)

Using this relationship the RGDAS data can be used to generate a speed measure over the state highway network.

The RGDAS advisory speed is **not** the same as the advisory speed used in the posting of curve advisory speed signs (PW25) in the Manual of Traffic Signs and Markings (Transit New Zealand & LTSA 1994).

Furthermore, a relationship between the observed 85th percentile speed of passenger cars and the RGDAS advisory speed has been derived (Wanty et al. 1995) based upon observations of 34 curves (Bennett 1994).

The RGDAS advisory speed provides a network-wide measure of speed suitable for use in this research. Combining this function with accident data and traffic volumes for the state highway network, the issues of accident severity and curve accident rates are re-assessed in this research.

# 4. METHODOLOGY

## 4.1 Data Sources

The project involves integration of the available data into a set of linked databases. Four sources of data are considered:

1. State highway geometry data collected using the Road Geometry Data Acquisition System (RGDAS);
2. Road cross-section data from the Road Assessment & Maintenance Management System (RAMM) to identify divided carriageways;
3. Accident data from the LTSA accident (Crash) Investigation System (CIS);
4. Traffic volume data from the National Traffic Database (NTD).

Highway geometry data obtained for all sealed state highways as at June 1992 were collected at 10 m intervals. The data have been aggregated into 200-m road segments as part of Transit New Zealand Research Project PR3-0020 (Cenek et al. 1997). Each 200-m road segment has a record in each direction, and these are identified by state highway (SH) /reference station (RS) /route position (RP) and a unique segment identification number (ID). For each segment, average advisory speed values over the section ($AS_{AV}$) and the average advisory speeds for both the preceding two segments and the preceding five segments ($PAS_{AV2}$, $PAS_{AV5}$) are recorded. These were calculated from the RGDAS curvature and cross-slope data.

Information from the RAMM system was also included with this data to produce a combined database of road segments. The RAMM data provided information such as the Annual Average Daily Traffic (AADT), carriageway width and lanes, and whether the segment was a motorway or divided carriageway.

Non-intersection injury accidents for the period 1990 to 1995 were obtained from the LTSA CIS. Non-intersection accidents were defined as those accidents that occurred more than 20 m from an intersection. Because of the variability of the RAMM traffic volumes, the NTD was used to obtain consistent AADT data. The NTD counts are based on 1994 data, so they were scaled down to represent the mid-point of the accident data's coverage (1992-93). The process to this point is outlined in Figure 4.1. Although a common approach has been adopted, two separate databases have been developed for use in the analysis phase of the research.

To consider the effects of speed on accident severity, the path on the left side of Figure 4.1 is followed. In this work road segments are treated as being two directional, the average cost of an accident is used and the importation of traffic volumes is not required.

The second part of the analysis considers the effect of accident rates on isolated curves and follows the path on the right side of Figure 4.1. The road sections are considered in each direction separately, with accidents being matched by the direction of travel of the key vehicle. This component considers only curve-related accidents. These are defined as those having first movement codes B, C, D, as defined by the LTSA coding system, a copy of which is included in Appendix 2. To consider the accident rates in terms of accidents per vehicle, traffic volumes need to be linked to the database.

## 4.2 Preparing the Data

The investigation requires that the accidents are linked with the nearest segment and to its associated properties. This linking was done using dBASE IV. The framework for this analysis is outlined in Figure 4.1.

The first step involved preparing the databases was "cleaning" the data so that the databases could then be linked. For a number of reasons, it is not possible to "accurately" link all accidents and road sections. Where there was any doubt, the data were deleted from the sample to avoid bias.

The accident data fields were re-structured to match the road data in type and length. Not every accident record had a complete route position. Some had state highway/reference station only, some had state highway number only. The LTSA accidents are located by co-ordinates taken from the NZ Map series. Although some LTSA regions will provide the route positions for accidents that occur on state highways, this practice is no longer universal. Some offices will only code to the state highway number or route station while others will only give values to the nearest 100 m. Those accidents that were not completely locatable were identified and deleted.

The road data identified SH1N and SH1S, but the accident data did not. The grid reference northings were examined and the suffixes "N" or "S" added accordingly. Only four instances of SH1 accidents had no grid reference, and these were altered manually. State highway prefixes or suffixes in the two databases were standardised to allow matching, and divided state highways or motorways were excluded from the analysis.

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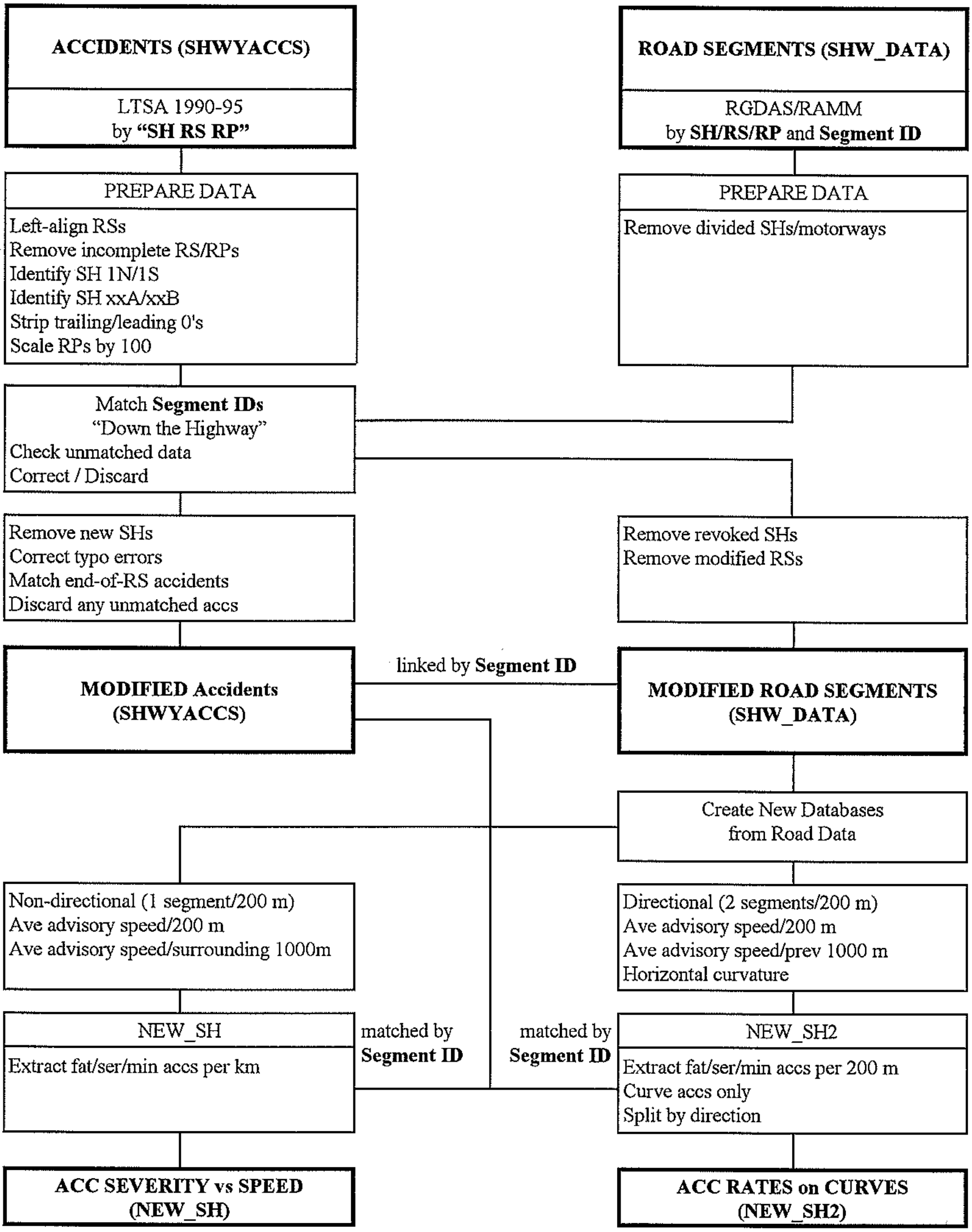
*Abbreviations used in Figure 4.1:*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| acc(s) | accident(s); | fat | fatal; | ser | serious injury; | min | minor injury |
| SH | State Highway; | RS | Reference Station; | RP | Route Position | | |
| ID | identification; | ave | average; | prev | previous | | |

Figure 4.1 Framework for combining the data for analysis.



## 4.3 Linking the Databases

The two files were then matched. Each accident record was matched by SH/RS/RP to the nearest road segment record (within 100 m).

A few operational problems were encountered with this approach because of inconsistencies in the accident data. For example, errors in reference station or route position values could cause the program to search for a non-existent value, e.g. RS 2222 or RP 53.100. State highways or reference stations that had been only recently designated could not be matched with the older road data.

Following an initial matching, checks were made on the residual data to determine the causes of non-matched records. The main reasons for non-matching were:

- Typographical errors in the accident data, e.g. RS 289 when only a RS 298 existed, or RP 35.000 instead of 3.500. Where the error was obvious, and could be confirmed by side roads or grid references, these records were manually corrected and matched, otherwise the record was discarded.

- Route positions at the very end of a reference station which could not be correctly matched with the next segment in the following reference station. For example, if successive segments were RS 23/14.150 and RS 37/0.020, then an accident recorded at RS 23/14.300 would be too far away from the first segment to match, but would not match (correctly) with the second segment because of a different reference station. These were manually matched where it was appropriate. A few accidents were recorded with route positions some distance beyond the expected end of a reference station. These were discarded.

- Reference stations that had changed (possibly caused by route changes since the data had been collected in 1991). For example, road sections might have RS 0, 13, 29, 45 while some accident records might refer to RS 0, 17, 32, 45. In this case, the affected road sections were discarded from the analysis. Where the affected sections included much of the total state highway, then the entire state highway was discarded for simplicity, e.g. SH74 was discarded.

- State highways that had been recently designated or revoked. For example, no accident records were available for SH52 which had its status revoked in the 1991 state highway review, but there were road data for it. Similarly, accidents have been recorded on SH20A, but there was no road information. In these cases the unmatched data were removed.

The extent of the data cleaning to this point is outlined in Table 4.1.

Table 4.1 The extent of data cleaning to allow linking by segment ID.

| Database | Original size | After cleaning | Action Undertaken |
|---|---|---|---|
| Road segment database (SHW_DATA) | 57,710 segments x two directions | 45,788 segments (79%) | Divided carriageways and altered state highways were removed |
| Accident database (SHWYACCS) | 14,135 accidents | 8,437 accidents (60%) | Incomplete route positions were removed |

Throughout the cleaning process the emphasis was on discarding data which were considered less than reliable. There are, however, serious concerns over the use of route position to locate accidents because of the inaccuracies associated with the LTSA accident records.

Within the LTSA accident database, grid co-ordinates are used as the key classification of accident location. Route positions for state highway accidents are only a secondary description and are recorded in the road name field. The route position may be established to varying degrees of reliability by:

- the police officer attending the accident who may measure or estimate the distance to the nearest route station;
- those coding the data into the database may determine the route position from the police officer's notes, which may give a measured or estimated position to a recognisable feature for which the route position may be known;
- the route position may be updated or generated by computer, following changes to the state highway network.

Considerable potential exists for errors in identifying and coding accident location. The RGDAS data are also likely to contain errors as they have been scaled to reconcile differences between the recorded distance and the known distance between route stations.

The combined concerns have led other researchers (Cenek et al. 1997) to recommend that research involving matching of this type should not be undertaken until a common Graphical Information System (GIS) has been established to relate accidents and highway data. Unfortunately such a system has not been implemented for state highways. The data cleaning resulted in losing 40% of the accident data because of an inability to match by the route position. This further supports the recommendations of Cenek et al. The only consolation is that the loss of data has not introduced bias in the matching of accidents to segments.

# 5. ACCIDENT SEVERITY & SPEED

## 5.1 Accident Severity Costs

To develop a measure of accident severity, the numbers of accidents of each severity class (fatal, serious and minor injury) that occur at different speeds need to be established. These are then weighted by the cost of a typical accident of that type. For this project, the accident costs have been taken from the PEM (Transit New Zealand 1996). The values used are provided in Table 5.1.

Table 5.1 Average accident costs (NZ$) based on PEM values
(Source: Table 6.9, PEM, Transit New Zealand 1996).

| Accident type | 100 km/h Regulatory Speed All accident movements combined |
|---|---|
| Fatal | $2,570,000 |
| Serious Injury | $236,000 |
| Minor Injury | $21,400 |

The accidents on all road sections of a given speed may be combined and weighted to give the average accident cost which represents the accident severity. The question then arises as to the length of road section on which to base the analysis. Too long a road section will result in large differences between the average minimum and maximum RGDAS advisory speed values. Too short a length will result in excessive variance and will not take account of the role of the road environment in determining the speed at a particular section.

### 5.1.1 Selection of Analysis Length

As a calculated value, the RGDAS advisory speed (AS) is available for every 10-m interval of state highway. A summary database has been constructed which aggregates RGDAS data into directional 200-m segments for which the average advisory speed (AAS) and the minimum advisory speed (MAS) are available for the 200-m segment. In addition to this, the average advisory speed has been calculated for the preceding 400-m sections and the preceding 1000-m sections.

The distance - 200 m, 400 m, 600 m, 1000 m, or some other interval - that is most suitable over which to establish measures of speed and accidents now needs to be decided.

Although accident locations in the LTSA database have co-ordinates to a theoretical accuracy of ±10 m, the route positions used to match accidents to the state highway RGDAS data are unlikely to be as accurately located. The potential for inaccuracies, discussed in Section 4.3 of this report, is further compounded by doubts about the accuracy recorded by the Police attending the accident. Did the Police record the point at which the accident occurred, or was it the point where the vehicle came to rest? Particularly with single vehicle accidents on rural roads, there may be hundreds of metres between the two points, and a reasonable analysis length is required to help minimise the effect of such errors.

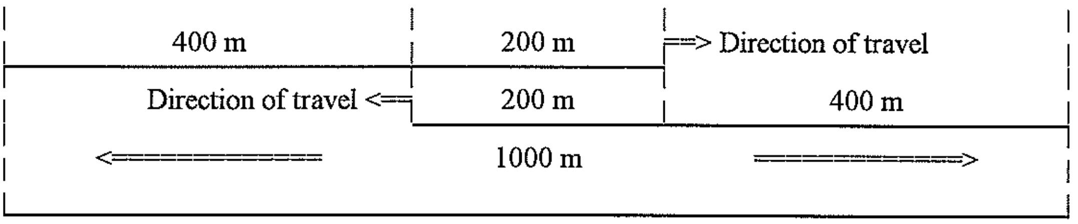
The way in which the results of this research will be used in practice also affects the choice of analysis length. The relationships developed in this study will be applied where projects will increase the mean traffic speed for a road section. While point speeds may be measured on site, the practicality is that improvements will occur over a length of road with the intention of improving the overall standard. The concept of a speed environment, i.e. a section of road of generally uniform characteristics, is important as it is the relationship between the overall speed environment and the geometric elements that determines the negotiating speeds of traffic (McLean 1979). The analysis length should therefore be related to the length of road required to establish the speed environment. Typical values suggested by AUSTROADS (1993) are given in Table 5.2.

Table 5.2 Length (m) of highway section required to establish a speed environment (km/h) (taken from AUSTROADS 1993).

| **Speed environment (km/h)** | **Approximate length of road (m)** |
|---|---|
| 70 | 250 |
| 90 | 1000 |
| 100 | 3000 |

Considering the above, and for easier computation, an analysis length of 1000 m has been chosen. The analysis therefore considers the average cost of an accident within a 1000-m section with the RGDAS average advisory speed for the 1000-m section. This length may be formed within the database using the advisory speed of the previous 400 m in each direction and that of the 200-m segment in question, as shown in Figure 5.1.

Figure 5.1 Construction of analysis length.



### 5.1.2 Database Modification

Concerns about the accuracy of locations in the RGDAS data were raised in Section 4.3 of this report. To account for likely inaccuracy, the data have been scaled to correct for the difference betweeen the recorded and known highway length. To minimise the effect of such errors, the data have been checked by comparing the directional values of advisory speed for the central 200-m segment. Table 5.3 provides the number of road segment records where the differences in directional advisory speed were less than a particular value.

Table 5.3 Distribution of road segments with directional differences in advisory speed.

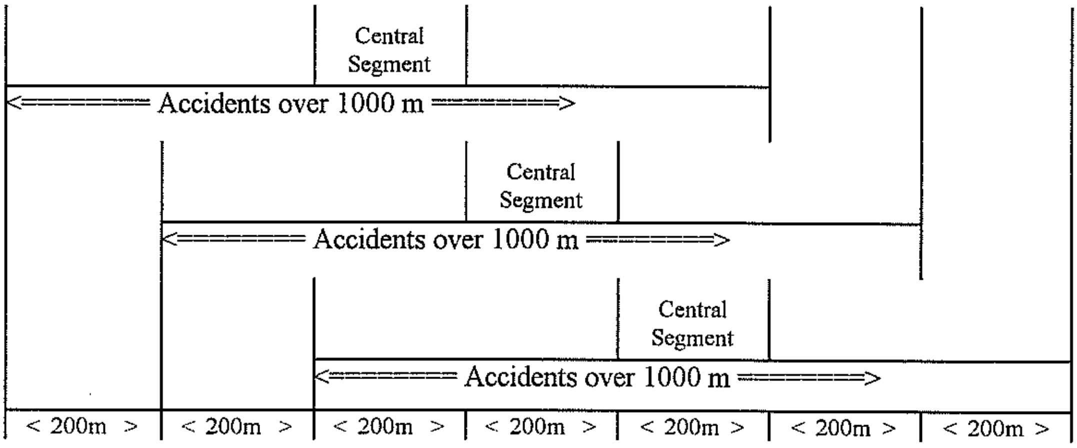
| Difference in advisory speed (km/h) between direction | ≤10 | ≤15 | ≤20 | All records |
|---|---|---|---|---|
| Number of segment pairs in database | 24,765 | 32,211 | 37,116 | 45,788 |
| % of records | 54 | 70 | 81 | 100 |

Given that approximately 8,400 accidents were recorded in the database, the decision was to use a 15 km/h difference in design speed. This choice is supported by AUSTROADS (1993) which specifies a maximum limit of 15 km/h between the design speed of consecutive elements.

A new database (NEW_SH) was created that combined the road segment data, as shown in Figure 4.1. Opposing road segments with advisory speed differences greater than 15 km/h were not included.

To interrogate the accident database, a "moving segment" approach (Figure 5.2) has been used. The 1000-m analysis length developed from the 200-m segments (Figure 5.1) is moved in 200-m increments down the road database.

Figure 5.2 Moving segment approach used to interrogate the accident database.



## 5.2 Analysis of Accident Severity

The analysis is based on the number of non-intersection related injury accidents over the period 1990 to 1995, within a 1000-m highway section. The accident numbers have been summed for each severity class: fatal, serious injury and minor injury. The accident is allocated to a severity class on the basis of the most serious injury recorded.

Any road segments with mixed urban/rural parts or incomplete advisory speed data were removed, as were segments with zero accident totals as they are of no use in calculating average accident costs. The average accident cost has been calculated by weighting each severity class by the "all movement" accident costs from Table 6.9 in the 1996 PEM.

The data has been grouped into 5 km/h "bins" based on the RGDAS speed measure. The 5 km/h bin was chosen to balance the need for enough data points for analysis while retaining a reasonable number of accidents and road segments within each bin.

In Figures 5.3 to 5.6 the term "speed environment" is represented by the RGDAS average advisory speed for the 1000-m section (AAS1000). Here the severity costs are based on the 100 km/h accident cost weightings since the road sections are generally in 100 km/h regulatory speed areas.

Figure 5.3 identifies the plateau where the RGDAS advisory speed clearly exceeds the maximum free speeds at which drivers will travel, and a bi-linear relationship has been fitted. The choice of intersection point is, at this stage of the analysis, a purely arbitrary decision which has been made to minimise any discontinuity between a fitted regression and the average accident cost over the high speed region. The intersection point is checked later when the speed relationship is capped, and is outlined in Section 5.3 of this report.

Separating the urban and rural accidents (Figure 5.4) shows that the urban accidents have a higher cost than the rural accidents which occur at typical urban speeds (60-65 km/h). The higher cost is because urban accidents have a higher average severity, and one reason for this higher severity is the higher proportion of accidents involving vulnerable road users, such as pedestrians. Among this group serious injury and fatalities are more common, as shown in Table 5.4.

Table 5.4 Comparison of total reported injury accidents and pedestrian accidents, 1990 - 1995.

| Speed limit (km/h) | 50 | 60 | 70 | 80 | 100 |
|---|---|---|---|---|---|
| Total reported injury accidents | 1,415 | 3 | 739 | 226 | 11,544 |
| Pedestrian accidents | 212 | - | 55 | 6 | 218 |
| % Pedestrian accidents | 15 | - | 7.4 | 2.7 | 1.9 |

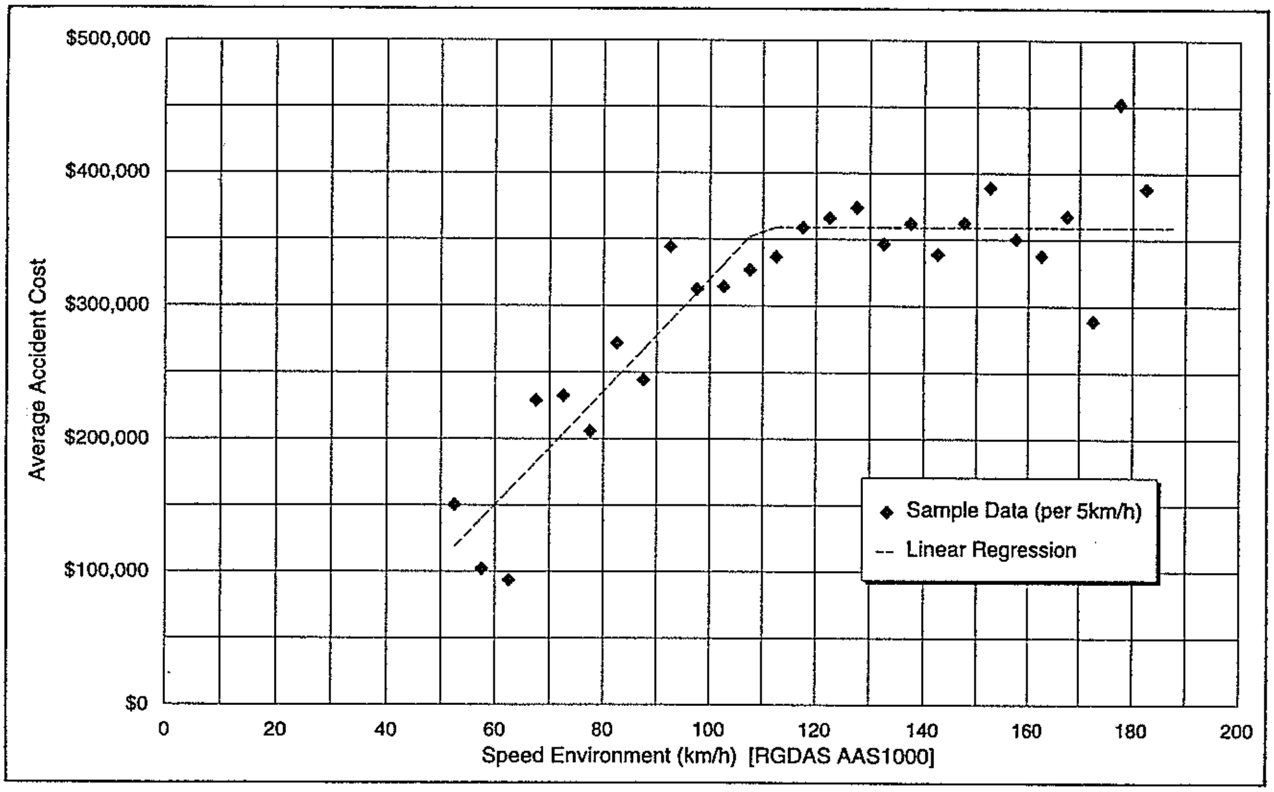


Figure 5.3 Average accident costs (NZ$) v speed environment (RGDAS AAS1000) for urban and rural accidents combined.

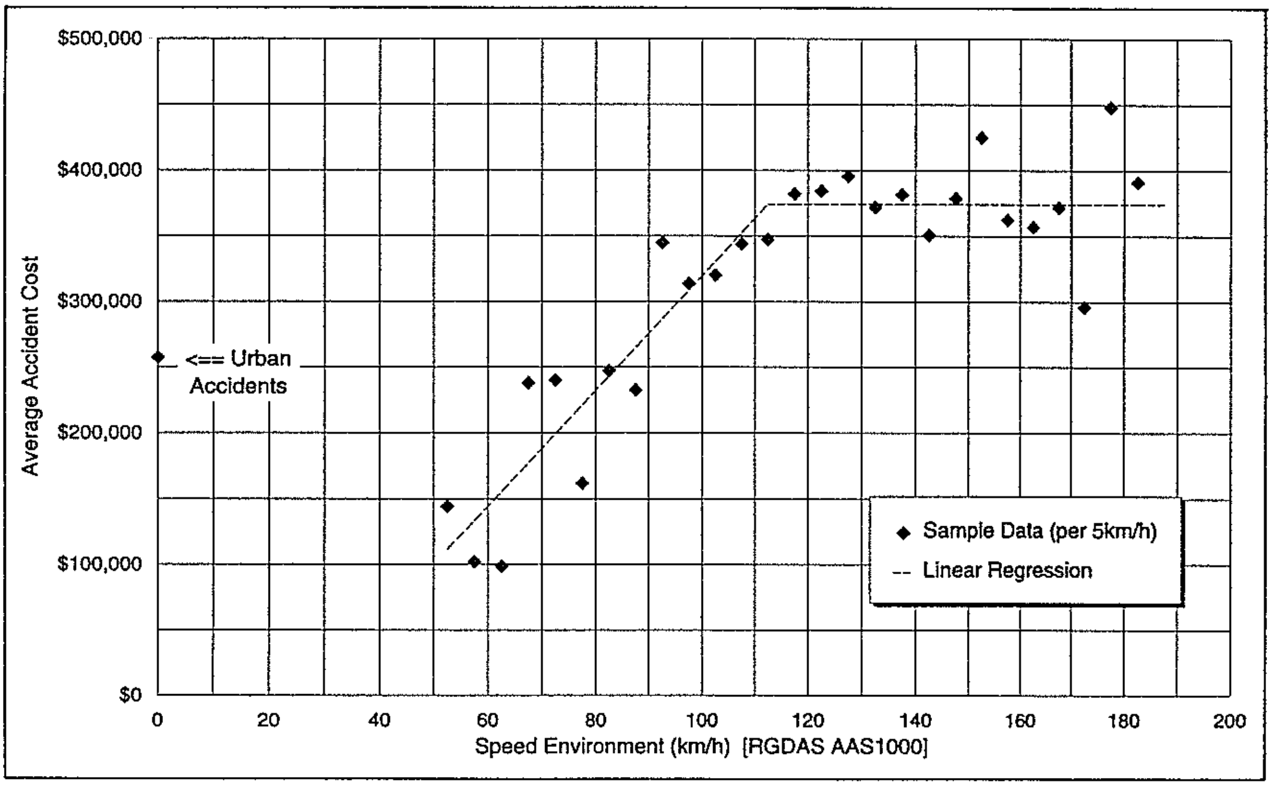


Figure 5.4 Average accident costs (NZ$) v speed environment (RGDAS AAS1000) for urban and rural accidents separated.

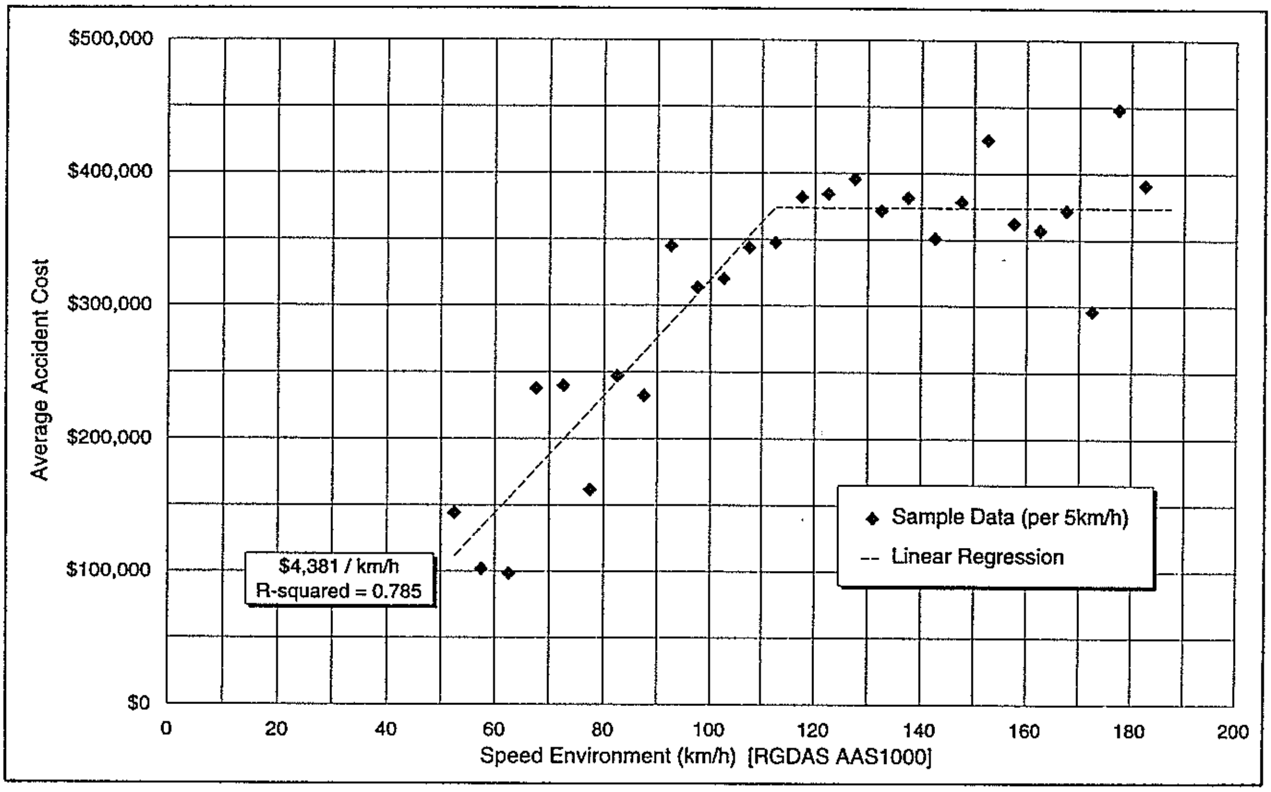


Figure 5.5 Average accident costs (NZ$) v speed environment (RGDAS AAS1000) for rural accidents only.

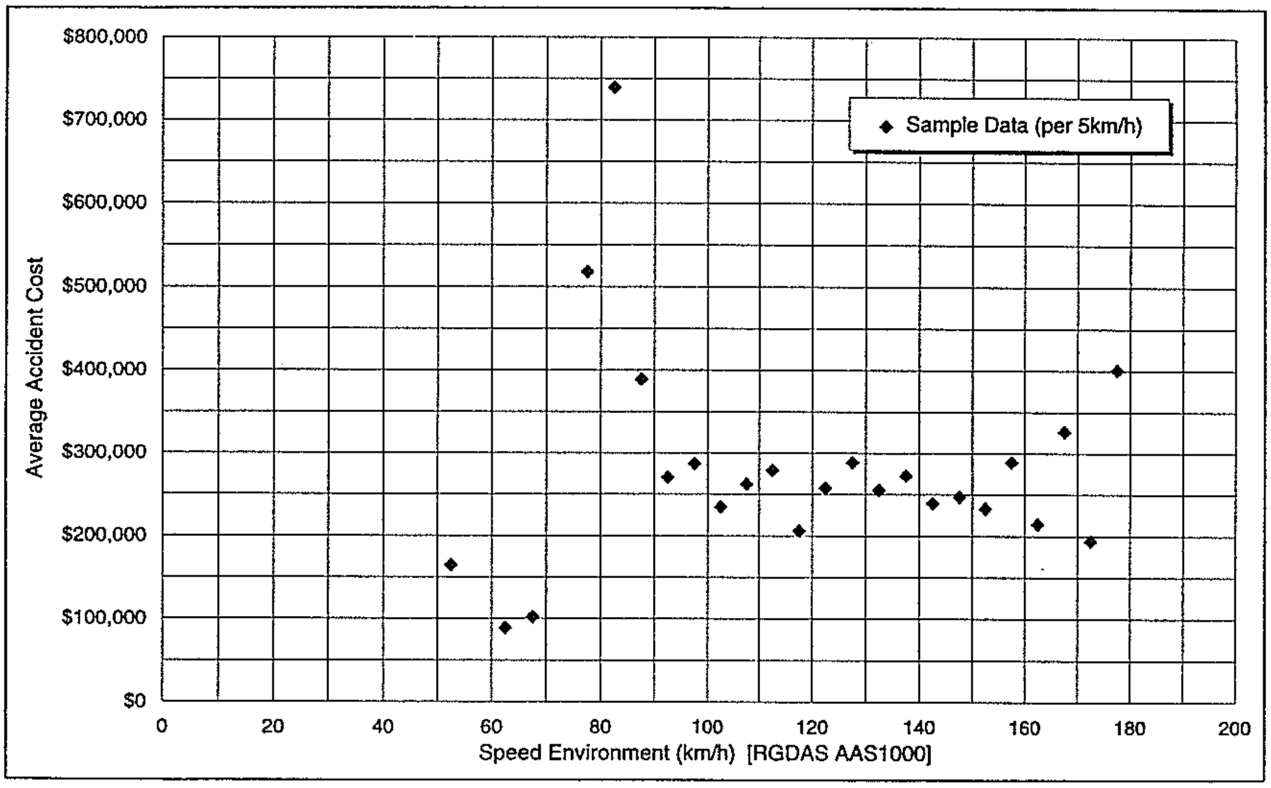


Figure 5.6 Average accident costs (NZ$) v speed environment (RGDAS AAS1000) for urban accidents only.

Figures 5.5 and 5.6 consider the rural and urban accidents separately. A comparison shows that removing urban accidents improves the relationship between speed and average accident cost. In this case the urban/rural split is based on the code allocated in the RAMM data.

For rural accidents, a further analysis has been undertaken based on the RGDAS average advisory speed for the central 200-m segment, as shown in Figure 5.7. Somewhat surprisingly, this produces a stronger relationship than using the average advisory speed for 1000 m.

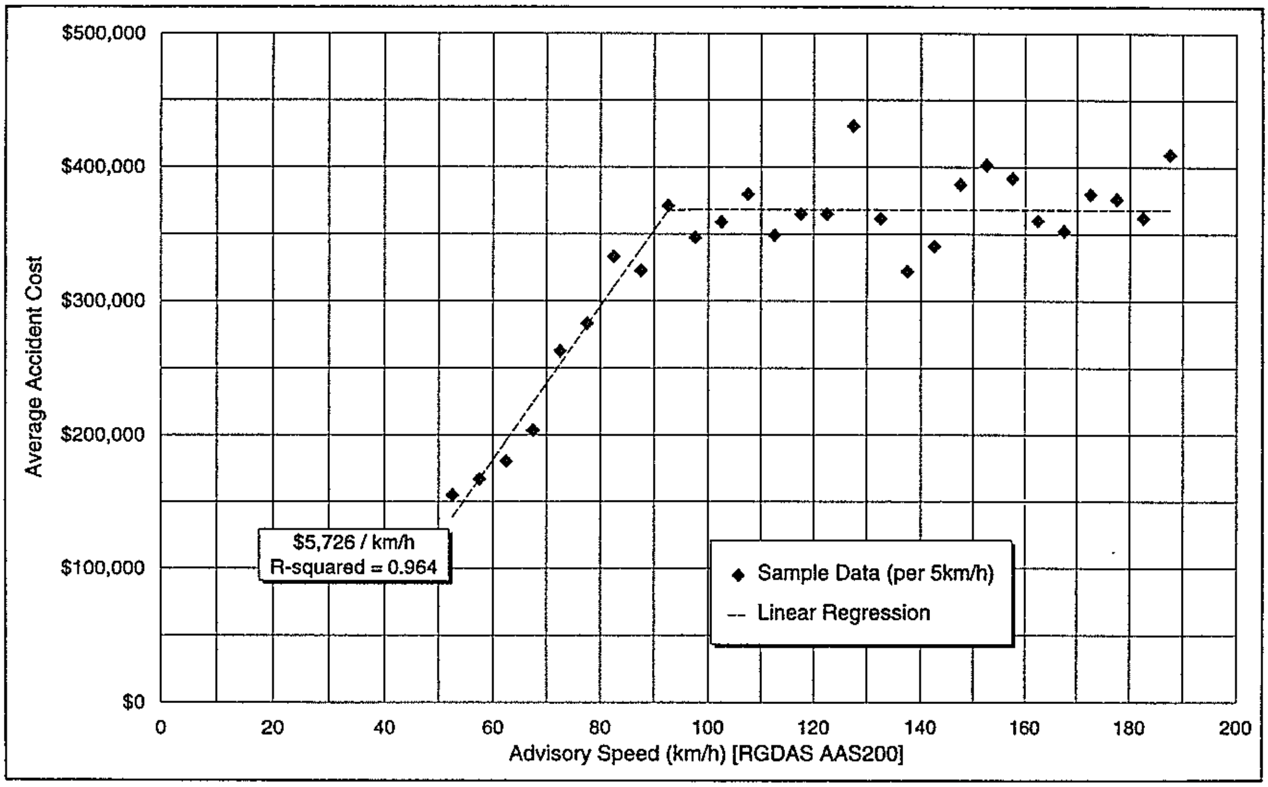


Figure 5.7 Average accident costs (NZ$) v advisory speed (RGDAS AAS200) for rural accidents only.

### 5.2.1 Urban Accident Relationships

From Figure 5.6 the approach adopted is clearly not suitable for the analysis of urban accidents. In urban areas, the road geometry does not generally determine the traffic speed which will be related to traffic volumes, intersection spacing and adjacent land use. Even if the data were "capped" to the maximum free urban speed recorded by LTSA, a relationship would not be possible to establish because, below 60-65 km/h, there are too few bins and the number of accidents and road segments in each are very small.

To further investigate the effect of speed in urban areas, speeds at a sample of accident sites need to be measured. As the traffic speed will vary throughout the day, speeds need to be measured at times when a high proportion of accidents occur. This procedure would require a large sample and special sample design. Although such work is beyond the scope of the present study, it is recommended for future consideration.

In the interim, three options are available to account for urban accidents:

1. Use an extrapolation of the rural trend;
2. Neglect the effect and use an average accident cost as identified in Figure 5.4;
3. Use part of the previous relationship based on 50 km/h and 70 km/h speed zones.

In making this decision, it is useful to consider the types of urban projects that will affect speed and accident severity. Most urban accidents are intersection-related. The severity of accidents involving vehicles pulling out of driveways or away from the kerb, pedestrian accidents, manoeuvring accidents and lost control accidents, is more likely to be related to the speed of free vehicles (Pasanen and Salmivaara 1993). While urban road projects may reduce journey times, this reduction is usually by removing delay rather than by increasing free vehicle speeds. Approach (3) is therefore preferred because the speed of vehicles is more likely to be related to speed limit.

## 5.3 Converting RGDAS Advisory Speeds to Traffic Speeds

Up to this point in the analysis the RGDAS measure of speed has been used. Such data are only available for the New Zealand state highway network as at 1991. The results are therefore difficult to apply to projects without calculating the RGDAS advisory speed. It is therefore necessary to convert the RGDAS speeds to mean traffic speeds. This process is outlined in Figure 5.8.

Since RGDAS calculates large values of advisory speed for long straight sections, these need to be capped to a realistic value. The LTSA conduct speed surveys in winter and summer months. Table 5.5 provides the 85th percentile free speeds for cars measured on long straight sections.

Table 5.5 85th percentile free speeds on straight road sections (R.Bean pers.comm.).

| Year | Summer (km/h) | Winter (km/h) |
|---|---|---|
| 1995 | 113 | 116 |
| 1994 | 111 | 115 |
| 1993 | 115 | 118 |
| 1992 | 114 | 116 |
| Assumed 85th percentile = 114 km/h | | |

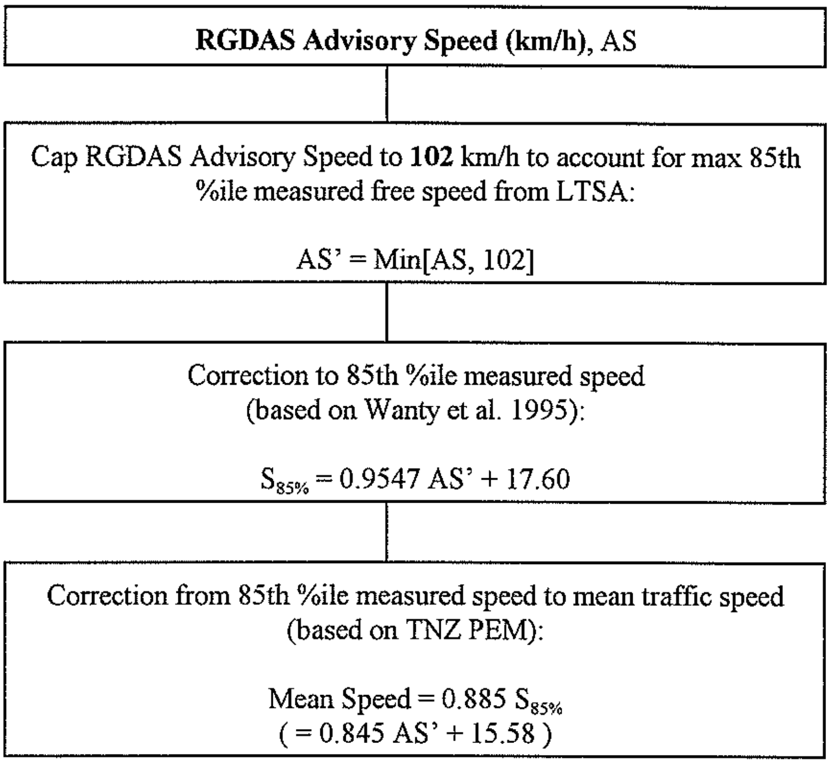


Figure 5.8 Process for converting RGDAS advisory speeds to mean traffic speeds.

Using the expression of Wanty et al. (1995), a maximum RGDAS advisory speed for the speed environment (1000-m section) of 102 km/h may be back-calculated. The expression is however based on a small data set. This adjustment is therefore the weakest link in the analysis, and should be investigated further once the immediate concerns have been addressed. For this reason, the bulk of the analysis has been based on the RGDAS advisory speed measures, with the conversion to mean speed being undertaken at the end of the analysis.

## 5.4 Discussion of Results

The current project evaluation procedures are based on a geometric relationship where accident cost increased 2.5% per 1 km/h increase in mean speed. As shown in Figure 5.9, the current study provides a geometric growth of 2.9% per km/h increase in mean speed. The data, however, do appear to have a strong linear trend, and an arithmetic growth is preferred.

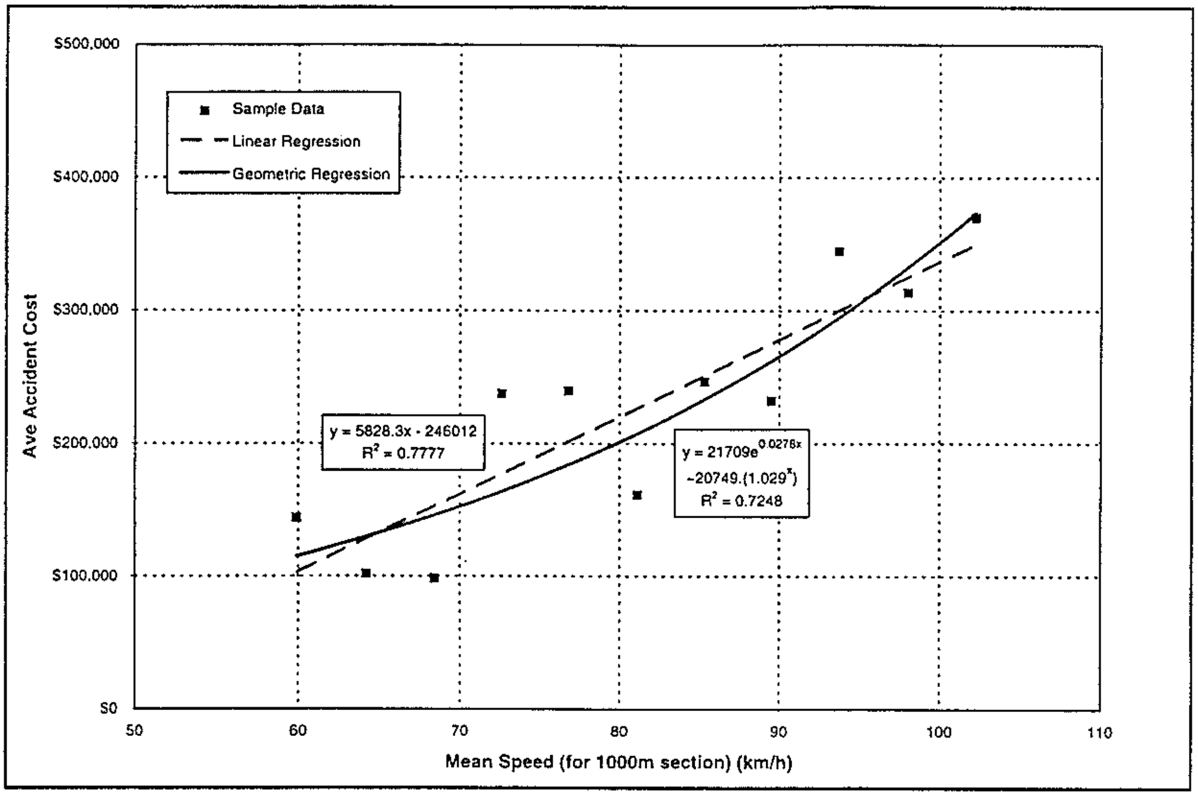


Figure 5.9 Average accident cost (NZ$) v mean speed (based on AAS1000).

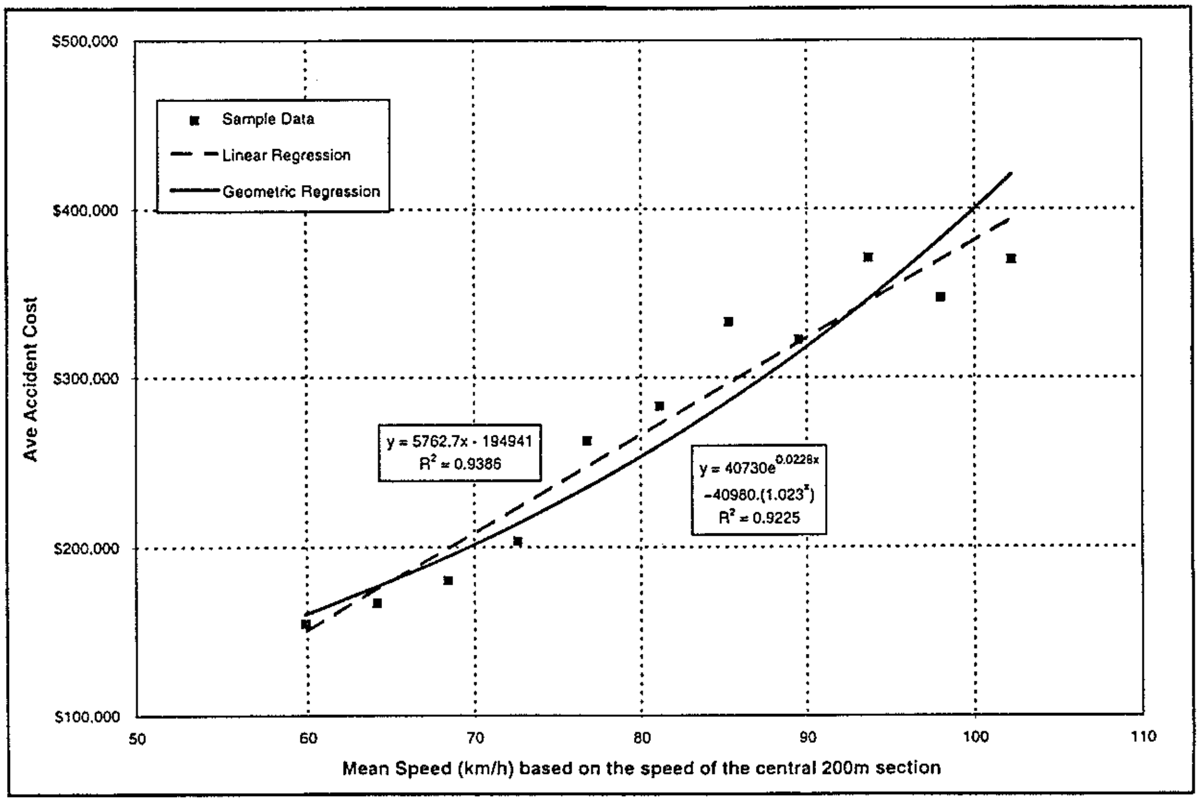


Figure 5.10 Average accident cost (NZ$) v mean speed (based on AAS200).

The use of a linear relationship would require some additional calculation steps when applied to project evaluation. The growth is NZ$5,828 per km/h (mean speed) in average accident cost. Rather than simply calculating the total accident cost and multiplying this by a percentage increase, the analyst would need to calculate the average accident cost (total accident cost/number of accidents), increase this by the arithmetic cost increase of $5,828 per km/h speed increase, and then multiply by the number of accidents to give the new accident cost.

Repeating the analysis using the average advisory speed of the central 200-m segment (AAS200), Figure 5.10 provides an arithmetic growth of $5,762 per km/h per accident. This is 99% of the value, as derived from the AAS1000. The difference is considered insignificant and does not warrant further investigation at this stage.

Although expressed in terms of a mean (traffic) speed, the relationship has been derived from a change in speed environment (an average over 1000 m) and should not be applied at a point or over short lengths. So where an improvement is made to bring a section of road or a curve into character with the surrounding alignment, the severity adjustment should not be made.

# 6. ACCIDENT RATE & CURVE SPEED

## 6.1 Background

The accident rate at curves has been shown to be strongly related to the difference between the approach speed environment and the design speed at the curve (Jackett 1992). This relationship is a measure of how "unexpected" a curve may be given the alignment preceding to the curve. The analysis must be undertaken directionally, and accidents have been allocated to a direction of travel based on:

- increasing route position, and
- decreasing route position.

The methods used to assign accident direction, the importation and scaling of the traffic volumes required to calculate the accident rate are detailed in Section 6.2 of this report. The analysis then proceeded using the RGDAS average and minimum advisory speeds for each 200-m segment to represent "curve" speeds, and the RGDAS average advisory speed for the preceding 1000 m to represent the approach speed environment, as discussed in Section 6.3.

## 6.2 Database Modification

A new database was created from the modified road segment data (SHW_DATA). This database contains 45,788 road segment pairs. The data needed to be directionally split to allow consideration of the approach speed environment. Each individual record, increasing or decreasing, was included separately with fields for segment location, AADT, horizontal curvature, advisory speeds and accident numbers.

The data for this phase required complete sets of accidents for the segments to correctly determine accident rates. If any doubt existed about accounting for all accidents, a road section could not be used. The LTSA Auckland and Christchurch regional offices no longer complete the route position data for all accidents, preferring to rely on grid co-ordinates instead. This resolution by different regional offices had been made at different times so that it was not clear exactly when the change had occurred. A decision was made therefore to exclude all data obtained from these regions, and to use road and accident data from only the LTSA Wellington region.

Since it was not possible to assume which RGDAS speed measures, the average or minimum advisory speed, over the 200-m curve or the 1000-m approach would provide the best relationship, each was included in the analysis.

The AADT was obtained from the NTD traffic counts. These had all been set to a base year of mid-1994. As the accident data were from 1990 to 1995, the traffic counts were scaled back to the midpoint of this period. The route position of each road data record was matched to the nearest NTD traffic count or estimate. This was halved to give flows in each direction and scaled down using the traffic growth factors from the PEM.

The resulting road data were also stripped of segments having mixed urban/rural parts or having incomplete advisory speed data. The final database (NEW_SH2W) contained 12,189 road segment pairs.

From the initial 8,437 accidents, in SHWYACCS, 5,660 accidents with curve-related movement types (codes B, C, D) were extracted. These accident types were used in the previous LTSA study, upon which the present PEM procedures were based. These accidents were then matched with the road segments available for the analysis to give a sample of 2,158 matched accidents.

The accidents were split into increasing or decreasing directions and assigned to the corresponding segment. Direction was generally determined by comparing the direction of the key accident vehicle with the bearing of the segment. If this was inconclusive, accident movement types where the direction of curvature could be identified (i.e. BB, BC, BD, DA, DB) were matched with the geometric curvature of the road. If there was still no match, the accident was randomly assigned to either of the two directions. and, of the 2,158 matching accidents, only 111 (5%) had to be randomly assigned. This process was required because accidents cannot be discarded without introducing bias into the accident rate. Randomly assigning those accidents for which the direction could not be established would increase the unexplained variance in any subsequent relationship, but not bias the results because these accidents would be located in the correct segment.

## 6.3 Analysis

The combined databases were then summarised for analysis. Segments were grouped by both speed environment and speed reduction at the road segment, and accident and vehicle counts (both for the six year period 1990-95) were tallied. Speed reductions were examined in terms of both 5 km/h and 5% intervals, with 5 km/h speed environment intervals.

The accident rate for each 200-m segment was then plotted against the speed differences, between approach and curve speed, and a linear relationship was fitted. The strength of each relationship, as measured by the correlation coefficient $R^2$, is recorded in Table 6.1.

Table 6.1 Preliminary analysis to determine the key variables for consideration in the accident rate analysis.

| Environment | Curve speed | Measure | Linear $R^2$ |
|---|---|---|---|
| RGDAS average advisory speed on preceding 1000 m (AAS1000) | RGDAS average advisory speed (AAS200) | % reduction | 0.082 |
| | | – difference | 0.477 |
| | RGDAS minimum advisory speed (MAS200) | % reduction | 0.920 |
| | | – difference | 0.983 |

Table 6.1 shows that the minimum advisory speed of the 200-m segment (MAS200) provides by far the best relationship. Within that group, a relationship based on the difference ($\Delta$SD) between minimum advisory speed and the average advisory speed of the previous 1000 m provided the strongest relationship for the total accident rate, as shown in Figures 6.1 and 6.2. Figures 6.3 to 6.5 show the breakdown by severity of accidents. Given the small sample for fatal accidents and given that the three severity classes have very similar relationships, a disaggregate analysis is not recommended.

## 6.4 Discussion of Accident Rates on Curves

### 6.4.1 Relationships to Speed

The relationship between RGDAS, minimum advisory speed and accident rate is not particularly useful. The analysis is based on a 200-m section and assumes that the curve is completely contained within the section. Clearly this will not be the case, and is borne out by the factor of about 2 between the accident rates used in the previous study (Jackett 1992) and those found in this study.

The relationships developed by the LTSA (Jackett 1992) form the basis of the method currently in the PEM. These were developed on the basis of a percentage speed reduction to negotiate a curve and are shown in Figure 6.6. In that study, an exponential growth curve of:

$$\text{accident rate (acc/}10^6\text{ vehicles)} = 0.0396\,e^{2.5674x} \qquad \text{(Equation 5)}$$

where x is the % speed reduction

has been fitted to this data. As shown in Figure 6.6, this expression may be closely approximated by a geometric growth curve of:

$$\text{accident rate} = 0.0395\,.\,(1.026^x) \qquad \text{(Equation 6)}$$

where x is the % speed reduction

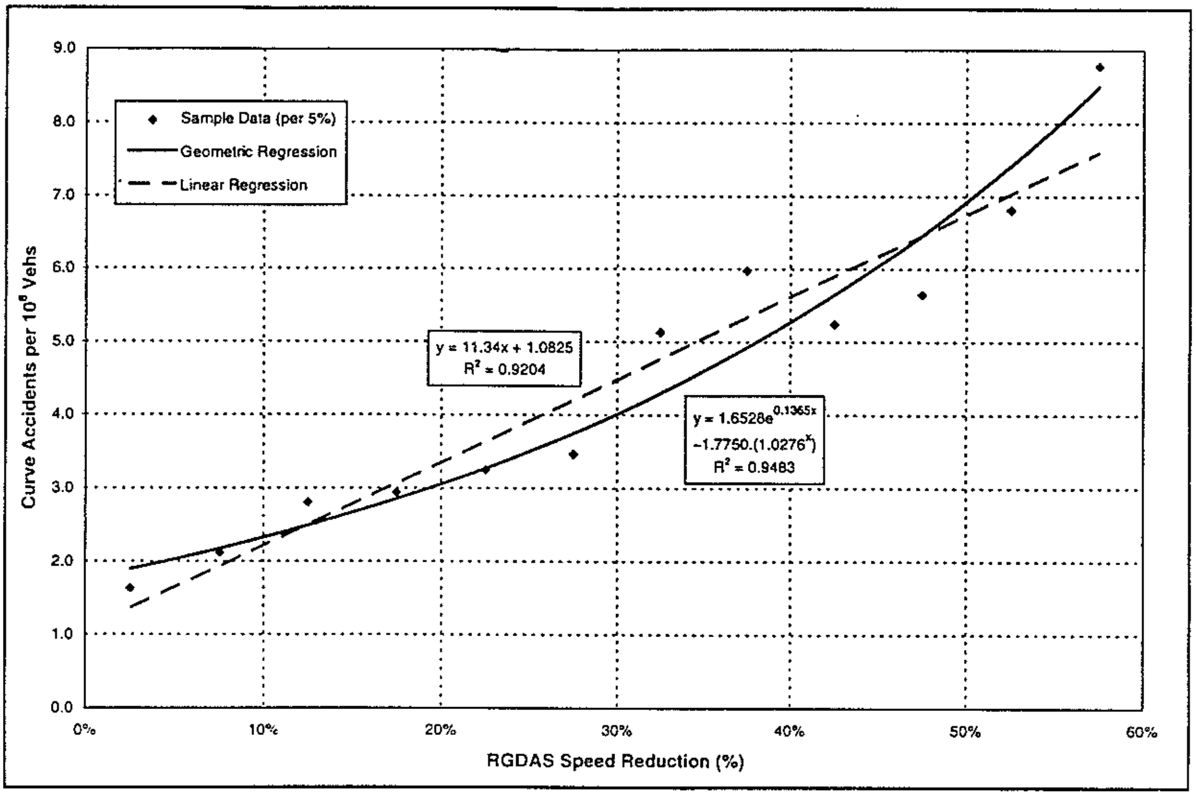


Figure 6.1 Curve accident rate v % speed reduction to minimum curve speed (MAS200).

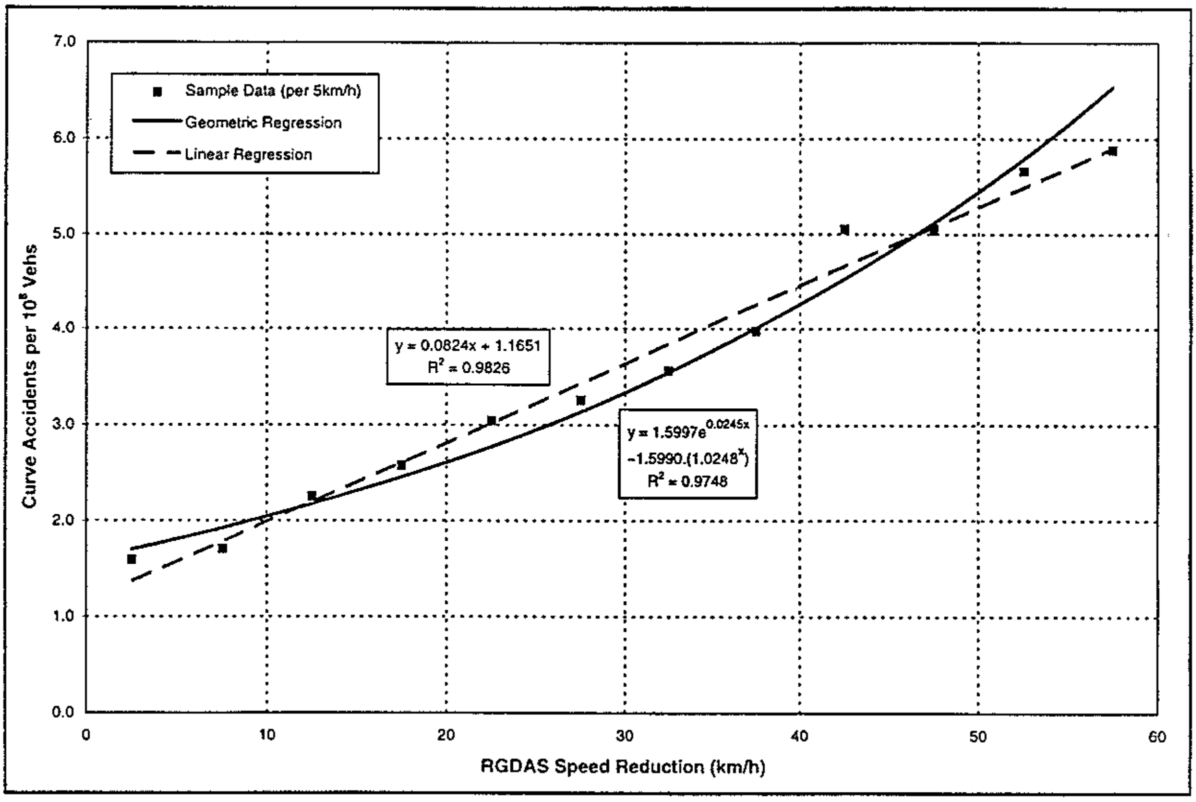


Figure 6.2 Curve accident rate v speed reduction (in km/h) to minimum curve speed (MAS200).

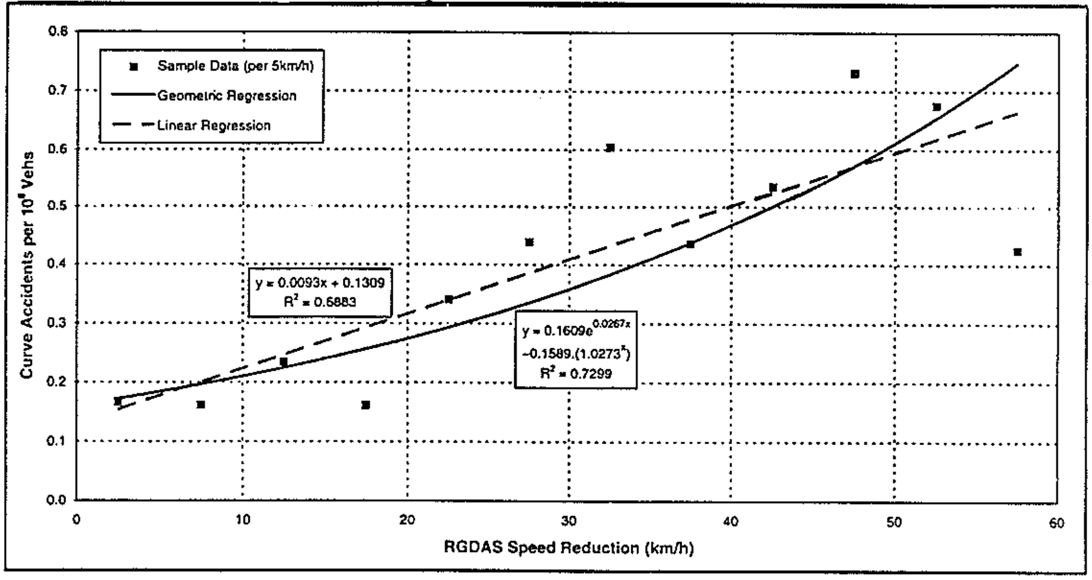


Figure 6.3 Fatal accident rate (scale 0.0 to 0.8) v reduction to minimum curve speed.

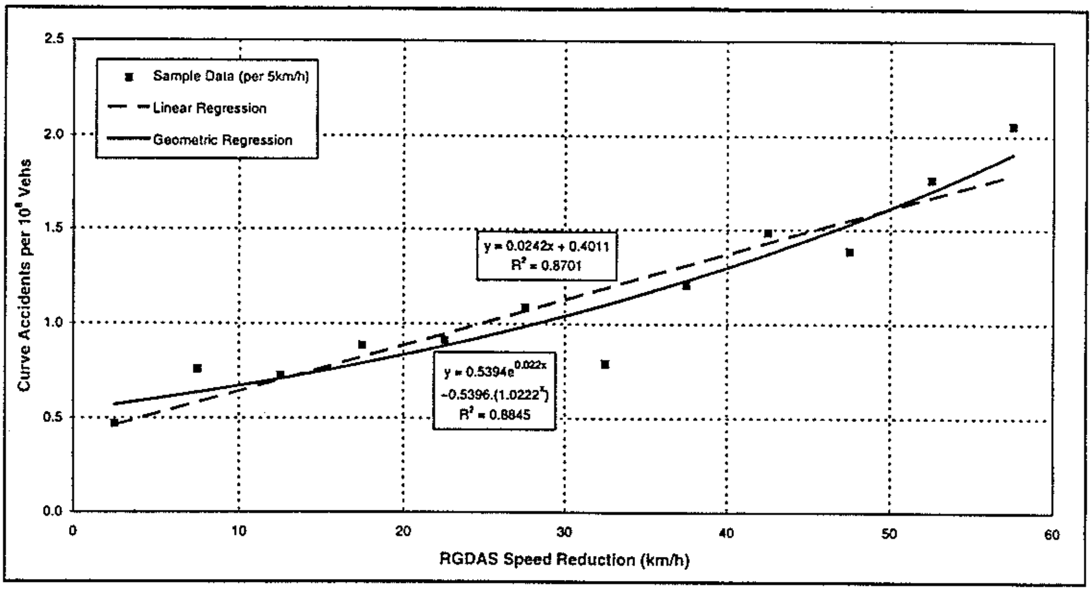


Figure 6.4 Serious accident rate (scale 0.0 to 2.5) v reduction to minimum curve speed.

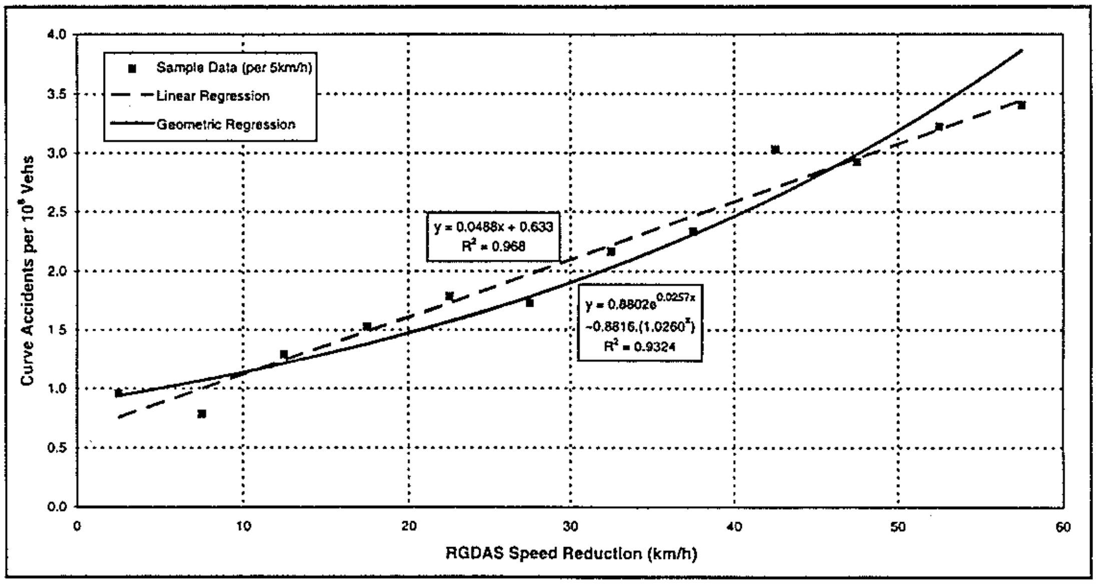


Figure 6.5 Minor accident rate (scale 0.0 to 4.0) v reduction to minimum curve speed.

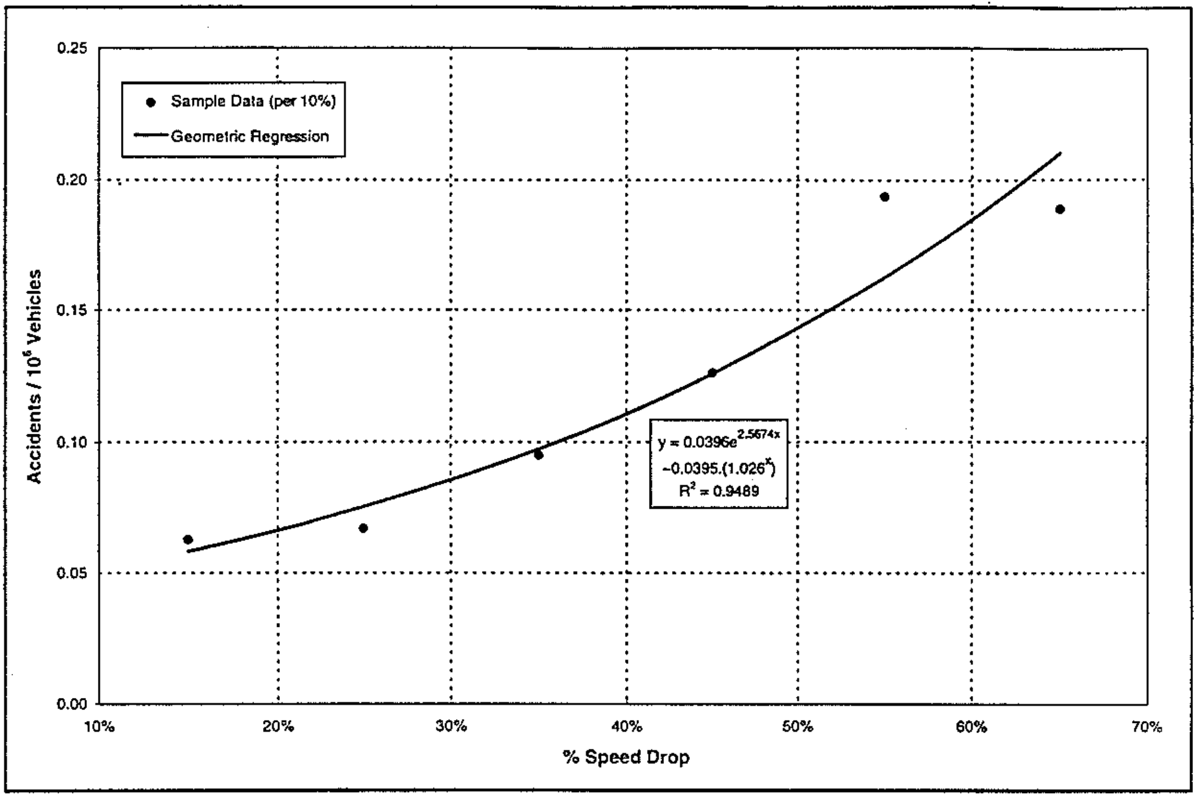


Figure 6.6 Accident prediction for rural curves (accidents/$10^6$ vehicles/curve) (from Jackett 1992).

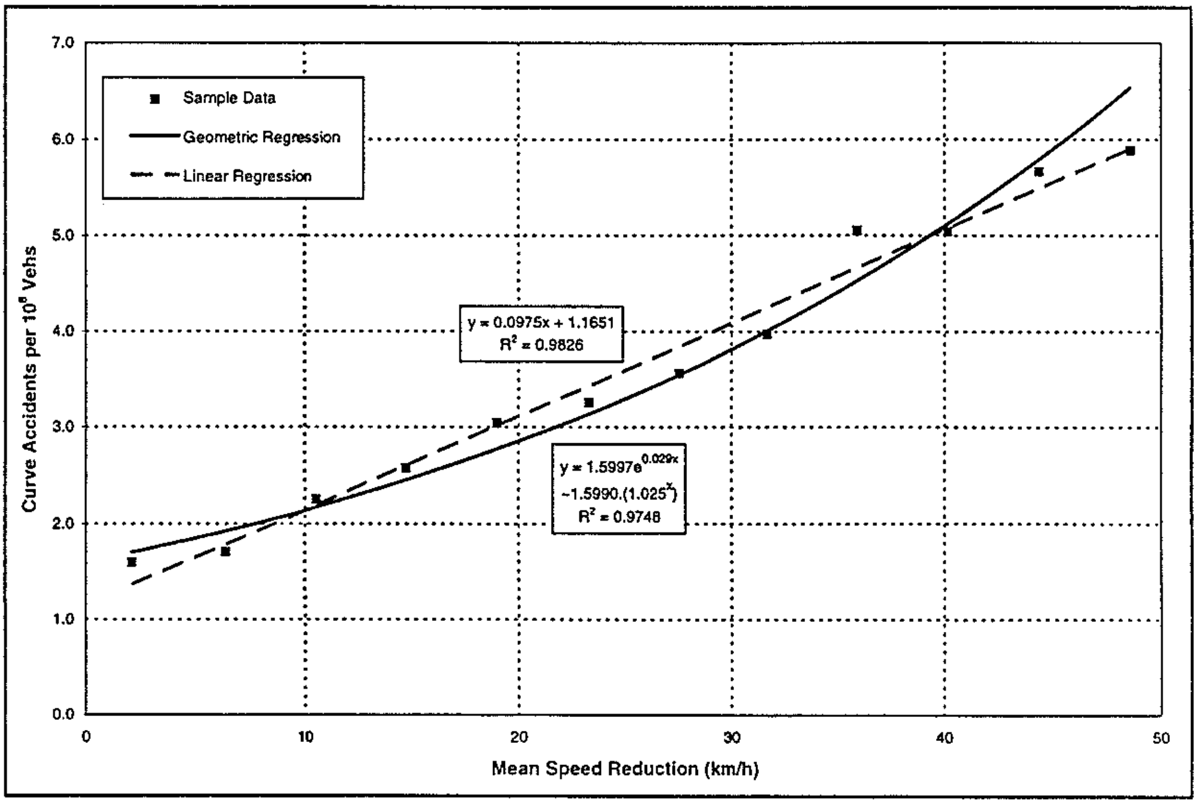


Figure 6.7 Accident rate on curves v reduction to minimum curve speed.

Having converted the RGDAS advisory speed to mean speed using the procedure outlined in Section 5.3 of this report, a similar approximation can be made using the current data (Figure 6.7). The resulting geometric growth curve is:

$$\text{accident rate (acc/}10^8\text{ vehicles)} = 1.599\ .\ (1.025^{x}) \qquad \text{(Equation 7)}$$

where x is the % speed reduction

The differences in the scaling factors of 0.0395 for an accident rate per $10^6$ vehicles per curve (Jackett 1992) and the scaling factor of 1.599 for an accident rate of $10^8$ vehicles per 200-m segment (this study) means that there is not a one to one relationship between curves and the 200-m segments. In fact, the difference in scale is a factor of 2.2.

For verification, the number of curves in the database (11,602) has been compared to the number of road sections (22,956), and the result is a factor of 1.98. In this context a curve is identified by a change in curvature with the RGDAS data, and it is only an approximate measure. However, this compares favourably with the difference in scaling factors above which is considered a reasonable comparison.

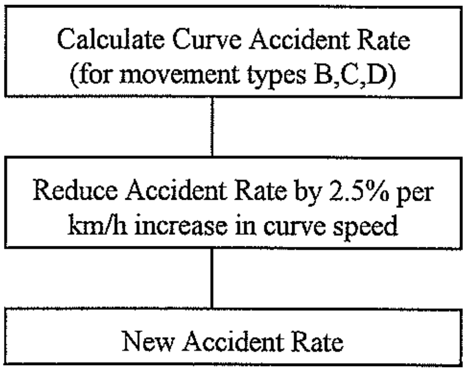
Although the accident rates resulting from the two studies are derived for different units of measure, it is not the absolute accident rates that are considered in project evaluation. Project evaluations for curve improvements generally consider a change in accident rate from the present accident rate.

It is therefore possible to fit a geometric growth function of the form:

$$y = a\ .\ b^{x} \qquad \text{(Equation 8)}$$

In this relationship the coefficient b is the percentage increase in accident rate for a given speed difference. This allows the change in accident rate to be established, as shown in Figure 6.8. It is also interesting to note that the coefficient b = 1.025 (from Equation 7) differs by 0.1% from that obtained by fitting a geometric growth curve to the data used in the earlier study (Jackett 1992).

Figure 6.8 Applying an accident rate reduction for curve improvements.



### 6.4.2 Application of Procedures

One application of the curve accident rate procedures has been to assess the potential for accident migration. When a curve is improved the approach speed to a downstream curve is likely to be increased. If so, the difference between the approach speed and design speed may increase, resulting in an increased accident rate at the downstream curve.

The analysis has been based on the use of a 1000-m section which represents the approach speed environment. Although not strictly true, this assumption may be used to represent the approach speed into a particular curve. This assumption allows maximum use of outputs of the study, but further research into speed predictions and accident rate is considered useful.

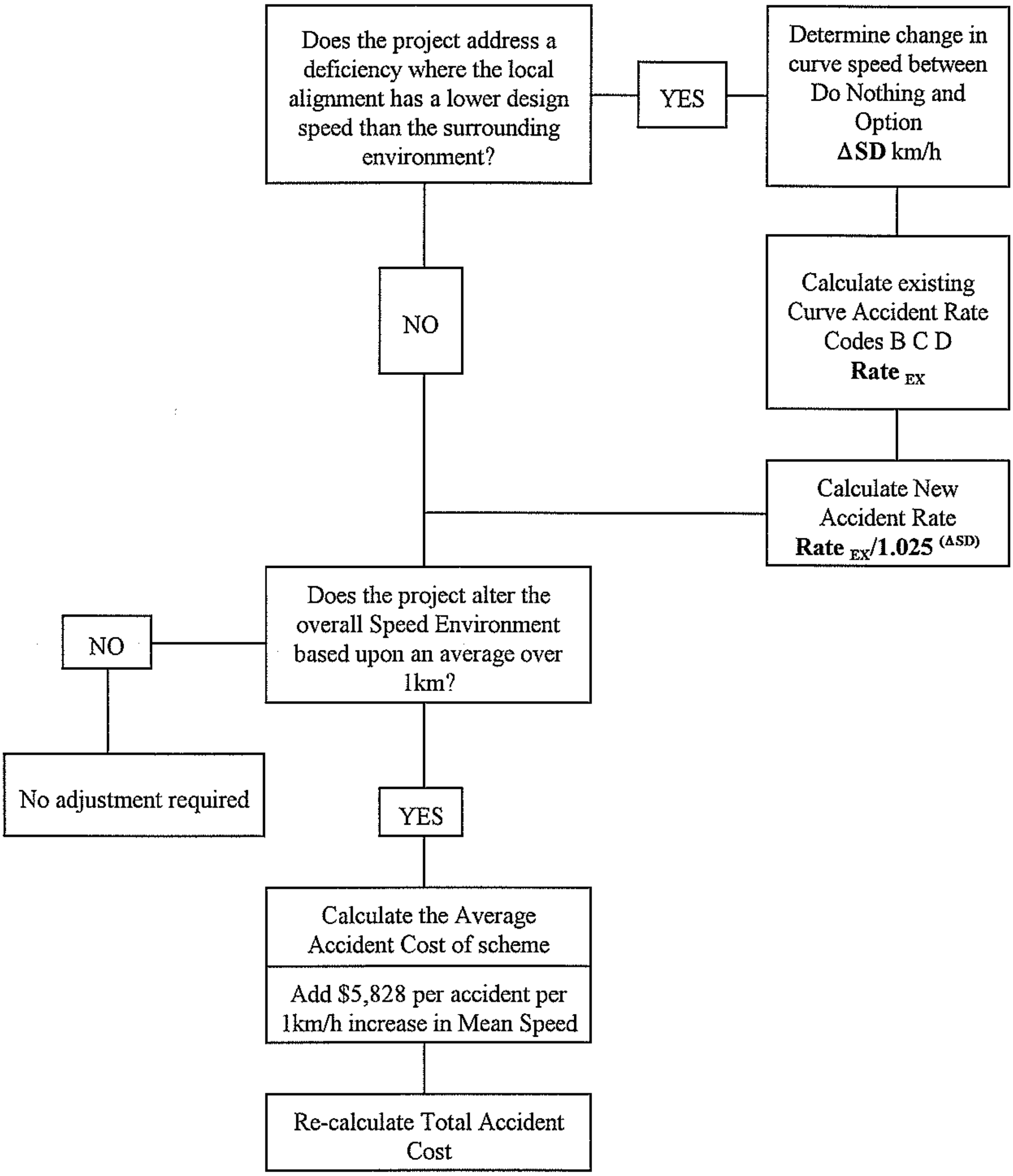
# 7. COMBINED PROCEDURES

The preceding analysis has considered both the increase in accident severity and the change in accident rates for curve improvements in terms of a common data set. Now it can be determined whether or not the project evaluation procedures for addressing these two issues should be applied together.

The results of each separate analysis are strongly related to the speed environment. The change in accident severity cost is expressed in terms of an average speed over a 1000-m section. This section length will include areas of sub-standard geometry. Therefore, if an improvement brings a curve into keeping with the overall environment, the severity effects have already been accounted for. Provided the improvement does not alter the speed environment, as measured by the mean speed over a 1000-m section, then no subsequent adjustment for the increased severity of accidents is required.

This procedure is outlined in Figure 7.1, and in Appendix 3 in which it is presented as a draft for adoption in the PEM.

Figure 7.1 Proposed accident analysis procedures, to adjust accident rates and severity, for inclusion in the PEM.



# 8. CONCLUSIONS

The current procedures used in the PEM for adjusting accident costs to account for the increase in accident severity that arises from an increase in mean traffic speed have been reviewed. The review has identified that the current procedures are based on an analysis of regulatory speeds. However, using regulatory speeds appears inappropriate when considering the effect of speed changes at specific highway locations.

Furthermore, relationships based on regulatory speeds suggest that the results should not be combined with the results of research into the reduction in accident rates that may arise from curve improvements.

The RGDAS data provide a network-wide measure of speed based on road geometry. Although based on limited data, this measure may be related to the 85th percentile traffic speed and from that to mean traffic speed.

The analysis of accident data from the LTSA CIS, traffic volume and cross-sectional data from the NTD and RAMM, and the RGDAS advisory speed data for New Zealand state highways, has confirmed that:

- the cost of rural accidents, i.e. accidents occurring at 100 km/h regulatory speed, increase at a rate of NZ$5,828 per accident per 1 km/h increase in mean traffic speed;

- the accident rate for curves is related to the difference ($\Delta$SD) between the approach speed or approach speed environment and the mean curve speed, and is such that the accident rate decreases by $1.025^{\Delta SD}$, i.e. a 2.5% reduction per km/h decrease in speed difference; and

- because the accident severity is related to the speed environment, a curve improvement that does not alter the overall speed environment should not be subject to an adjustment for accident severity increase.

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# APPENDICES

# APPENDIX 1.
# TRANSIT NEW ZEALAND PROJECT EVALUATION MANUAL 1996: ACCIDENT ANALYSIS PROCEDURES

Facsimile of relevant pages of PEM, from Appendix A6.

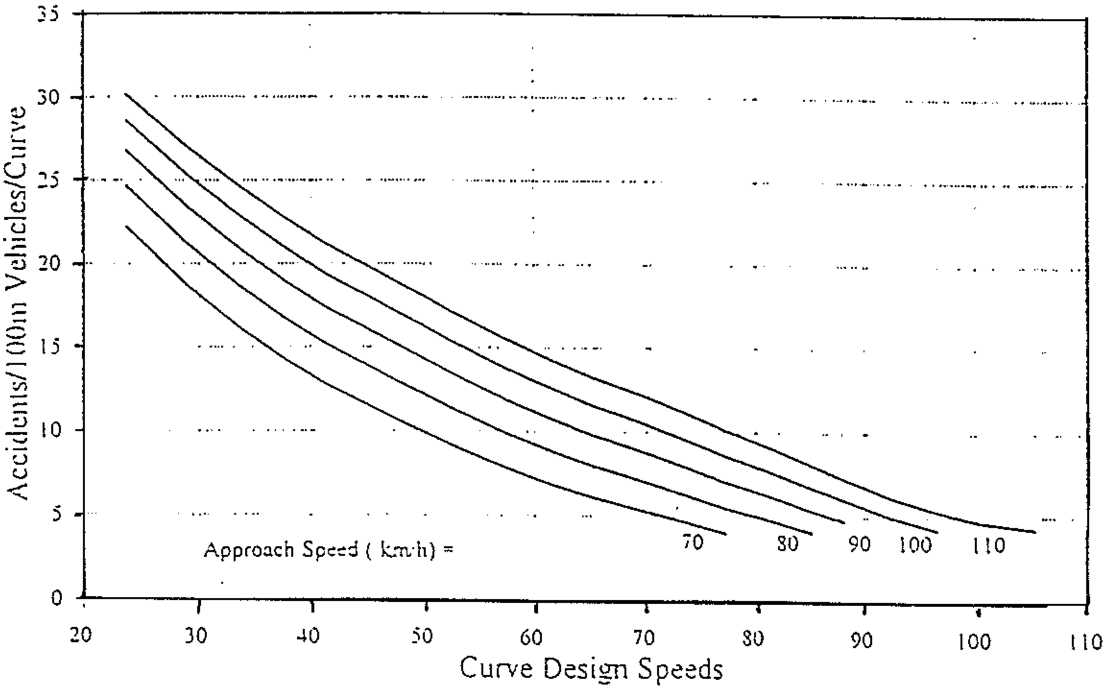
## A6.4.8 Curves in 100 km/h Speed Limit Areas

Figure A6.2 provides typical injury accident rates for loss of control and head-on injury accidents on rural curves, adjusted for the general trends in accidents.

When using the graph it should be noted that:

(i) the rate is in terms of injury accidents per 100 million vehicles through the curve and *not* accidents per 100 million vehicle kilometres,
(ii) the design speed of the curve is as determined from the publication "Rural Road Design", AUSTROADS, 1989, Page 9,
(iii) the approach speed to the curve is the estimated 85th percentile speed at a point prior to slowing for the curve (for longer tangents this would approximate to the speed environment),
(iv) the data are for typical injury accident rates for sealed rural state highways. The rates are based on the assumption that the highway under consideration is not affected by ice or other adverse factors such as poor visual conditions.

FIGURE A6.2 ACCIDENT RATES FOR RURAL ROAD CURVES 100 km/h SPEED LIMIT AREAS.



## A6.6 EFFECT OF SPEED ON ACCIDENT COSTS

The number of people injured and the degree of injury severity per accident generally increases with traffic speed. Present evidence indicates that injuries per accident and the proportion of fatal and serious injuries increase linearly with speed above 50 km/h. This should be taken into account when undertaking accident-by-accident analysis of projects which serve to increase the mean speed of traffic by 5 km/h or more, such as road realignments, passing lanes and possibly four-laning where there is no change in the posted speed limit. For such projects, although the numbers of accidents might be reduced, the accident cost saving can be small or sometimes negative due to the increased accident severity resulting from the increased speed. When undertaking accident-by-accident analysis if the mean speed increases by 5 km/h or more an adjustment is made to the accident costs for the option(s).

**Procedure:**

| Step | Action |
|---|---|
| 1 if there is no change in the posted speed limit between the do minimum and the option | subtract the mean speed in the do minimum from the mean speed in the option(s), |
| 2 if the difference in the mean speed between the do minimum and the option is ± 5 km/h or more *and* the mean speed for the do minimum and/or the option is greater than 50 km/h | apply an adjustment to the total accident costs for the project option(s) at the percentage rate per km/h of speed difference shown below. |
| 3 as an exception to 2 above, if there is a change in the posted speed limit between the do minimum and the option | use the accident costs for the appropriate posted speed limits in the do minimum and in the option(s) |

**ADJUSTMENTS TO ACCIDENT COSTS - for changes in mean traffic speed of 5 km/h or more.**

| | Posted Speed Limit | | |
|---|---|---|---|
| | 50 km/h | 70 km/h | 100 km/h |
| % change in costs of accidents | 2.5 % per km/h | | |

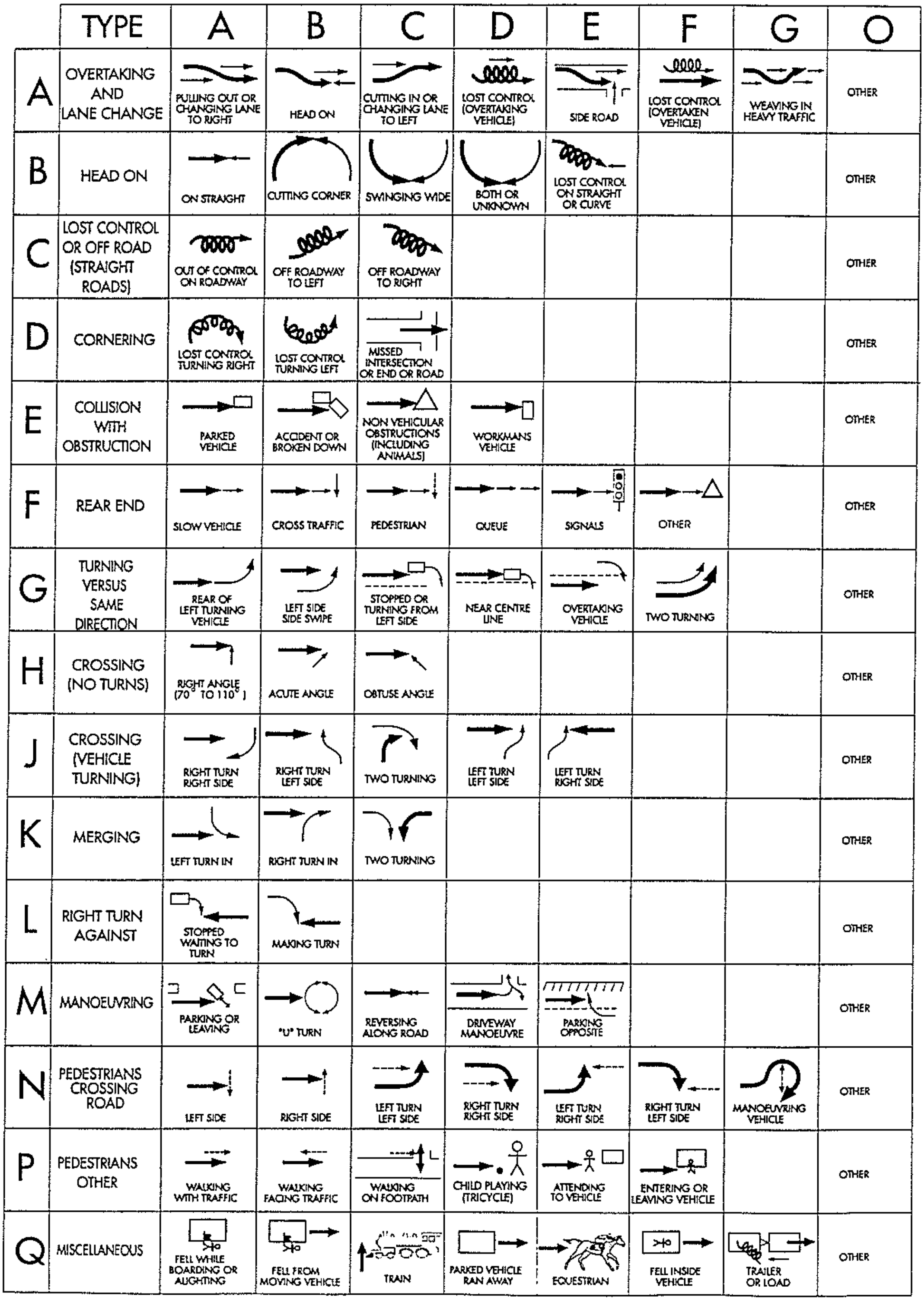
Note: 50 km/h should be used as the lower bound for the mean speed. For example if the mean speed for the do minimum is 45 km/h and for the option is 57 km/h then the adjustment would be based on a difference of 7 km/h, i.e. from 50 to 57 km/h, and the adjustment would be 7 x 2.5% per km/h = + 17.5% (or times 1.175) to adjust the accident costs of the option.

# APPENDIX 2.
# LAND TRANSPORT SAFETY AUTHORITY: ACCIDENT MOVEMENT CODES

LAND TRANSPORT SAFETY AUTHORITY

# VEHICLE MOVEMENT CODING SHEET

(For use with accidents occurring on and from 1/1/92)



| | TYPE | A | B | C | D | E | F | G | O |
|---|---|---|---|---|---|---|---|---|---|
| A | OVERTAKING AND LANE CHANGE | PULLING OUT OR CHANGING LANE TO RIGHT | HEAD ON | CUTTING IN OR CHANGING LANE TO LEFT | LOST CONTROL (OVERTAKING VEHICLE) | SIDE ROAD | LOST CONTROL (OVERTAKEN VEHICLE) | WEAVING IN HEAVY TRAFFIC | OTHER |
| B | HEAD ON | ON STRAIGHT | CUTTING CORNER | SWINGING WIDE | BOTH OR UNKNOWN | LOST CONTROL ON STRAIGHT OR CURVE | | | OTHER |
| C | LOST CONTROL OR OFF ROAD (STRAIGHT ROADS) | OUT OF CONTROL ON ROADWAY | OFF ROADWAY TO LEFT | OFF ROADWAY TO RIGHT | | | | | OTHER |
| D | CORNERING | LOST CONTROL TURNING RIGHT | LOST CONTROL TURNING LEFT | MISSED INTERSECTION OR END OR ROAD | | | | | OTHER |
| E | COLLISION WITH OBSTRUCTION | PARKED VEHICLE | ACCIDENT OR BROKEN DOWN | NON VEHICULAR OBSTRUCTIONS (INCLUDING ANIMALS) | WORKMANS VEHICLE | | | | OTHER |
| F | REAR END | SLOW VEHICLE | CROSS TRAFFIC | PEDESTRIAN | QUEUE | SIGNALS | OTHER | | OTHER |
| G | TURNING VERSUS SAME DIRECTION | REAR OF LEFT TURNING VEHICLE | LEFT SIDE SIDE SWIPE | STOPPED OR TURNING FROM LEFT SIDE | NEAR CENTRE LINE | OVERTAKING VEHICLE | TWO TURNING | | OTHER |
| H | CROSSING (NO TURNS) | RIGHT ANGLE (70° TO 110°) | ACUTE ANGLE | OBTUSE ANGLE | | | | | OTHER |
| J | CROSSING (VEHICLE TURNING) | RIGHT TURN RIGHT SIDE | RIGHT TURN LEFT SIDE | TWO TURNING | LEFT TURN LEFT SIDE | LEFT TURN RIGHT SIDE | | | OTHER |
| K | MERGING | LEFT TURN IN | RIGHT TURN IN | TWO TURNING | | | | | OTHER |
| L | RIGHT TURN AGAINST | STOPPED WAITING TO TURN | MAKING TURN | | | | | | OTHER |
| M | MANOEUVRING | PARKING OR LEAVING | "U" TURN | REVERSING ALONG ROAD | DRIVEWAY MANOEUVRE | PARKING OPPOSITE | | | OTHER |
| N | PEDESTRIANS CROSSING ROAD | LEFT SIDE | RIGHT SIDE | LEFT TURN LEFT SIDE | RIGHT TURN RIGHT SIDE | LEFT TURN RIGHT SIDE | RIGHT TURN LEFT SIDE | MANOEUVRING VEHICLE | OTHER |
| P | PEDESTRIANS OTHER | WALKING WITH TRAFFIC | WALKING FACING TRAFFIC | WALKING ON FOOTPATH | CHILD PLAYING (TRICYCLE) | ATTENDING TO VEHICLE | ENTERING OR LEAVING VEHICLE | | OTHER |
| Q | MISCELLANEOUS | FELL WHILE BOARDING OR ALIGHTING | FELL FROM MOVING VEHICLE | TRAIN | PARKED VEHICLE RAN AWAY | EQUESTRIAN | FELL INSIDE VEHICLE | TRAILER OR LOAD | OTHER |

# APPENDIX 3.
# DRAFT PROCEDURE FOR PROJECT EVALUATION MANUAL

## ADJUSTMENT FOR ACCIDENT SEVERITY & CURVE IMPROVEMENTS

The following procedures shall be used to adjust the accident rates and severity when the works proposed are expected to address issues of design and operating speed.

- Where the design speed of a road is increased so that the average traffic speed increases (as measured over a 1000-m road section), the average accident severity increases by NZ(1996) $5,828, per accident, per kilometre-increase in mean traffic speed.
- Where a localised improvement is proposed in order to attain uniform design standard, no correction in severity is required.
- Where a curve is improved, an accident rate reduction is calculated for curve-related accidents, using a reduction in accident rate of 2.5% for every km/h improvement in mean speed (or design speed) through the curve.
- This procedure is outlined in the following chart.

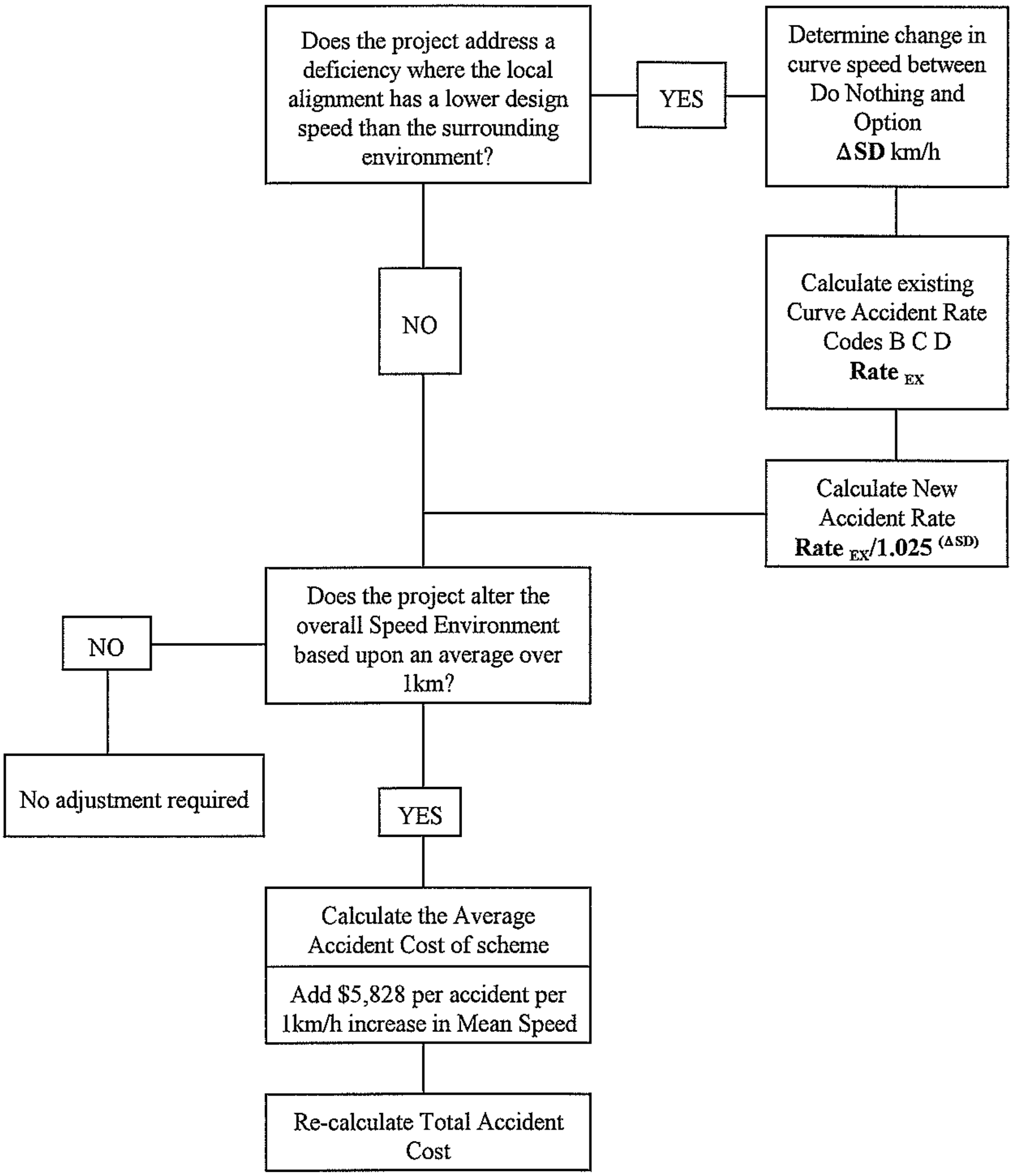


Chart of accident analysis procedures followed to adjust accident rates and severity.