MACROSCOPIC MODELS RELATING TRAFFIC VOLUMES & FATALITIES

BECA CARTER HOLLINGS & FERNER LTD
Auckland, New Zealand

Transit New Zealand Research Report No. 48

ISBN 0-478-10505-3
ISSN 1170-9405

PO Box 5084, Lambton Quay, Wellington, New Zealand
Telephone (04) 499-6600; Facsimile (04) 496-6666

Beca Carter Hollings & Ferner Ltd 1995. Macroscopic models relating traffic volumes and fatalities. *Transit New Zealand Research Report No. 48.* 35pp.

Keywords: accidents, fatalities, fatality rate, macroscopic, modelling, roads, safety, traffic, traffic accidents, traffic safety, traffic volume

AN IMPORTANT NOTE FOR THE READER

CONTENTS

EXECUTIVE SUMMARY

1. Introduction

Interest in the application of macroscopic models for the description of improvements in traffic safety has increased since the early 1980s. Macroscopic models utilise a small number of variables, with each variable being regarded as an aggregate or large unit (e.g. annual number of fatalities, vehicle kilometres travelled, population).

In 1949, a comparison of road safety in 20 countries had been made, based on the total number of fatalities to the number of cars and to the size of population, and a regression model was also developed.

Several years later, in 1989 and 1991, two new models were developed: one to establish relationships for traffic volumes, and the other for traffic safety, based on fatality rates, using data from six countries (Netherlands, USA, West Germany, Great Britain, Japan and Israel). A relationship between the two models is suggested that links safety outcomes to developments (particularly increases) in traffic volume. Once validated, predictions can be made for traffic volume, fatality rates and fatalities on the basis of time parameters only.

2. Objective

The objective of this project is to apply New Zealand and Australian data to these two models and to compare the results with the six countries mentioned above. As the modelling is performed at the macroscopic level, sensitivity analysis of a range of input values and comparisons with other countries are both essential to the work.

3. Conclusions

The macroscopic models relating traffic volumes and traffic safety have been applied to New Zealand and Australia data. The models are

- a negative exponential learning curve for fatality rate and
- a logistic model for traffic volume represented by vehicle kilometres travelled (VKT).

While sufficient regression model fits are made, they are not as well-fitting as those for other countries.

This study suggests that New Zealand has a poor safety record compared with a number of other countries. Of the six countries considered, as well as Australia and New Zealand, New Zealand has the worst record when considering improvements in fatality rate (i.e. fatalities with respect to vehicle kilometres travelled).

Although New Zealand had a very good safety record (measured by fatalities) during the 1950s and 1960s, its rate of improvement up to 1991 has been one of the poorest compared with other countries.

However since 1991, when the modelling and comparisons with other countries were performed, progress in improving the fatality rate in both New Zealand and Australia has been good.

4. Recommendations

- A clear case exists for New Zealand to attempt to accelerate its safety improvement during the next decade. There are many precedents from performance in analogous countries (e.g. Australia) that this can be done.

- The applicability of Smeed's (1949) formula in New Zealand may have some merit, recognising the need to change regression parameters to account for the changes that are occurring over time.

- For Australia, further comparisons could be made between its States.

ABSTRACT

Interest in the application of macroscopic models for the description of improvements in traffic safety has increased since the early 1980s.

Two models that have been developed to establish relationships between traffic volumes and traffic safety (based on fatality rates) are applied to New Zealand and Australian data to compare these countries' developments in traffic safety to those of six other countries. Up till 1991 performance in reducing fatality rates was relatively poor in New Zealand and good in Australia.

Since 1991, when the modelling and comparisons with other countries were performed, progress in reducing the fatality rates in both New Zealand and Australia has been good.

1. INTRODUCTION

1.1 Background

Interest in the application of macroscopic models for the description of improvements in traffic safety has increased since the early 1980s. Macroscopic models utilise a small number of variables, with each variable being regarded as an aggregate or large unit (e.g. annual number of fatalities, vehicle kilometres travelled, population).

Smeed (1949) published a paper comparing road safety in a number of countries. He compared the total number of fatalities in 20 countries to the number of cars and the size of population. He also developed a regression model based on the data. Since 1949 Smeed's formula has been discussed a good deal.

Hakim et al. (1991) present a thorough review of macroscopic models for road accidents, with the objective of identifying and establishing the significance of policy and socio-economic variables affecting the level of accidents.

Jones (1994) has investigated a number of different approaches, including time series and regression analyses, for trend determination of New Zealand's road toll. His work provides a good summary of the application of modelling techniques to this country.

Recent work in Victoria, Australia, by Thoresen et al. (1992) has shown that, when they can be measured explicitly, social factors such as unemployment and alcohol sales, and major safety measures such as seat belt use and random breath testing, can be shown to have clear links with total fatalities in a State.

Oppe presented two models in his 1989 and 1991 studies: one for traffic volumes, and the other for fatality rate based on data from six countries (Netherlands, United States (USA), West Germany, Great Britain, Japan and Israel). A relationship between the two models is suggested that links safety outcomes to developments (particularly increases) in traffic volume. Once validated, predictions can be made for traffic volume, fatality rates and fatalities on the basis of time parameters only.

1.2 Objectives

The primary objective of this project is to apply New Zealand and Australian data to the Oppe models and to compare the results with the six countries used by Oppe to see if any relevant conclusions can be made. As the modelling is performed at the macroscopic level, both sensitivity analysis of a range of input values and comparisons with other countries are essential. A paper outlining the results of the project was presented at the 1994 IPENZ Annual Conference (Wong-Toi 1994).

2. METHODOLOGY

2.1 The Oppe Models

The models established in the Oppe papers (1989, 1991) and the terminology used in this report are as follows:

F_t	number of fatalities *(F)* for a country in a particular year *(t)*
V_t	number of vehicle kilometres travelled (VKT), i.e. volume, in that year *(t)*
V_m	maximum number of vehicle kilometres *(V)*
$R = F/V$	fatality rate

Oppe derives two models, namely:

Model 1: A negative exponential learning curve

$$\ln(R_t) = \ln(F_t/V_t) = \alpha t + \beta \qquad (1)$$

where the ln function is the natural logarithm.

This means that the logarithm of the ratio between the number of fatalities and the number of vehicle kilometres (i.e. F_t/V_t) decreases (if α is negative) proportionally with time. α and β are the slope and intercept (for $t = 0$) of the straight-line model fit.

Model 2: A logistic model for the number of vehicle kilometres

$$\ln(V_t/(V_m - V_t)) = at + b \qquad (2)$$

This means that the logarithm of the ratio between the traffic volume already realised at time t and the remaining traffic volume potential to be realised in the future (i.e. $V_t/(V_m - V_t)$) increases proportionally with time. a and b are, respectively, the slope and intercept (for $t = 0$) of the straight-line model fit.

2.2 Comparison of the Oppe Papers

The changes between the analysis techniques used in the two papers are minor, and the main differences are as follows:

- Six countries are analysed in the later 1991 paper. The countries are Netherlands, USA, Germany, Great Britain, Israel and Japan. Japan provides an extreme point in the analysis.

  Minor changes have been made in the time periods used (to provide a more consistent comparison between the countries). The greatest change is for the analysis of the USA data, for which the derived parameters have been changed slightly.

- For convenience, the notation has been changed to α,β (fatality rates) and a,b (traffic volumes). This has no impact on the nature of the results.

- Graphs are provided in the 1991 paper for all three basic untransformed plots (volume, fatalities and fatality rate) for each country. These graphs were not possible to duplicate as the raw data were not provided in the paper.

- The six countries are compared in the 1991 paper in a more graphical form. An additional plot shows the intersection of the linear fits, and this is then interpreted physically.

Where appropriate, techniques used in the papers were applied to the New Zealand and Australian data. Where duplication occurred, the more recent terminology was used.

2.3 Analysis Tasks

The analysis sections of the project were carried out in four stages: namely obtain accident data; obtain traffic flow data; analyse the data; carry out additional analysis.

2.3.1 Accident Data

Annual fatality data for the years 1951 to 1991 for New Zealand were obtained from the Land Transport Safety Authority (LTSA, formerly part of Ministry of Transport). These were readily available from their annual Statistical Statement, and were updated to include the fatalities for 1990 and 1991. This time period is the same as that used for the studies cited in Oppe (1991) for the other countries (with the obvious extension for recent data), and is only limited by the available data on vehicle kilometres travelled.

2.3.2 Traffic Volume Data

Synthesised annual vehicle kilometres travelled (VKT) data, from 1951 to 1991 (40 years) for New Zealand were determined after consideration of a number of data sources, including LTSA figures based on returns from transport operators and estimates of fuel usage, Transit New Zealand's indexes of travel on state highways, and the draft report (1991) from Beca Carter Hollings & Ferner Ltd (hereafter abbreviated as BCHF) to Transit New Zealand on vehicle kilometres travelled on New Zealand public roads.

2.3.3 Analysis

The techniques used in the Oppe 1991 paper were adhered to, and preliminary exploratory data analysis was performed on the data before detailed analysis. This preliminary analysis indicated that no outliers existed and that the data were acceptable for the subsequent stages of the project.

Coefficients were derived using standard linear regression techniques, after performing the appropriate transformations of the data. Graphs have been produced similar to those in the Oppe 1991 paper and are presented later in this report.

A variation from the methodology as stated in the Oppe 1989 paper was necessary to obtain the regression for $\ln(V/(V_m - V))$, as follows:

- when determining the parameters of the equation by choosing V_m to maximise the fit with respect to V and not $\ln(V/(V_m - V))$, the linear regression results are in terms of the transformed variable and not of V;
- the estimate of V_m was derived through a somewhat coarse iterative process. although the model was relatively insensitive to minor changes in V_m.

2.3.4 Additional Analysis

For comparison purposes, a number of other overseas countries were also analysed. The Transport Departments and major road research organisations in those countries were contacted to obtain, if available, both more recent and similar data and that country's methodology in determining VKT. The countries contacted included the six used in the Oppe analysis (i.e. USA, Great Britain, Netherlands, Germany, Israel and Japan) and Australia, Denmark, France, Italy, Sweden and Switzerland.

Particular emphasis was placed on the Australian data because of the obvious similarities between Australia and New Zealand. It has, however, been widely documented that Australia's recent record in road safety improvements has been considerably better than that of New Zealand (Land Transport Division (LTD)/MOT 1992).

Australian data for the period from 1976 to 1991 have been analysed. It is not strictly reasonable to use this different time period for comparisons with New Zealand and with the six countries analysed by Oppe (1991) because, generally, the number of fatalities had risen in Australia, New Zealand, and in most of the countries analysed by Oppe before 1976.

The comparison was carried out on the following data:

- best fit for VKT,
- sensitivity analysis with the straight-line fit, and
- LTSA data.

A number of estimates of VKT have been made in the past, many of which are discussed in the BCHF (1991) draft report on VKT to Transit New Zealand. Although the main objective of this project is not to devise best estimates of historical VKT, nevertheless as VKT is one of the key datasets used in the project, it is important to appreciate how the estimate affects the results of the study. For this reason, sensitivity analysis was performed with a range of VKT series to evaluate the effect.

Until 1985, the Land Transport Safety Authority (LTSA) has published VKT estimates for each year as part of their Annual Statistical Statement. Because of concerns about the accuracy of the later data (i.e. from early 1980s), any reference to VKT is omitted from these annual publications (LTD/MOT 1992). The LTSA (1994) believes the data up to the late 1970s are accurate.

A number of studies were made in the mid-1970s and in the mid-1980s and these are discussed more fully in BCHF (1991). That report concludes by stating:

> *"There is reasonable agreement among the earlier estimates for total VKT to have been 18,000 million (± 10%) in the mid-1970s, rising to 25,000 million (± 15%) in the mid-1980s. A means of indexing VKT that will be stable over a reasonable period of time remains to be confirmed."*

The trend as indicated by the derived estimate of VKT is in conformity with general consensus, i.e. that VKT remained relatively constant through the mid- to late 1970s and increased steadily throughout the 1980s.

3. RESULTS

3.1 Traffic Volume Data

An overlay graph of: (1) the Transit New Zealand indexes; (2) the derived VKT values; (3) the LTSA values; and (4) the studies referred to in BCHF (1991) is presented in Figure 3.1. Appendix Figure A3.1 shows additional VKT data for 1951 to 1991, for reference.

Because of concerns about the accuracy of the synthesised New Zealand values, sensitivity analysis was performed based on a range of estimates for the period from 1975 onwards. The straight-line fit for that period was used as the highest estimate of VKT, as the data were considered a "worst case" in the absence of any data for the intervening period. Sufficiently accurate estimates of VKT are available for both the mid-1970s and the mid-1980s. The LTSA collection of data was used as the lowest estimate of VKT.

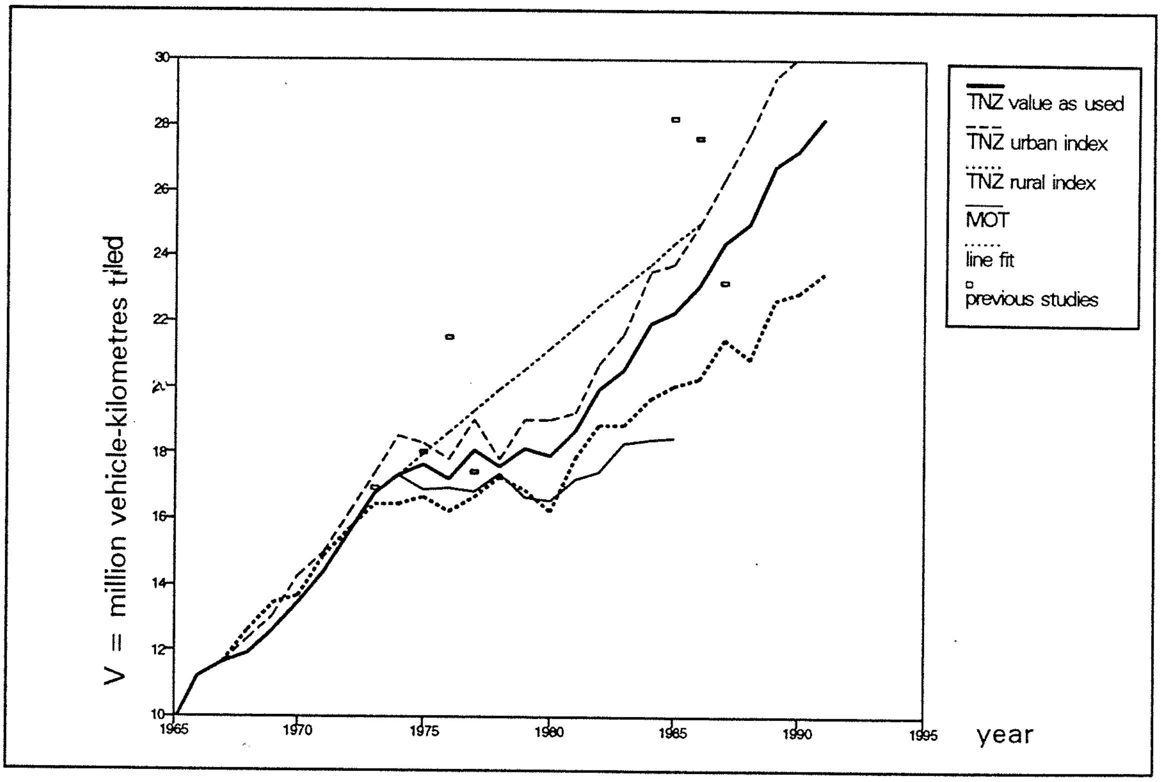

Figure 3.1 Vehicle kilometres travelled (VKT) in New Zealand for the period 1974-1991.

It is important to consider the methods used for estimation in countries other than New Zealand. In the absence of evidence to the contrary, methods similar to those cited in the Oppe paper can be used. However, this would lead to the increased likelihood of discrepancies when comparisons are made. A brief description of the methods used by the six countries that had been analysed by Oppe (1991) and other countries (e.g. Australia) were obtained to overcome this problem.

The USA and Great Britain both have comprehensive systems based on a large number of count stations. Canada and Sweden do not have an annual measure of VKT. For Australia the Department of Transport was able to supply the data which have been used in this study. Recent work has been carried out by Vic Roads (Roads Corporation of Victoria, Australia) developing annual vehicle kilometre estimates using fuel sales and vehicle consumption trends. Replies were not received from Germany or the Netherlands.

The VKT estimates of particular interest are shown in Table 3.1. The main limitation in the use of these estimates for this project is that, as trends over time are required, the VKTs for the intermediate years (i.e. between 1975 and 1985) need to be estimated. The Transit New Zealand indexes of traffic volumes on rural and urban roads were considered adequate to use, although they have inadequacies, particularly for the urban traffic volume index which: (1) does not take account of the expanding road network; and (2) is based on a very small sample of roads.

The Transit New Zealand index is nevertheless sufficiently similar to the LTSA data from 1975 to 1978 for this study, but it then starts to increase at a faster rate. It is still lower than the BCHF 1985 estimates but is within the wide ranges given. As well it shows a considerable difference between the urban and rural trends (Transit New Zealand best fits for the 1980s are 5.1% to 2.9% per annum).

The proportion of travel on urban and rural roads for the period from 1975 to 1985 is estimated to have been 61% and 39% (BCHF 1975). The data were used to derive the VKT estimate from 1975 onwards.

The BCHF 1991 report uses traffic volume indexes with 1975 as the base year, which is consistent with several other studies. A further check of the accuracy of this approach is a comparison with the more recent studies where it appears that volume values around the mid-1980s may possibly be a little low.

The trend as indicated by the derived estimate of VKT conforms with the general consensus, i.e. that VKT increased relatively constantly through the mid- to late 1970s and increased steadily throughout the 1980s.

Table 3.1 VKT estimates for New Zealand traffic flows obtained from studies carried out between 1973 and 1991.

Basis	Performed by [1]	Year	VK(M)T [2] Estimate	Comments
Transport Policy Study	Wilbur Smith and Associates/MOT	1973	16.9	It is not immediately obvious how the estimates were derived.
Energy Use in Transport	BCHF for NZ ERDC	1975	18.0	Details for vehicle type and by urban/rural road. Now considered to be an under-estimate.
Driver Exposure	MOT	1976-77	17.4	Based on interviews of a sample of drivers. Now considered to be an under-estimate.
Energy Use in Transport, update	BCHF for NZ ERDC	1986	27.6 (in 1985) 21.5 (in 1976)	Using previous surveys and sample surveys of vehicle utilisation.
Investigation into Road Research Unit's Budget Level and Priorities	WD Scott Deloitte	1987	23.2	Based on survey of local authorities and state highway traffic counts. Probably an under-estimate.
Transit New Zealand Research Project	BCHF	1991	28.2 (in 1986)	Based on travel on state highways and local authorities roads.
Transit New Zealand Research Project	BCHF	1991	18.0 ± 1.8 (for mid-70s) 25.0 ± 3.8 (for mid-80s)	Based on a comprehensive assessment of all previous studies.

[1] MOT Ministry of Transport
BCHF Beca Carter Hollings & Ferner Ltd
NZ ERDC New Zealand Energy Research & Development Committee

[2] VK(M)T vehicle kilometres (in millions) travelled

3.2 New Zealand Results

3.2.1 Regression Curves

The plots obtained for fatalities (F), fatality rate (F/V) and vehicle kilometres travelled (VKT) for New Zealand are shown in Figures 3.2 and 3.3. The three plots are combined in Figure 3.2, but Appendix Figures A3.2 - A3.4 show separately the corresponding regression curves. Figure 3.3 shows projections to the year 2011 of fatalities. The regression curves are obtained by applying the relevant Oppe models to the data and the parameters used in the regression models are listed in Table 3.2.

The proportion of the variation explained by the model, or regression goodness of fit R^2, of 0.92 for the fatality rate is lower than the range of 0.93 to 0.98 for the other six countries.

The α and a values represent the rate of change for the fatality rate and traffic volume parameters respectively. New Zealand's low α value indicates that its fatality rate is not improving as fast as those in other countries.

Table 3.2 Main parameters for fatality rates *(F/V)* and traffic volumes *(V_t)* for the regression fits based on the Oppe models.

Country	V_m (10^9VKT)	**Fatality Rate *(F/V)* parameter**		**Traffic Volume *(V_t)* parameter**	
		α	β	a	b
Netherlands	75	-0.06997	141.96	0.15760	-310.13
United States	4386	-0.02861	59.66	0.06355	-125.54
Germany	407	-0.06404	130.44	0.12692	-249.78
Great Britain	358	-0.03997	82.36	0.08224	-161.96
Israel	18	-0.05720	117.07	0.13821	-273.06
Japan	436	-0.12479	250.28	0.23082	-454.89
Australia	**200**	**-0.06000**	**121.97**	**0.08680**	**-171.00**
New Zealand (LTSA)	20	-0.01955	42.33	0.11970	-235.15
New Zealand	30	-0.02738	57.68	0.09840	-194.12
New Zealand (VKT)	**35**	**-0.02349**	**50.06**	**0.08010**	**-158.20**

Note: The six countries Netherlands to Japan were analysed by Oppe (1991).

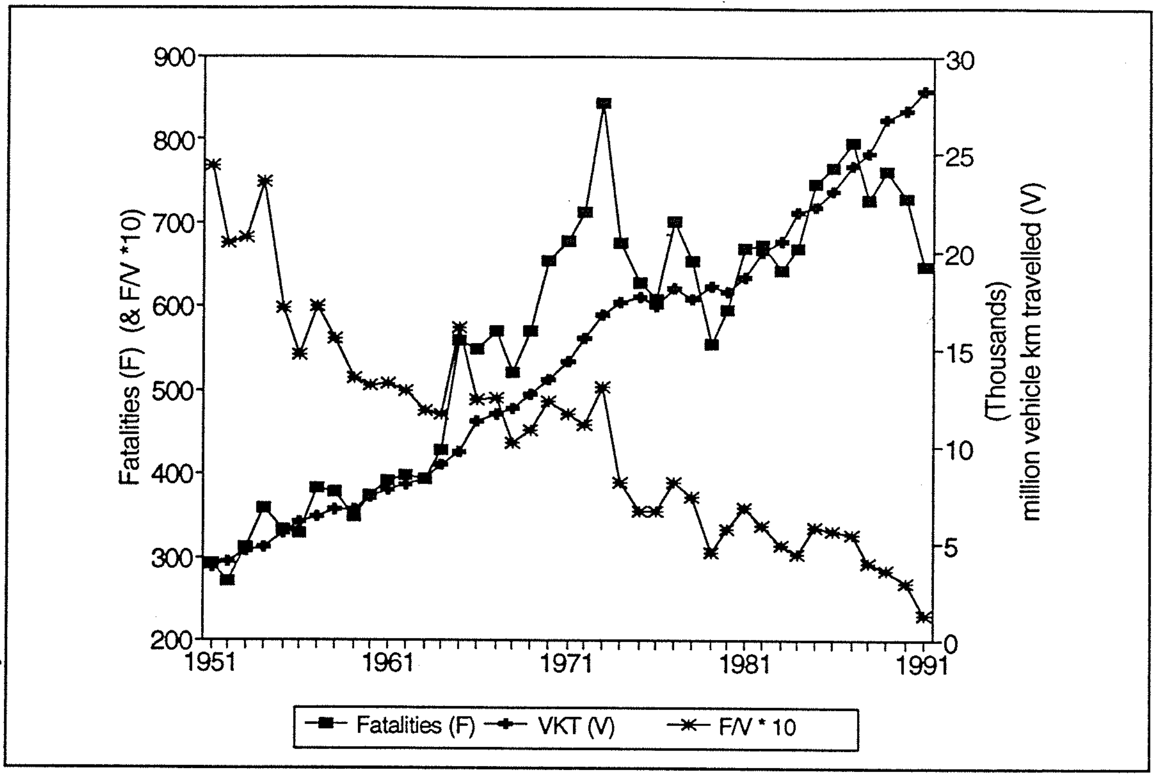

Figure 3.2 Combined data for fatalities (F), fatality rate (F/V), and vehicle kilometres travelled (VKT) for New Zealand between 1951-1991.

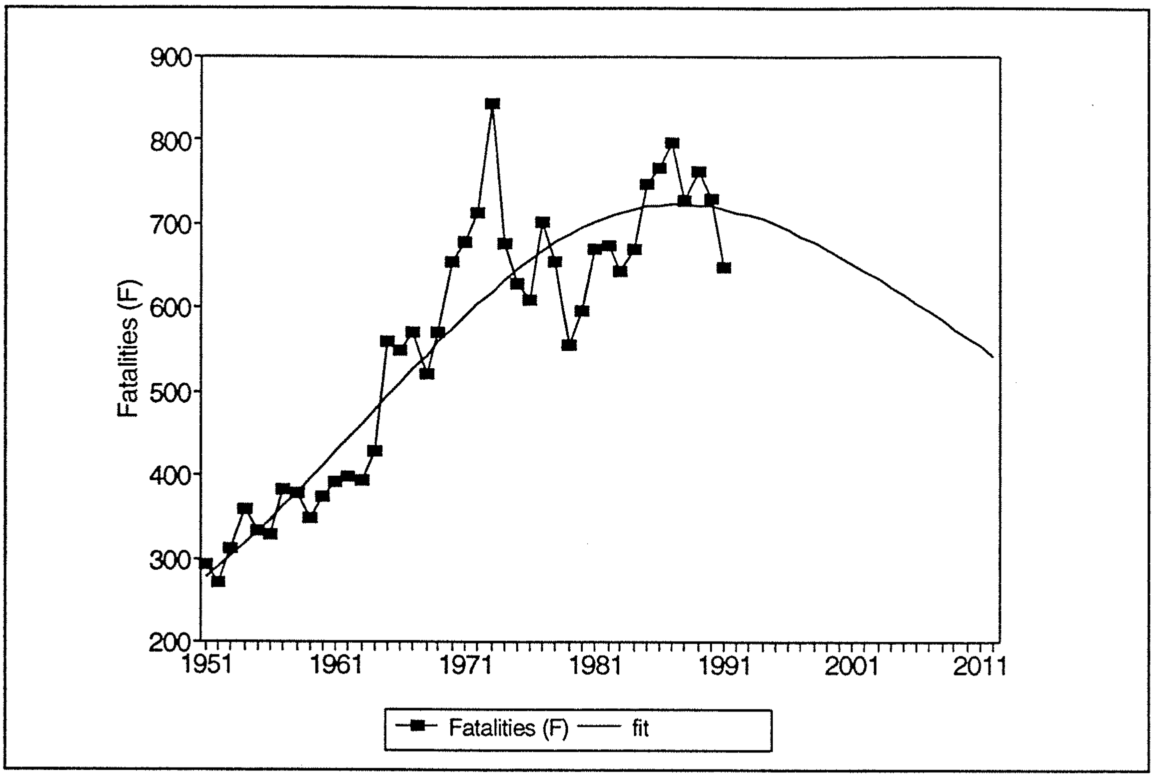

Figure 3.3 Projection of fatalities (F) for New Zealand from 1991 to 2011, extrapolated from 1951-1991 data.

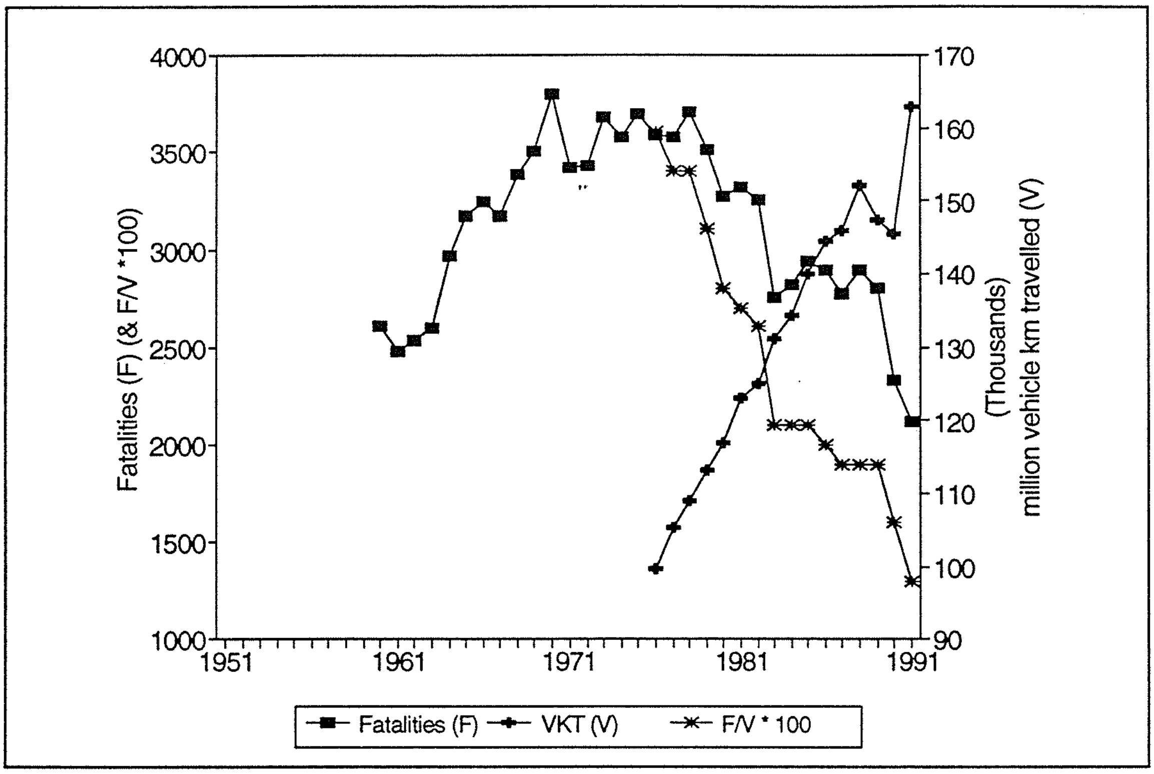

Figure 3.4 Combined data for number of fatalities (F), fatality rate (F/V), and vehicle kilometres travelled (VKT) for Australia between 1960-1991.

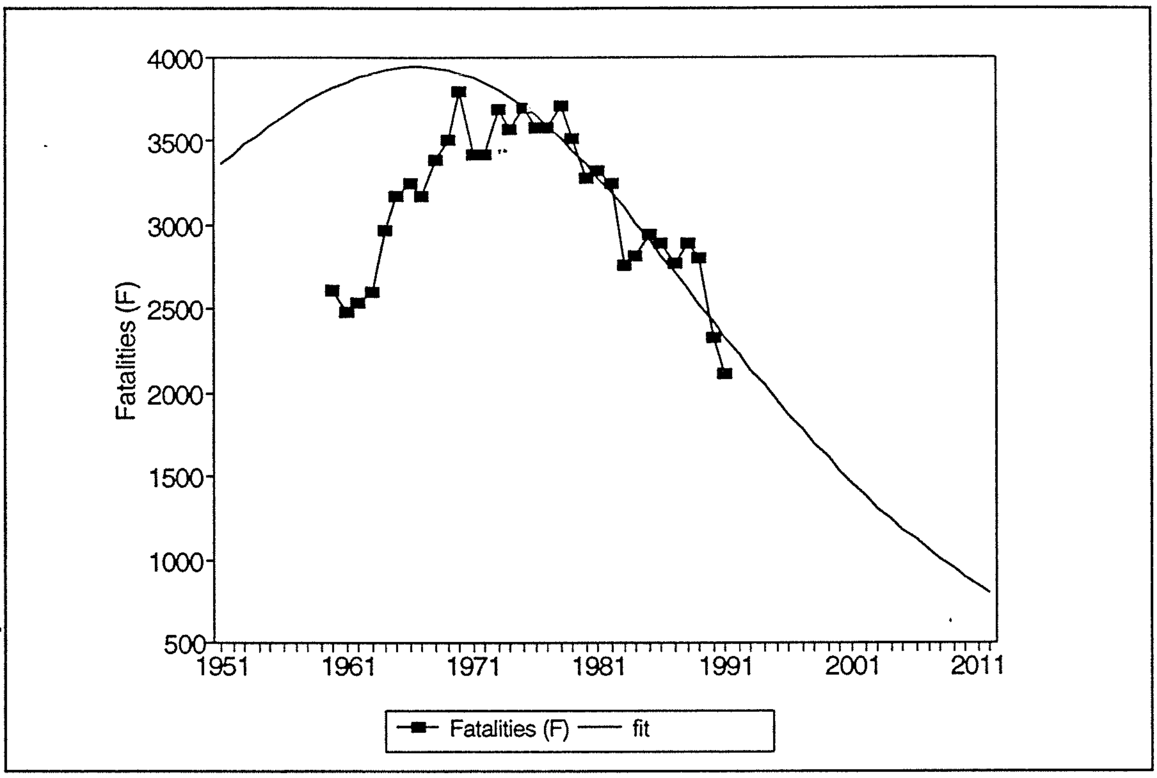

Figure 3.5 Projection of fatalities (F) for Australia from 1991 to 2011, extrapolated from 1960-1991 data.

3.2.2 Sensitivity Analysis

V_m (the maximum future VKT value) differs considerably between the two cases as shown in Table 3.2. It is $20x10^9$ for the LTSA data and $30x10^9$ for the straight-line fit. This compares with a value of $35x10^9$ for the best fit based on the Transit New Zealand VKT data.

This is related to the considerable difference in the traffic volume fits, and with flow-on effects to the fatality rate fits. These are evident in the graphs of the parameters (Figures 3.6 and 3.7), and consistent with the curves for the full study period of 1951-1991.

3.3 Australian Data

Figures 3.4 and 3.5 present results for the Australian data. (Note that the vertical scales are different to those of the New Zealand graphs.) The results are considerably different to those for New Zealand because of Australia's good road safety record in recent times and because early Australian data were not available. For the fatality rate, the regression goodness of fit R^2, is 0.95, similar to that of other countries (excluding New Zealand). The three plots are combined in Figure 3.4, but Appendix Figures A3.5 - A3.7 show separately the corresponding regression curves. Figure 3.5 shows projections to the year 2011 of fatalities.

Figures 3.2 and 3.4 show the observed and expected values for traffic volumes (VKT), fatality rates (F/V) and fatalities (F) for New Zealand and Australia respectively. The graphs tend to reiterate the earlier findings of the comparisons between countries as shown in Table 3.2, but they go further in that the temporal variations and deviations can be seen.

3.4 Comparisons with Other Countries

3.4.1 Explanation

The primary objective of this project is to compare the New Zealand results with those from other countries and with those presented in the Oppe papers. A number of graphs are presented as Figures 3.6 - 3.9, and the additional lines in these are:

- Australian results based on data of fatalities from 1960 to 1991, and for VKT from 1976 to 1991. This is a significantly smaller dataset than that used for the other countries in the study and, given the noticeable increased road safety shown in the last decade in Australia, the results are to an extent misleadingly favourable.
- New Zealand data from 1951 to 1991, with varying VKT values as follows:
  - A best estimate based on the Transit New Zealand rural and urban indexes of travel.

- The LTSA data. (Although suspect for the period, these data do provide a lower bound on the VKT.)
- A straight-line fit for the years 1975 to 1985. (While this is also considered a poor estimate of VKT, it provides another extreme for the sensitivity analysis.)

The parameters of Models 1 and 2 for the six countries used in the Oppe 1991 paper, and for New Zealand and Australia, are presented in Table 3.2. Oppe's data were for the period from around 1950 to around 1985, New Zealand data were for 1951 to 1991, and the Australian data from 1976 to 1991.

Although this research did not include the additional data for Oppe's six countries to increase the number of overlapping years, such work may be a worthwhile next step.

The estimate of V_m was derived through a somewhat coarse iterative process (generally four iterations were considered adequate) in conjunction with linear regression to optimise the proportion of explained variance. It was found that the model was relatively insensitive to minor changes in V_m, i.e. the resulting parameters varied little.

Results indicate that the New Zealand Fatality Rate parameter, α, is particularly low when compared to the other countries, especially Western English-speaking nations. New Zealand's value of approximately (–)0.02 is slightly lower than that for the USA. This indicates a slow cumulative effect of all the efforts and abilities of society to handle the safety problem. New Zealand's traffic volume parameter, a (i.e. rate of advancing towards volume saturation), is greater than that for the USA and similar to that for Great Britain.

3.4.2 Traffic Volumes

For Oppe's 1991 Model 2, the level of saturation for traffic volume (i.e. when V_m is reached) is fast approaching for Japan and the European countries. Similarities between Great Britain and the USA, which have percentages of remaining growth before reaching traffic volume saturation (i.e. remaining % of V_m) of 20% and 40% respectively, and between New Zealand and Australia which have remaining % V_m of 20% and 19% respectively. This is compared with the other Oppe countries with less remaining growth (5% to 15%).

The Oppe 1991 paper suggests that, while the models describe the data adequately, there are substantial systematic deviations between observed and predicted values. Deviations differ between countries, with smaller countries having larger deviations. Oppe also suggests that, for countries with a large a parameter (and hence a fast growth in traffic volume), a common tendency is to grow faster than expected before 1970 and more slowly after 1970. Presumably this tendency corresponds with the energy crisis of the early 1970s.

The New Zealand values support this, with a distinct levelling off from around 1973 through the 1970s and a steady increase beginning in the early 1980s. However, the Australian data, while only available from 1976, indicate a steady growth throughout the 1970s and, in fact, have only two years (both recent) when there was a drop in VKT.

3.4.3 Fatality Rates

Oppe (1991) states that the deviations for the fatality rates are generally larger in the early years of the study (before 1975), with no obvious common trends. In fact, it appears that the curve fits for most countries from 1975 are good.

The New Zealand data are somewhat erratic and are certainly not more regular in the later years. Another noticeable feature is the rather flat and linear nature of the curve (*F/V* in Figure 3.2), in comparison with the other Oppe countries (see Oppe 1991 for Figures). Oppe suggested that the erratic nature of the USA data is unusual considering the large amount of data, and could be related to differences in state policy with regard to safety.

The Australian results are limited by the short period over which VKT data were available. Nevertheless the curve (in Figure 3.4) is surprisingly smooth. This could be partly related to the scale of the plot being sensitive to the slope of the curve, and it is likely that the points for the earlier years would have higher absolute deviations than those observed in the later years. The surprisingly good fit may also be related in part to the method by which the VKT was estimated.

3.4.4 Fatalities

The fatality data are understandably more variable than the VKT data. The fitted curve for the fatalities *(F)* is derived from a multiplication of Model 1 (which is for *F/V)* and Model 2 (when expressed in terms of *V*). Oppe explains this increased variability as being related to the multiplication of the two models resulting in larger variations than for the basic models. It appears that, for all six countries modelled in Oppe (1991), a consistently higher actual than predicted peak has been recorded in the period from 1970 to 1980. This strongly suggests that refinement in the model could be considered.

The fits for the New Zealand and the Australian data show considerable differences. The New Zealand data collection results in a very flat curve (Figure 3.3) in comparison with the other Oppe countries (see Oppe 1991 for Figures), with the peak barely having been reached by 1991.

The Australian data are significantly different from the fatality data of all other countries in that the fit appears poor (Figure 3.5). This is because the modelling is based only on the years for which VKT data were available, i.e. from 1976 onwards. The period from 1961 to 1975 has not been used in any of the model fitting. It is important to appreciate that if it was possible to fit a model to the entire range of available fatality data, it would indicate a more drastic reduction in fatality rate (i.e. producing a more compressed curve) than has been modelled.

3.4.5 ln$(V/V_m - V))$ Values

The straight-line fits for the a and b parameters (from Table 3.2) of the equation in Model 2 (see Section 2.1) for the various countries are shown in Figure 3.6. Investigation of the fits for the different countries suggests that the straight lines intersect at a common point, the ordinate value zero. Oppe (1991) states that this may be logically interpreted as the phenomenon that the relation between the developments of traffic volume in the six countries is based on the common development of the Western economy.

Despite the fact that the developmental speeds and the maximum values of traffic are very different, all countries have the largest growth volume when $\ln(V/(V_m - V)) = 0$, which is around the year 1970. Oppe explains this as being related to the energy crisis which took place shortly after.

Oppe then postulates that several factors influence developmental speed such as economic development, economic strength, population density and socio-economic infrastructure. He suggests the maximum amount of traffic volume may be dependent on the population size, levels of activity, wealth and geographical circumstances.

While New Zealand is generally similar to at least one of the six countries for each factor, no single country could be considered sufficiently similar to enable a direct comparison of all factors.

3.4.6 ln(F/V) Values

Figure 3.7 shows the straight-line fits for the α and β parameters of the equation in Model 1 (see Section 2.1). Again the lines intersect at much the same time, around 1980. Oppe suspects that the possible shift of approximately 10 years in time could be caused by the occurrence of a delay between the recognition of system failures and the planning and application of effective countermeasures.

New Zealand and Australian values fit comfortably into the comparison. The sole possible outlier appears to be Japan, which is distinctly separate from the main group and has slopes for both graphs greater than the other Oppe countries.

3.4.7 Comparison of the Model Parameters

Figure 3.8 shows the comparison between the a and α parameters. These are related to the growth rate of traffic volume and the decrease rate for the fatality rates.

The simple relation of $a = -2\alpha$ is derived by Oppe and consistent with the assumption that fatalities are a function of the derivative of volume with respect to time. Oppe suggests the development of safety is a direct consequence of the development of the traffic system.

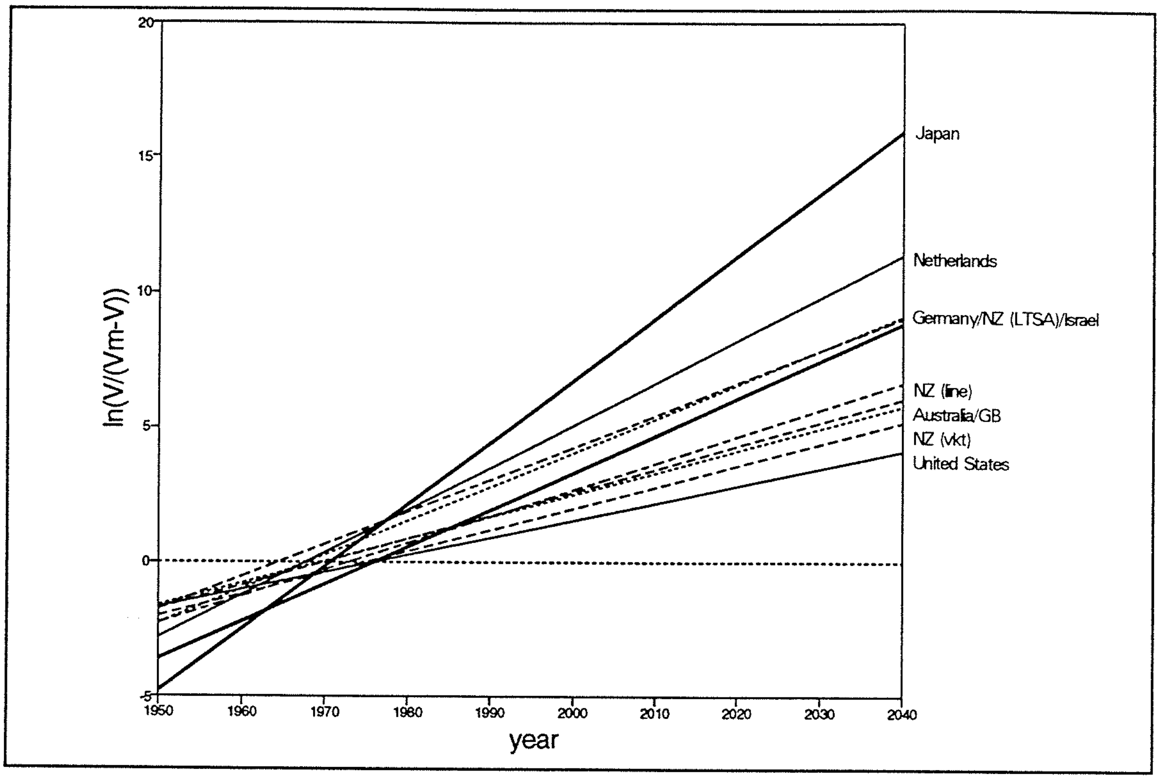

Figure 3.6 Expected values for $\ln(V/V_m - V))$ according to Model 2.

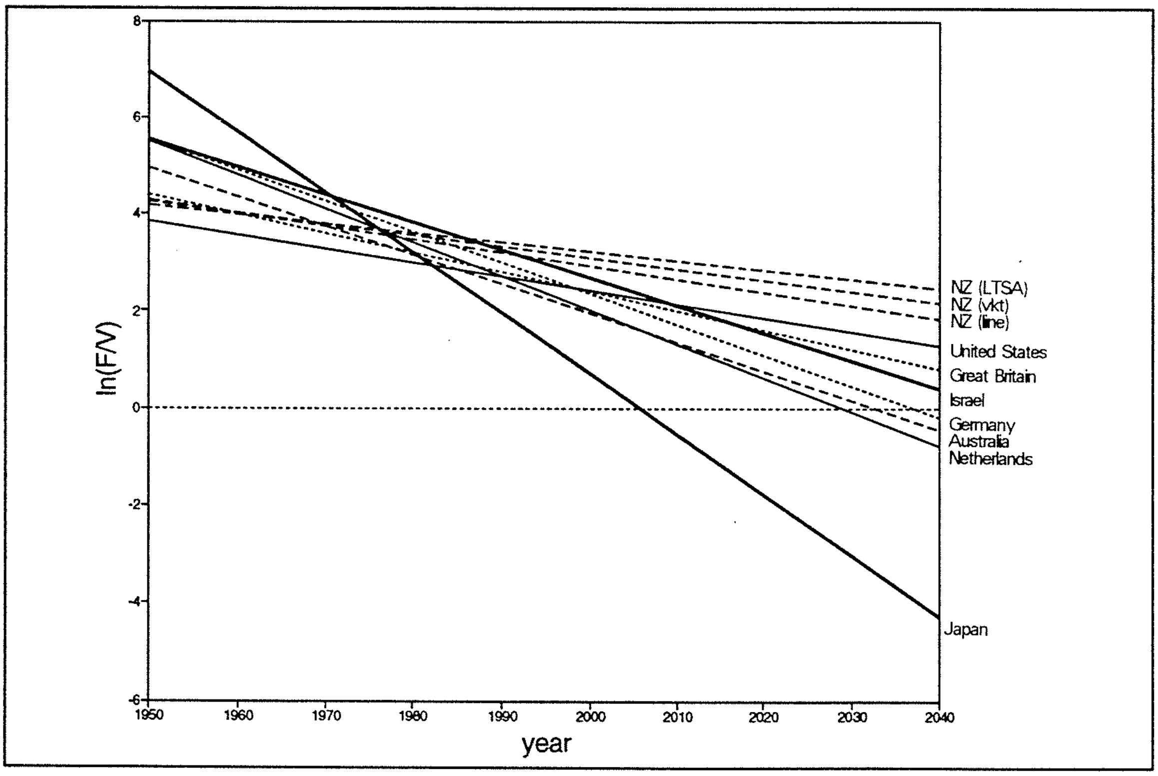

Figure 3.7 Expected values for $\ln(F/V)$ according to Model 1.

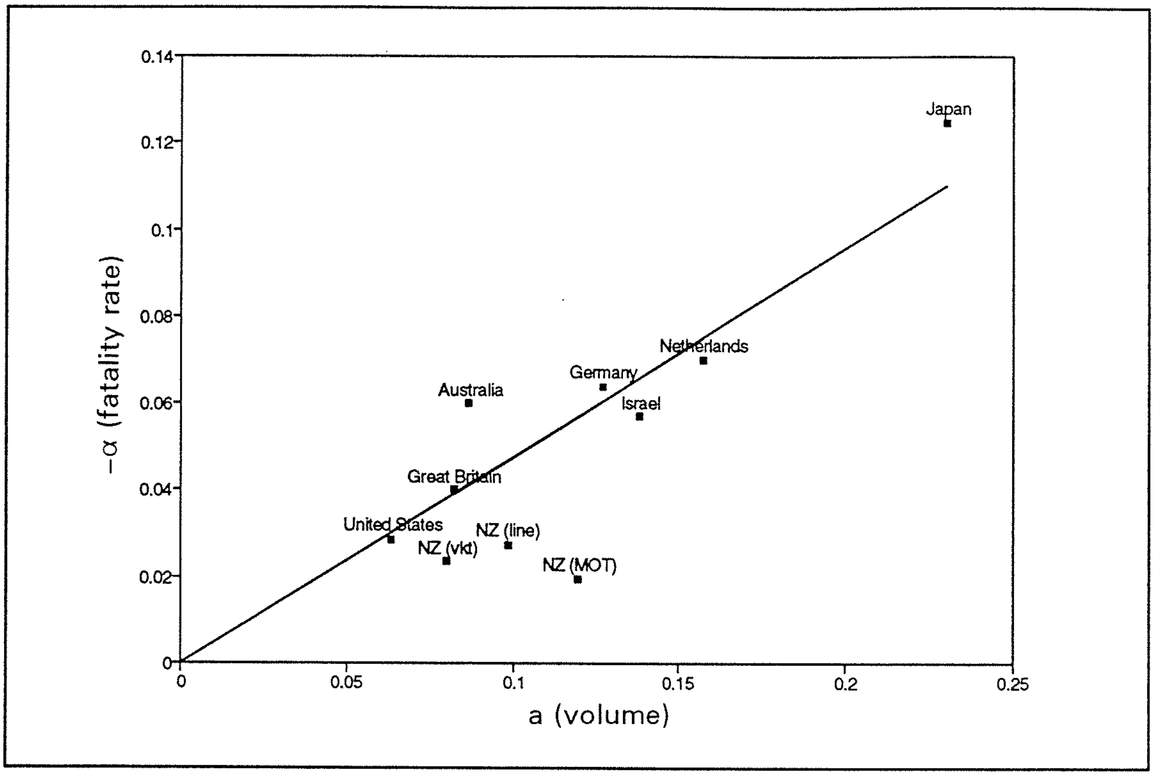

Figure 3.8 Relation between traffic volume (a) and fatality rate (α) parameters from Model 1 and Model 2.

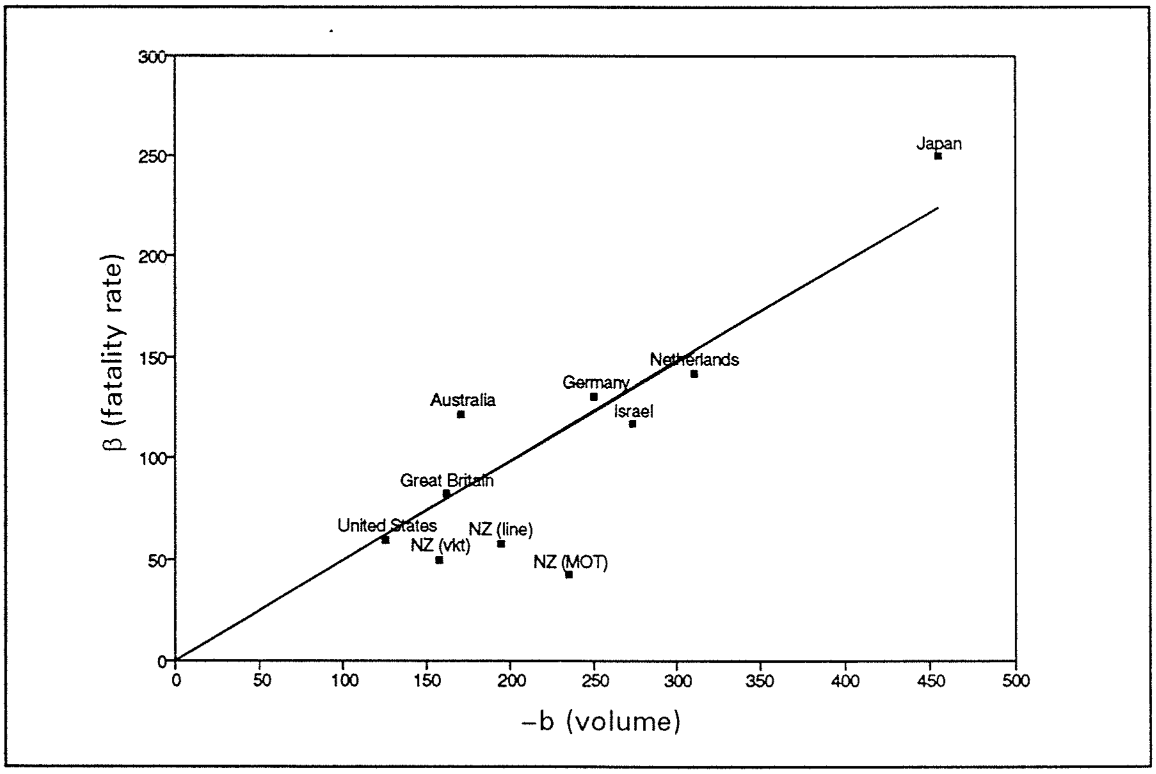

Figure 3.9 Relation between traffic volume (b) and fatality rate (β) parameters from Model 1 and Model 2.

It is also relevant that, without exception, the countries with the higher populations, and hence more data which would minimise the proportional variability (i.e. USA, Great Britain, Germany and the Netherlands), are those closer to the model line $a = -2\alpha$.

The relation, while good for the six countries in Oppe's study, is considerably poorer for both New Zealand and Australia. The ratio which should be 2 is 3.4 and 1.4 for the two countries respectively. The fact that Australia has a ratio less than half that of New Zealand's should be a serious concern. This may be partly related to the limited data available for Australia, which contained no VKT data for over half the study period.

Oppe concludes that the number of fatalities appears to be a function of the derivative of the number of vehicle kilometres, with respect to time. This conclusion suggests that the development of safety is a direct consequence of the development of the traffic system.

Figure 3.9, which compares the b and β parameters is almost identical to Figure 3.8. Being lower on the model line of the other countries means that New Zealand, advancing towards its saturation traffic volume, is not improving its fatality rate in a similar ratio to other countries. The explanation offered by Oppe that the absolute value of the parameters is related to population also does not appear to apply for New Zealand, which would be expected to be considerably higher on the graphs (at least double for both values).

3.4.8 Recent Trends

Since 1991 progress in improving New Zealand's fatality rate has been good. In recent years, there have been 646 fatalities in 1992, 600 in 1993, and the current projection is approximately 560 for 1994 (LTSA 1994 pers.comm.). This compares with 650 fatalities in 1991.

Similarly, Australian fatalities in recent years have decreased significantly, with 1974 fatalities in 1992 and 1949 in 1993. This compares with 2113 fatalities in 1991.

While data for these two additional (completed) years will not greatly affect the results of the modelling which is based on data for the preceding 41 years, it will, nevertheless, help improve New Zealand's poor safety record and enhance Australia's good safety record compared with other countries.

4. DISCUSSION

This report raises the question about using only VKT and time to compare fatalities between countries. For example fatalities tend to be more a rural phenomenon in New Zealand, but VKT is an aggregate of all vehicle kilometres across all road categories and vehicle types. The contribution of 2-wheelers between countries could also vary considerably. For example, the improvement in New Zealand's fatality rate in recent years has been largely attributed to a reduction in motorcycle accidents.

Investigating the applicability of Smeed's (1949) formula in New Zealand may also have some merit, recognising that the regression parameters may be changing over time. Young (1989) gives a good summary of the application of Smeed's formula. It is possible that Smeed's formula may be more realistic than Oppe's work. Oppe (1991), however, has suggested that probably Smeed did not use vehicle kilometres travelled because they were not available at that time.

For Australia, further comparisons could also be made between the States, bearing in mind the underlying assumptions in the estimates of VKT (Federal Office of Road Safety 1994). Furthermore, it appears that minor inconsistencies exist between the Australian VKT data for the later years as used in this report and in more recent sources (Federal Office of Road Safety 1994).

Another interesting comparison can be made based on kilometres of road per population. Australia has approximately 801,000 km of road for 17.6 million people (i.e. 45.5 m per capita) compared with New Zealand's 95,000 km of road for 3.4 million people (i.e. 27.5 m per capita), which is similar to New South Wales' 30.7 m per capita.

5. CONCLUSIONS

The macroscopic models relating traffic volumes and traffic safety established by Oppe (1989, 1991) have been applied to New Zealand and Australia data. The models are

- a negative exponential learning curve for fatality rate and
- a logistic model for traffic volume represented by vehicle kilometres travelled (VKT).

While sufficient regression model fits are made, they are not as well-fitting as those for other countries.

This study suggests New Zealand has a poor safety record compared with a number of other countries. Of the six countries considered in the Oppe 1991 paper, as well as Australia and New Zealand, this country has the worst record when considering improvements in fatality rate (i.e. fatalities with respect to vehicle kilometres travelled).

Although New Zealand had a very good safety record (measured by fatalities) during the 1950s and 1960s, its rate of improvement up to 1991 has been one of the poorest compared with other countries. Countries such as Australia and the USA, which have similarly high vehicle ownerships, have both performed better than New Zealand over the past 30 years.

Since 1991, when the modelling and comparisons with other countries were performed, progress in reducing the fatality rate in both New Zealand and Australia has been good.

Australia has a remarkable safety record in recent times, and of the countries studied is matched only by Japan. However, it is possible that the Australian results may be partly related to the lack of earlier VKT data and to the method used in the estimation of the data.

6. RECOMMENDATIONS

- A clear case exists for New Zealand to attempt to accelerate its safety improvement during the next decade. There are many precedents from performance in analogous countries (e.g. Australia) that this can be done.

- The applicability of Smeed's (1949) formula in New Zealand may have some merit, recognising the need to change regression parameters to account for the changes that are occurring over time.

- For Australia, further comparisons could be made between its States, bearing in mind the underlying assumptions applied in the estimates of VKT (Federal Office of Road Safety 1994).

7. REFERENCES

Beca Carter Hollings & Ferner Ltd. 1975. Energy use in transport, data report. For New Zealand Energy and Research Development Committee. *BCHF Report* No. 27. Updated 1986.

Beca Carter Hollings & Ferner. 1991. Annual vehicle kilometres of travel on New Zealand public roads. Draft report to Transit New Zealand. Beca Carter Hollings & Ferner Ltd (BCHF), Auckland, New Zealand.

Federal Office of Road Safety. 1994. *Road fatality statistics Australia.* FORS, Canberra.

Hakim, S. et al. 1991. A critical review of macro models for road accidents. *Accident Analysis and Prevention* 23 (5): 379-400.

Jones, W. 1994. Targets, trends and New Zealand's road toll. *Draft Working Document* 285. Land Transport Safety Authority (LTSA), Wellington, New Zealand.

Land Transport Division (LTD)/ New Zealand Ministry of Transport (MOT). 1992. *Motor accidents in New Zealand: Statistical statement of the calendar year 1991.* Ministry of Transport, Wellington, New Zealand.

Oppe, S. 1989. Macroscopic models for traffic and traffic safety. *Accident Analysis and Prevention* 21 (3): 225-232.

Oppe, S. 1991. The development of traffic and traffic safety in six developed countries. *Accident Analysis and Prevention* 23 (5): 401-412.

Smeed, R.J. 1949. Some statistical aspects of road safety research. *Journal of the Royal Statistical Society* A(I): 1-34.

Thoresen, T., Fry, T., Heiman, L., Cameron, M.H. 1992. Linking economic activity, road safety countermeasures and other factors with the Victorian road toll. *MUARC Report* No. 29. Monash University Accident Research Centre, Clayton, Victoria.

Wong-Toi, D. 1994. Macroscopic models relating traffic volumes and fatalities - a case study of New Zealand and Australia. *Road and Transport Research* 3(4): 28-40.

Young, P.J. 1989. *Managing the road toll: an acceptable-risk problem.* Paper submitted for the RCA/RTA Road Safety Prize, Vic Roads, Kew, Victoria.

APPENDIX

Additional figures to Section 3

Additional VKT (vehicle kilometres travelled) Data for New Zealand

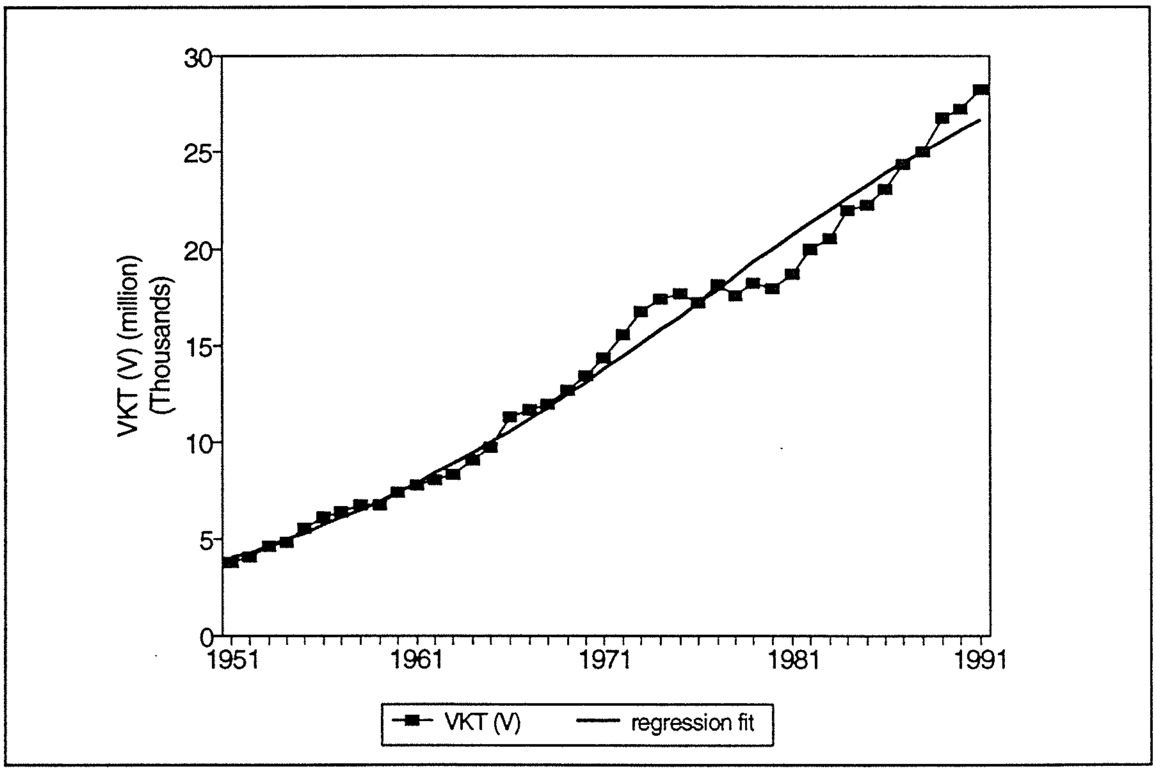

Figure A3.1 Vehicle kilometres travelled (VKT) for the period 1951-1991.

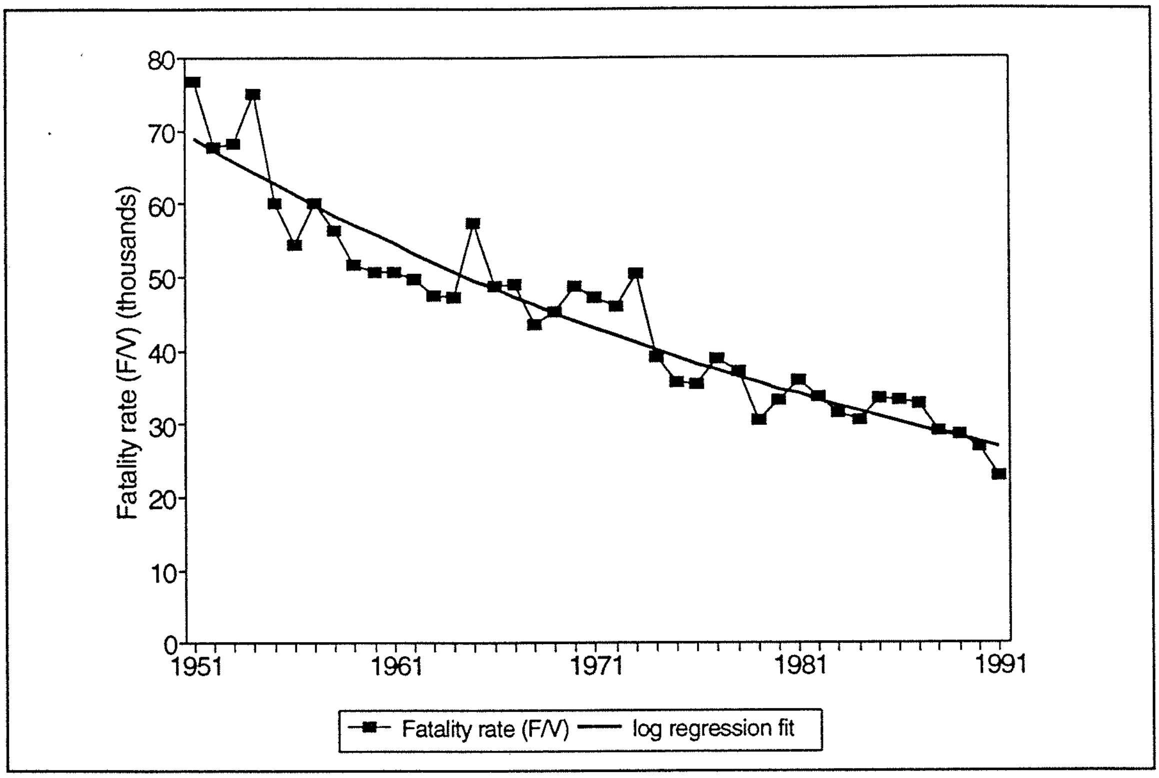

Figure A3.2 Fatality rate (F/V), between 1951-1991.

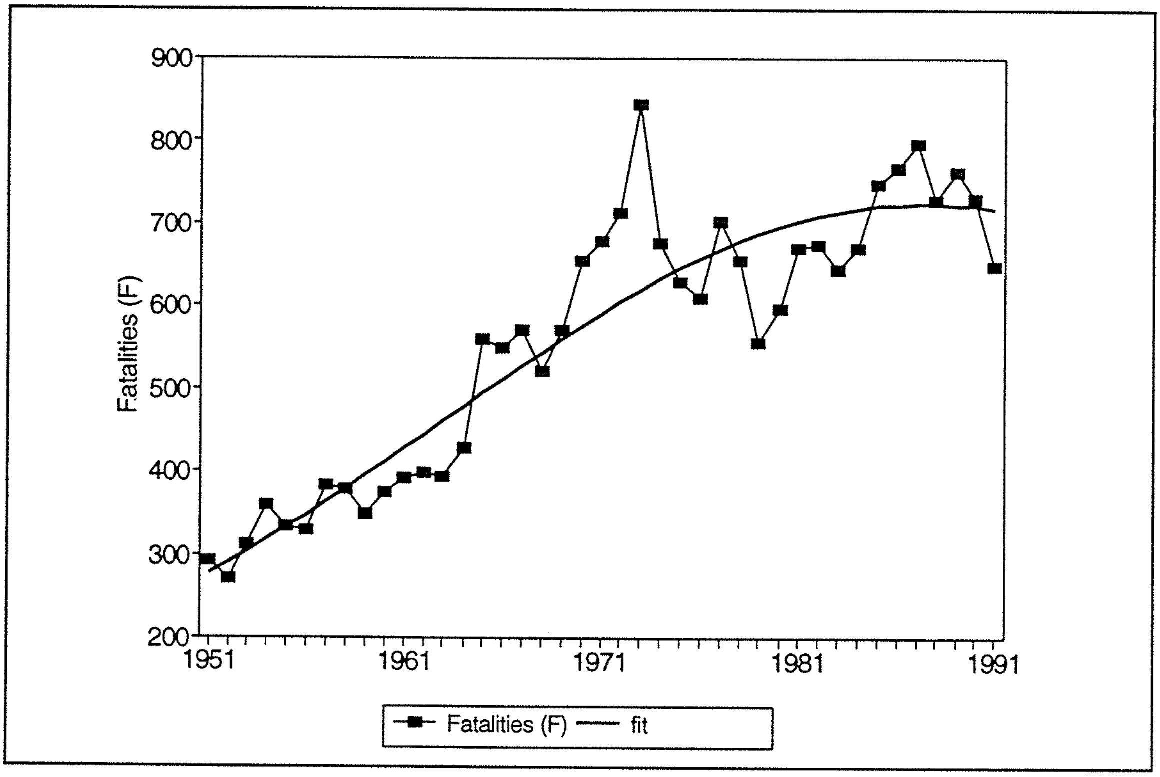

Figure A3.3 Fatalities (F), for 1951-1991.

Additional VKT Data for Australia

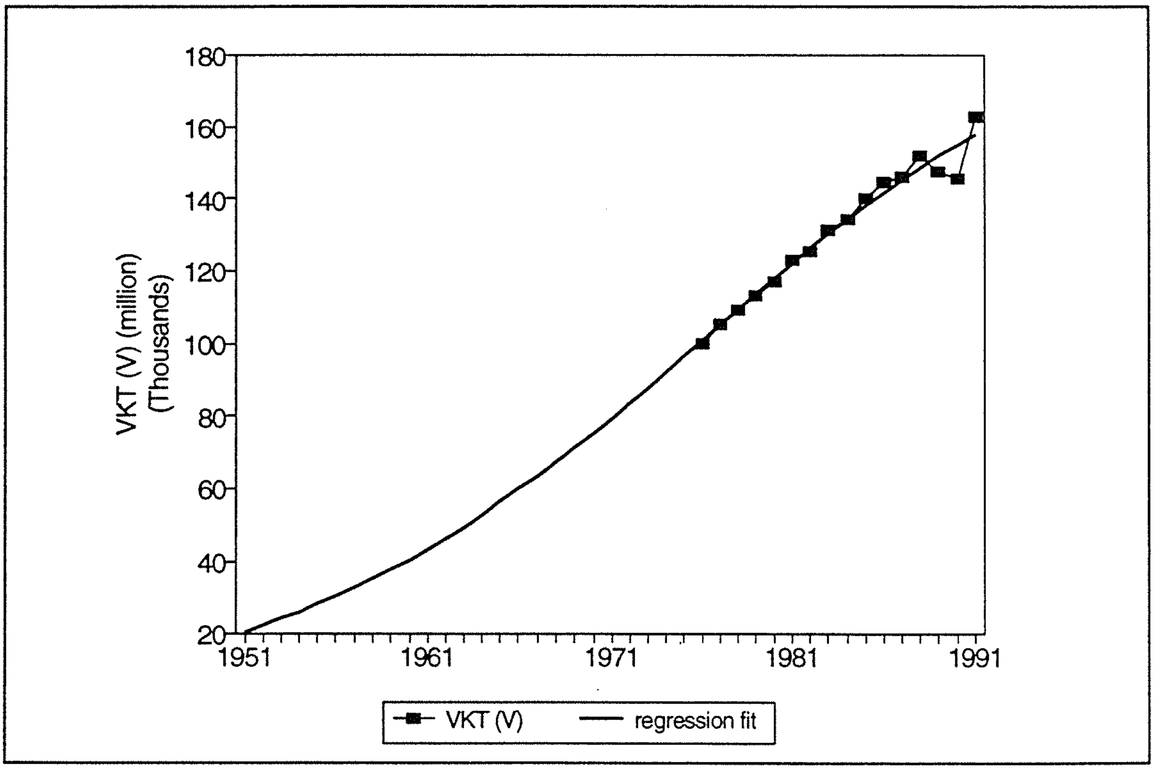

Figure A3.4 Vehicle kilometres travelled (V) between 1975-1991.

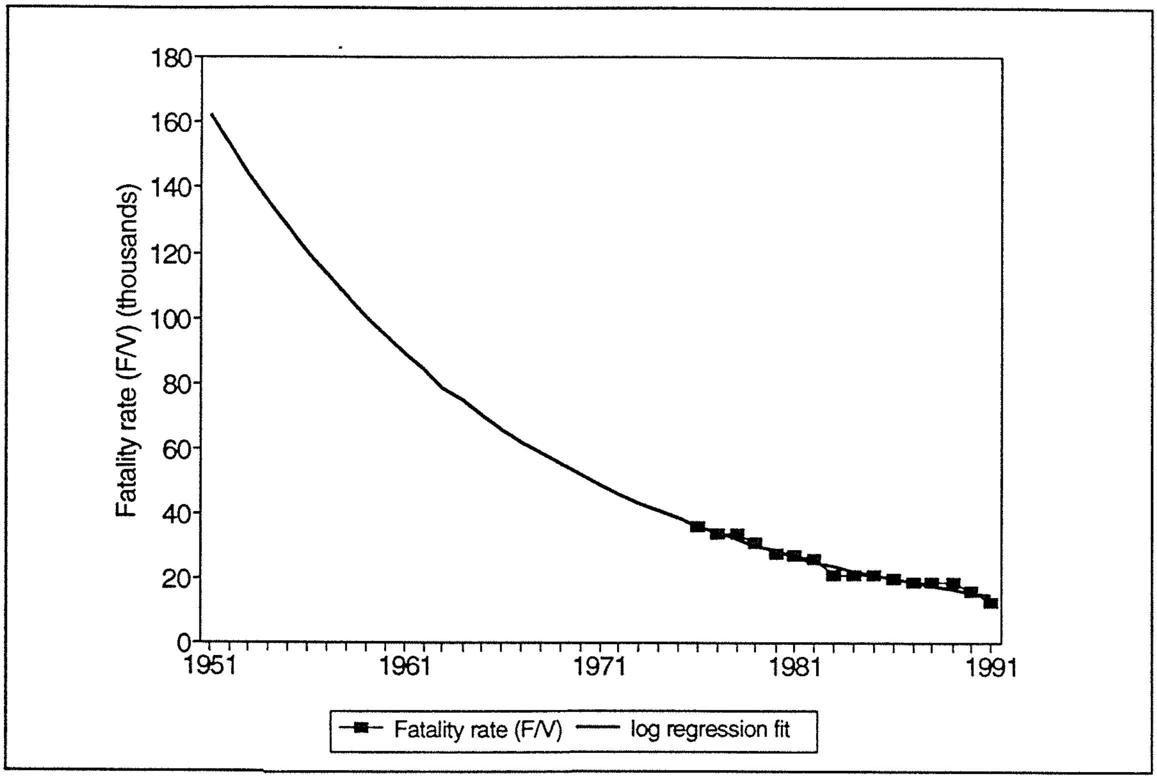

Figure A3.5 Fatality rate (F/V) between 1975-1991.

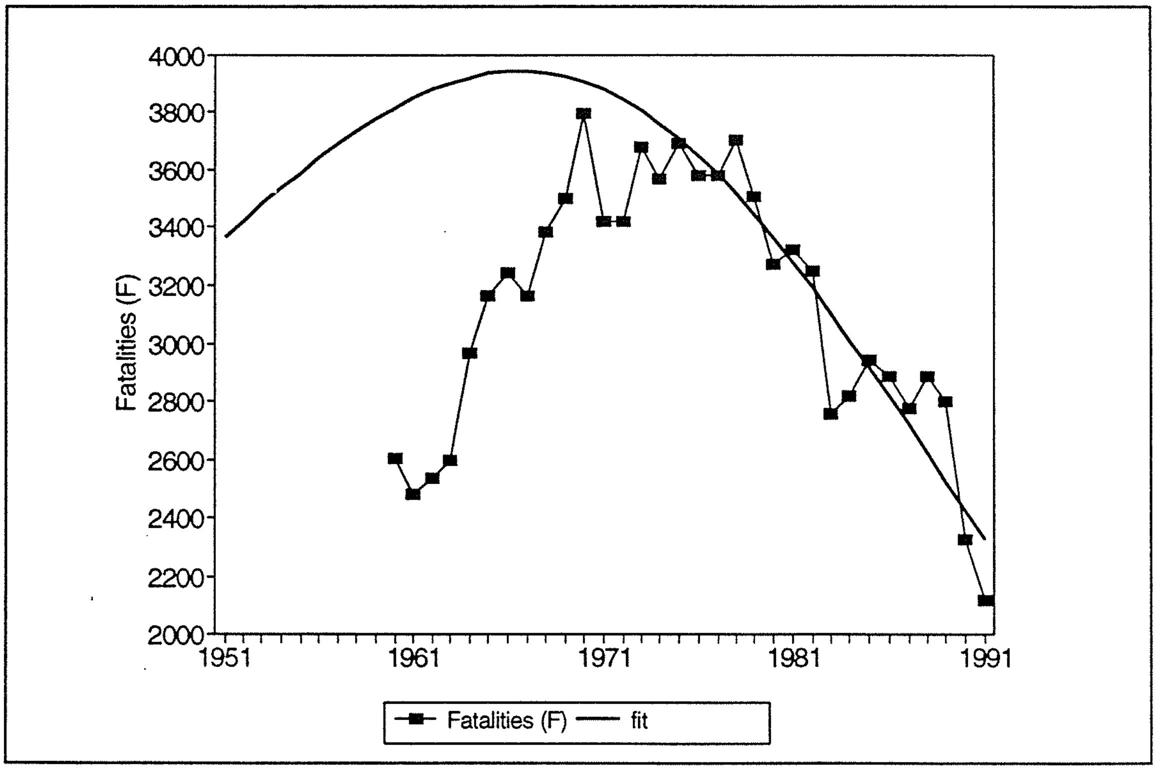

Figure A3.6 Fatalities (F) between 1960-1991.

3. RESULTS

3.1 Traffic Volume Data

An overlay graph of: (1) the Transit New Zealand indexes; (2) the derived VKT values; (3) the LTSA values; and (4) the studies referred to in BCHF (1991) is presented in Figure 3.1. Appendix Figure A3.1 shows additional VKT data for 1951 to 1991, for reference.

Because of concerns about the accuracy of the synthesised New Zealand values, sensitivity analysis was performed based on a range of estimates for the period from 1975 onwards. The straight-line fit for that period was used as the highest estimate of VKT, as the data were considered a "worst case" in the absence of any data for the intervening period. Sufficiently accurate estimates of VKT are available for both the mid-1970s and the mid-1980s. The LTSA collection of data was used as the lowest estimate of VKT.

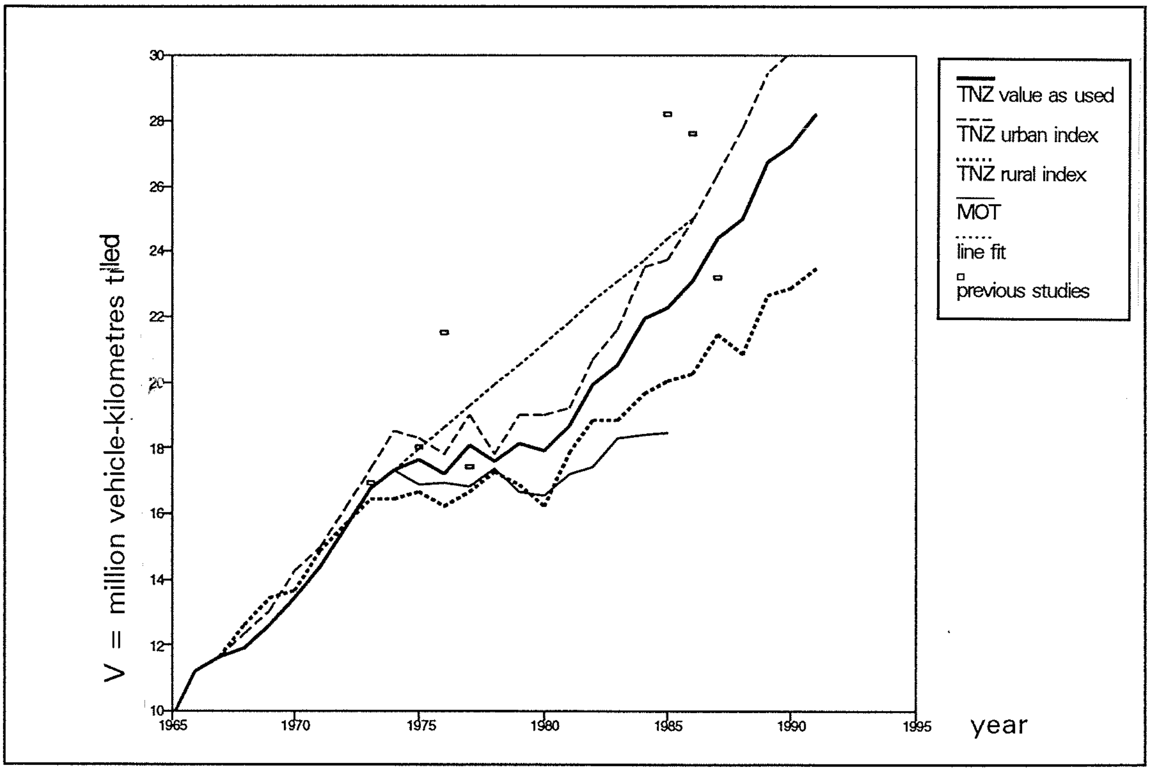

Figure 3.1 Vehicle kilometres travelled (VKT) in New Zealand for the period 1974-1991.

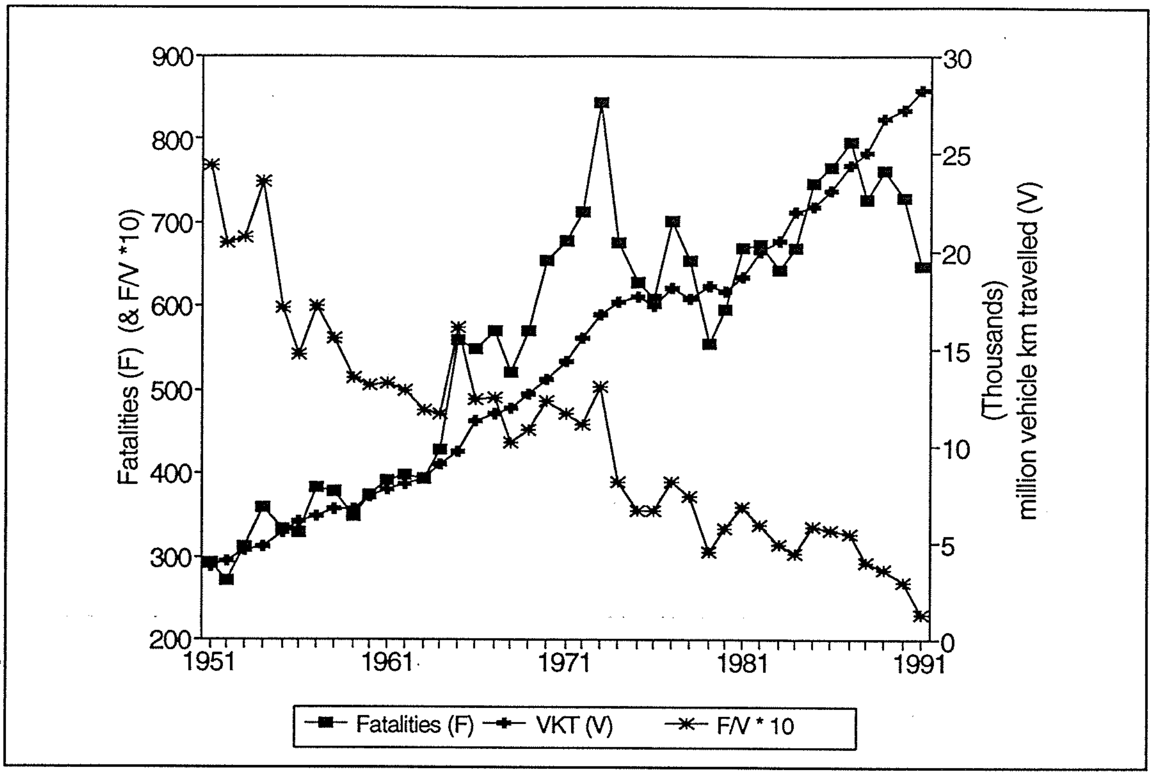

Figure 3.2 Combined data for fatalities (F), fatality rate (F/V), and vehicle kilometres travelled (VKT) for New Zealand between 1951-1991.

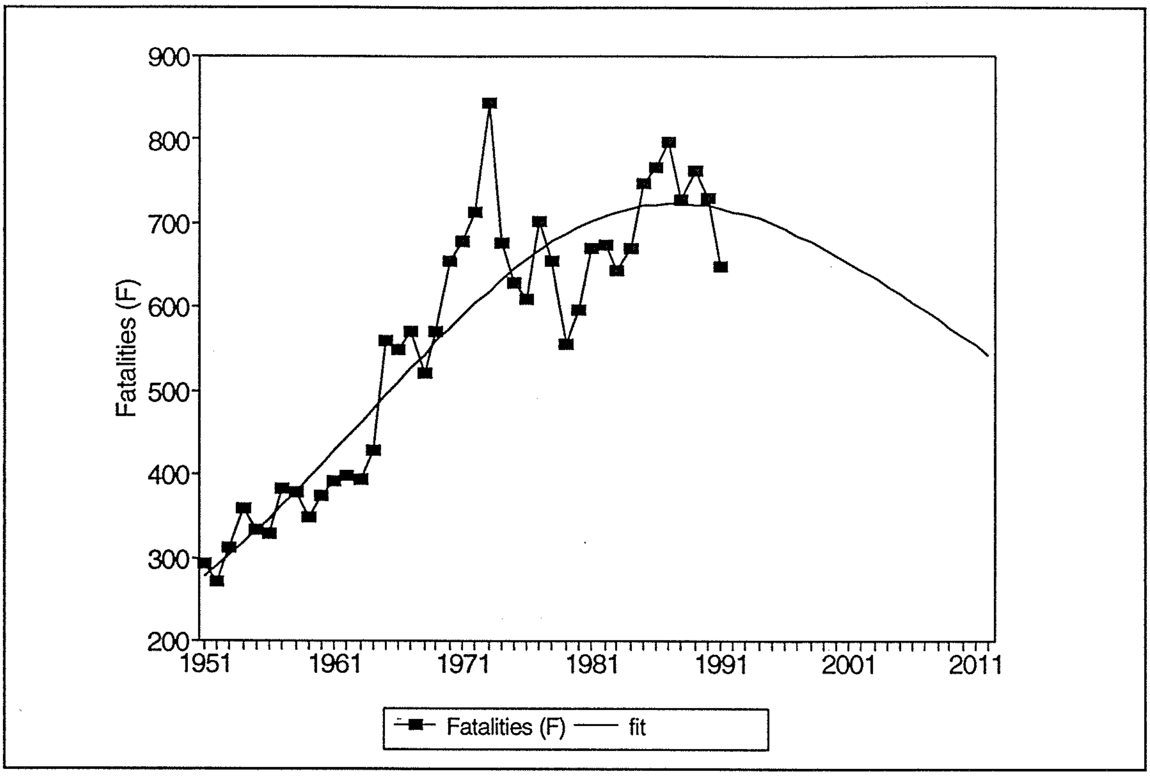

Figure 3.3 Projection of fatalities (F) for New Zealand from 1991 to 2011, extrapolated from 1951-1991 data.

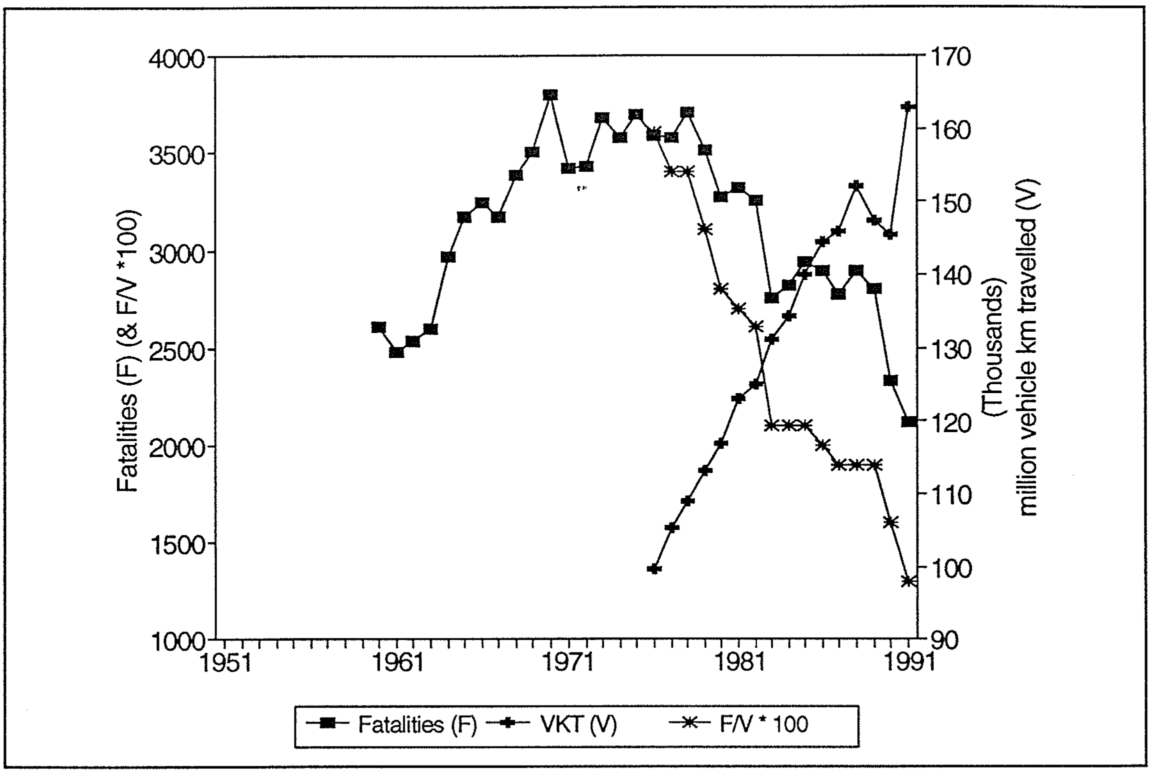

Figure 3.4 Combined data for number of fatalities (F), fatality rate (F/V), and vehicle kilometres travelled (VKT) for Australia between 1960-1991.

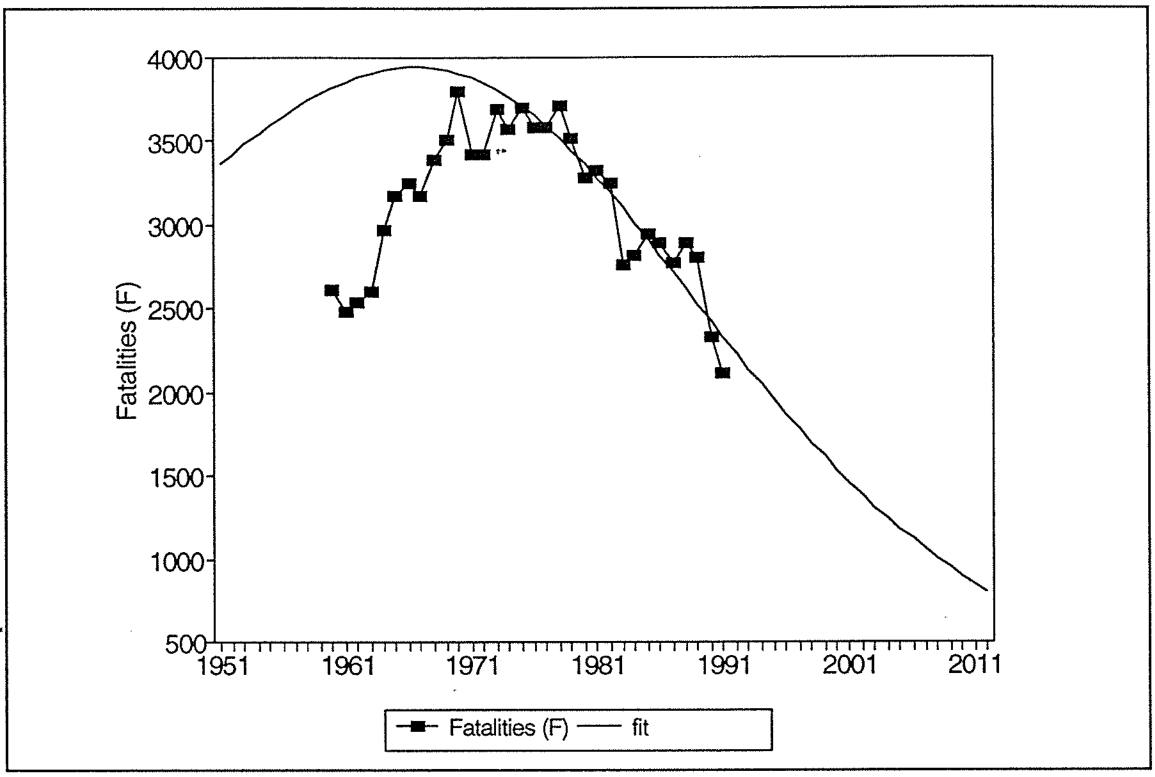

Figure 3.5 Projection of fatalities (F) for Australia from 1991 to 2011, extrapolated from 1960-1991 data.

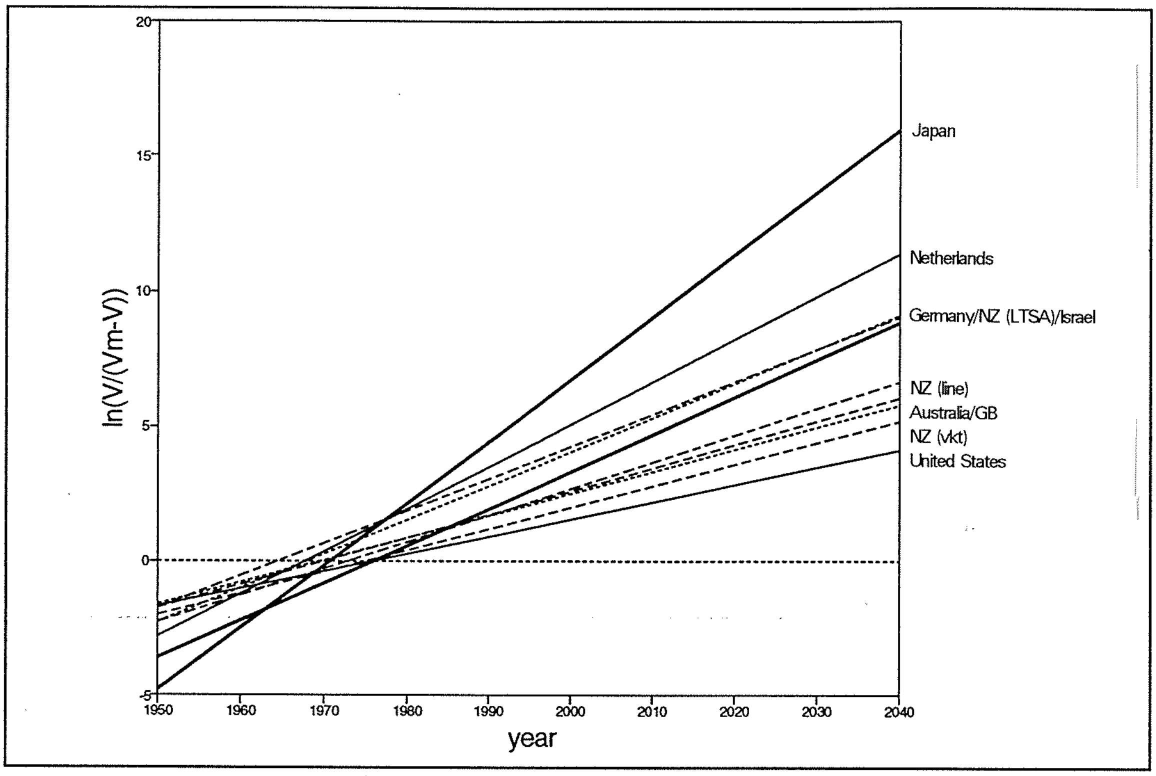

Figure 3.6 Expected values for ln$(V/V_m - V))$ according to Model 2.

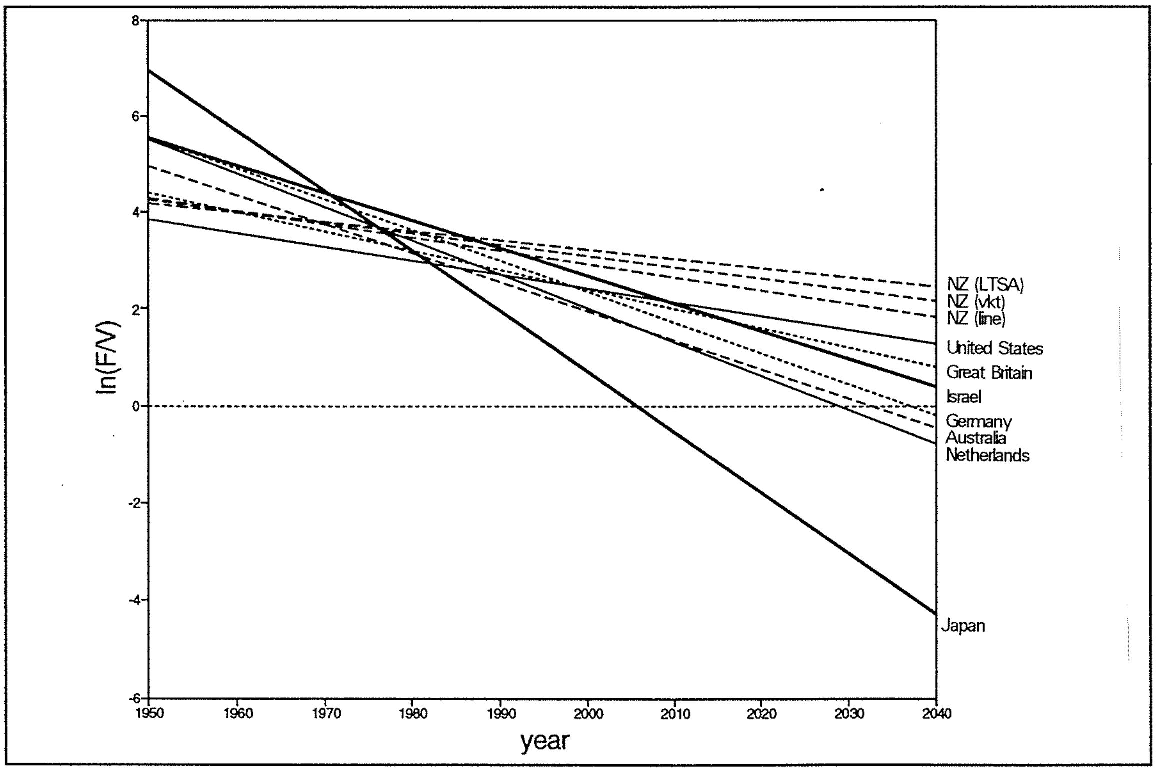

Figure 3.7 Expected values for ln(F/V) according to Model 1.

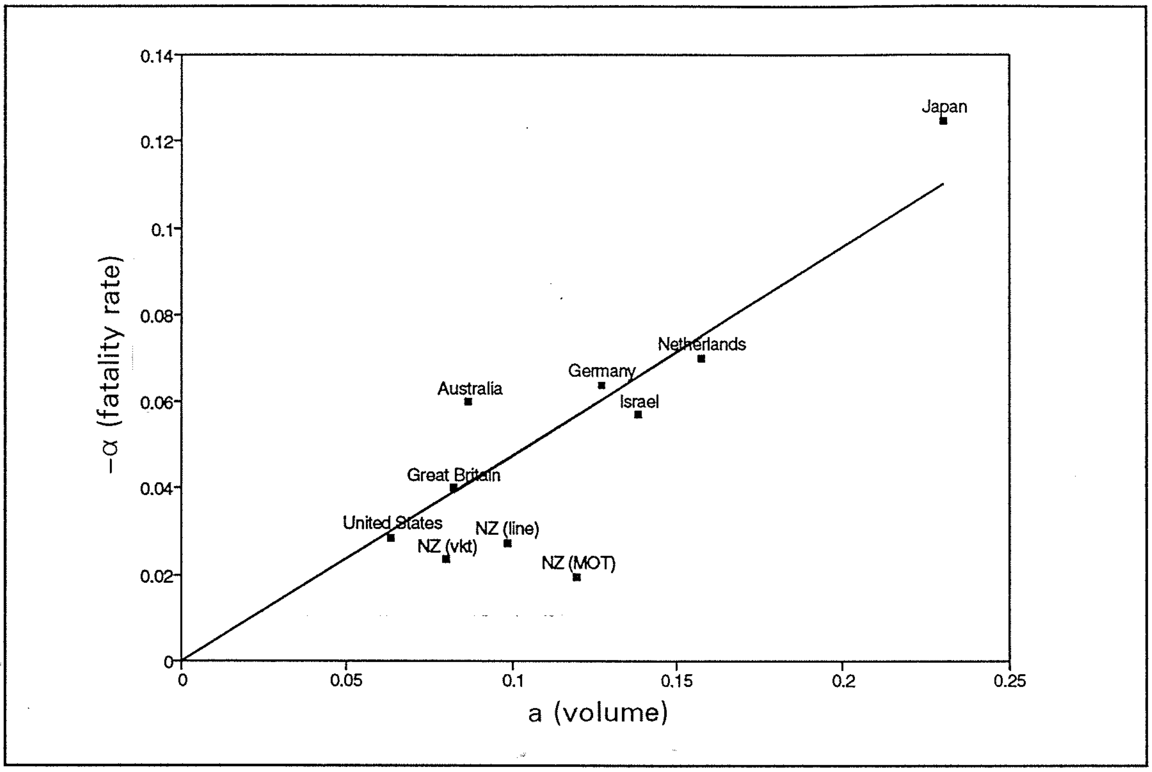

Figure 3.8 Relation between traffic volume (a) and fatality rate (α) parameters from Model 1 and Model 2.

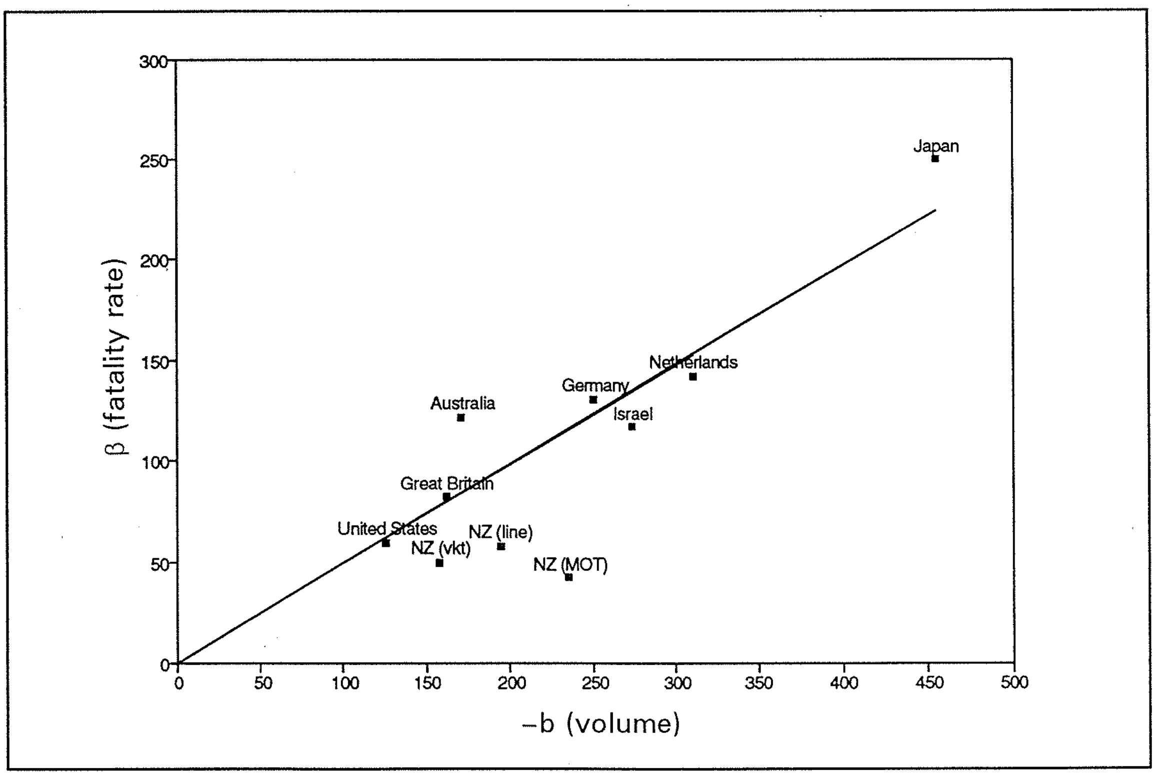

Figure 3.9 Relation between traffic volume (b) and fatality rate (β) parameters from Model 1 and Model 2.

Additional VKT (vehicle kilometres travelled) Data for New Zealand

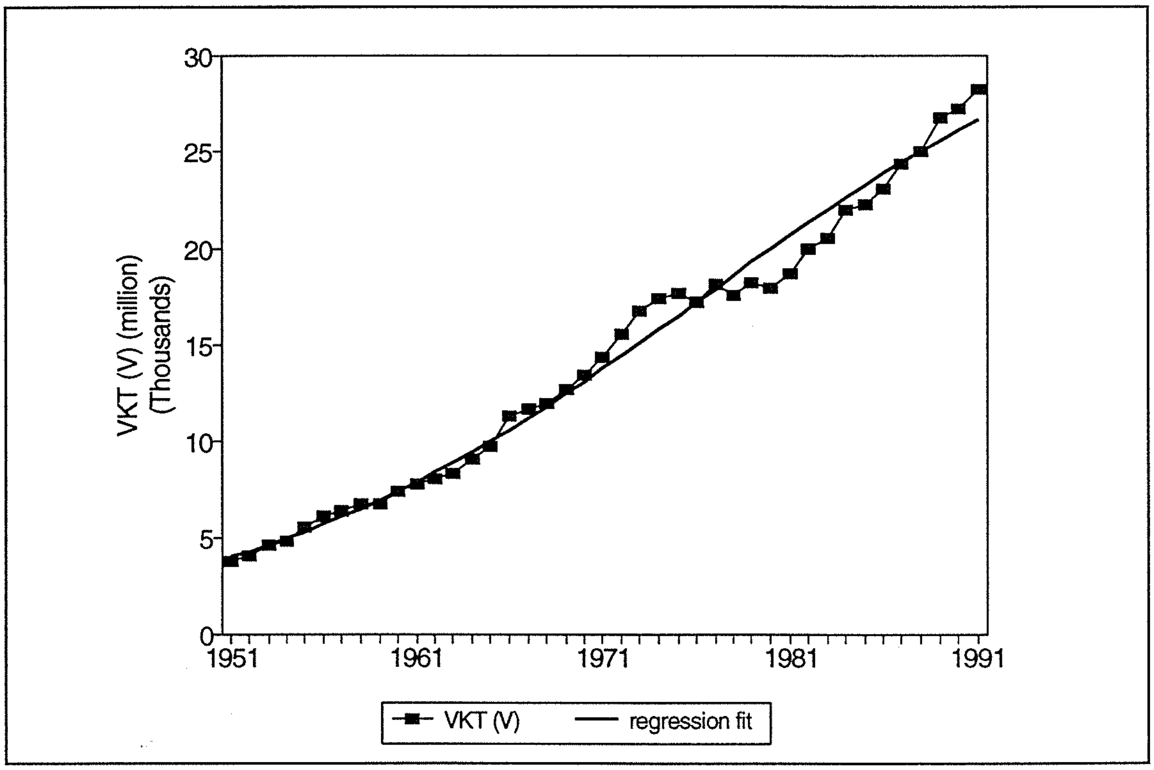

Figure A3.1 Vehicle kilometres travelled (VKT) for the period 1951-1991.

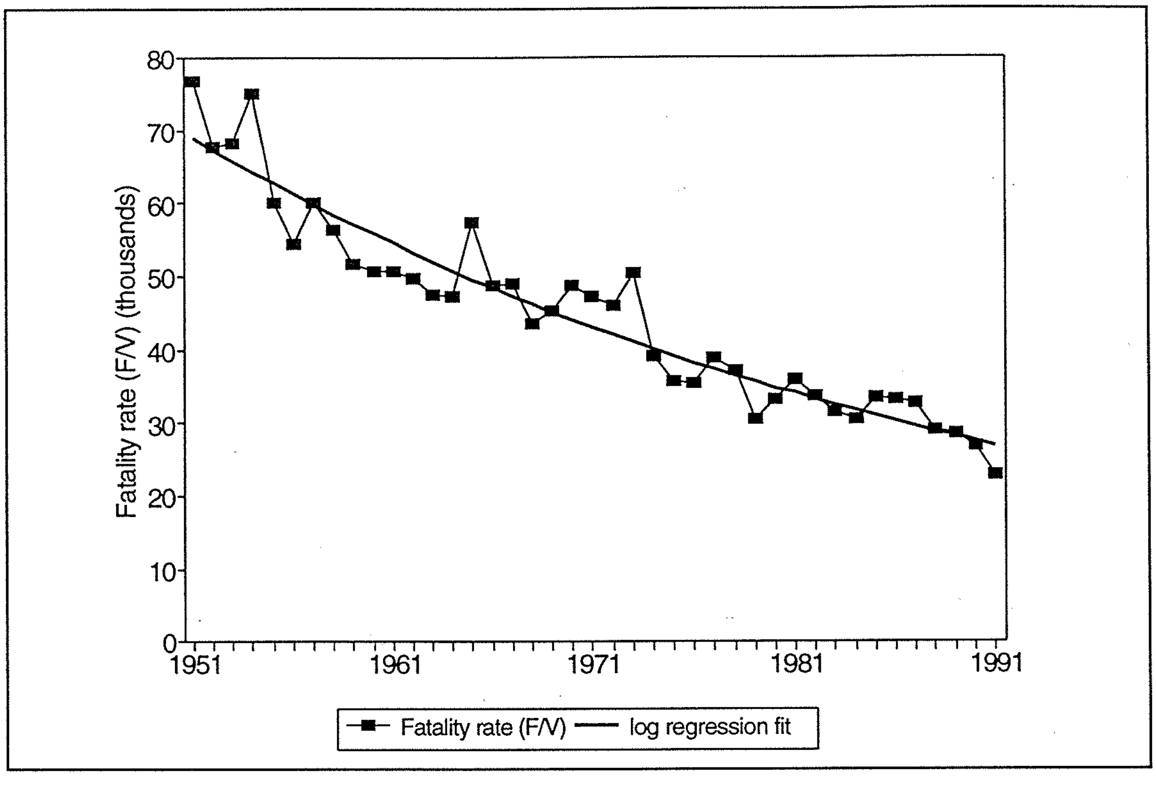

Figure A3.2 Fatality rate (F/V), between 1951-1991.

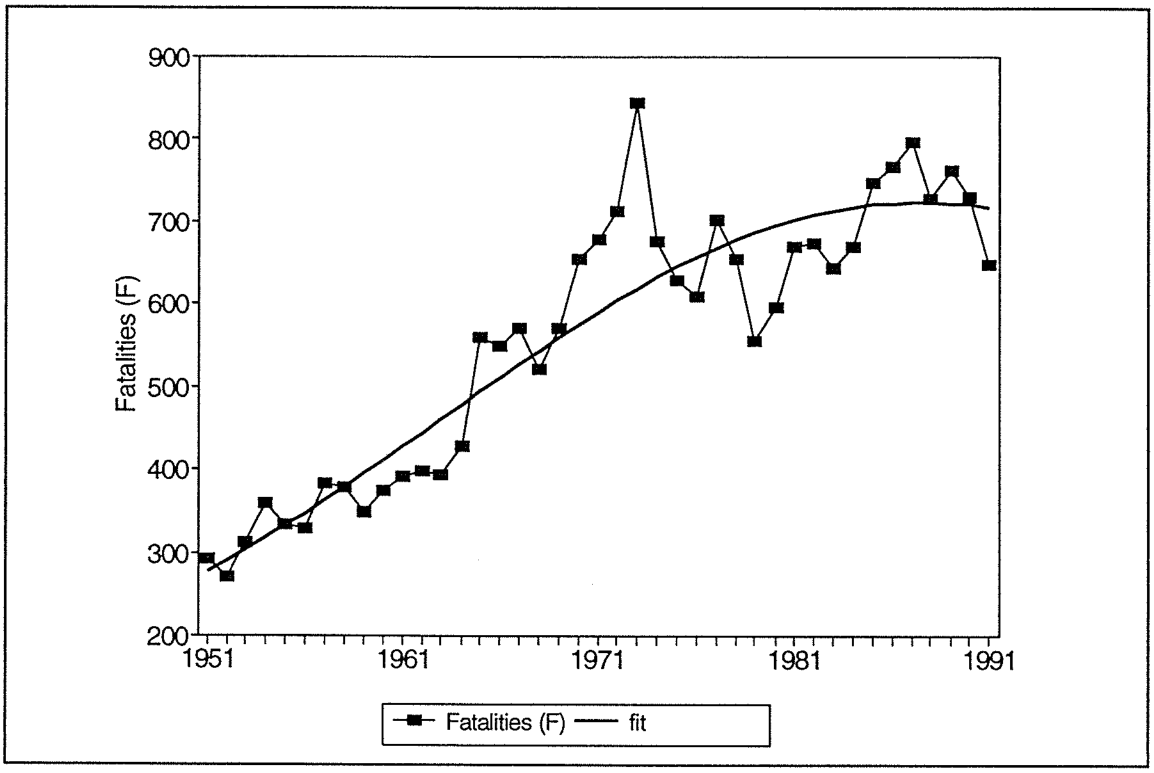

Figure A3.3 Fatalities (F), for 1951-1991.

Additional VKT Data for Australia

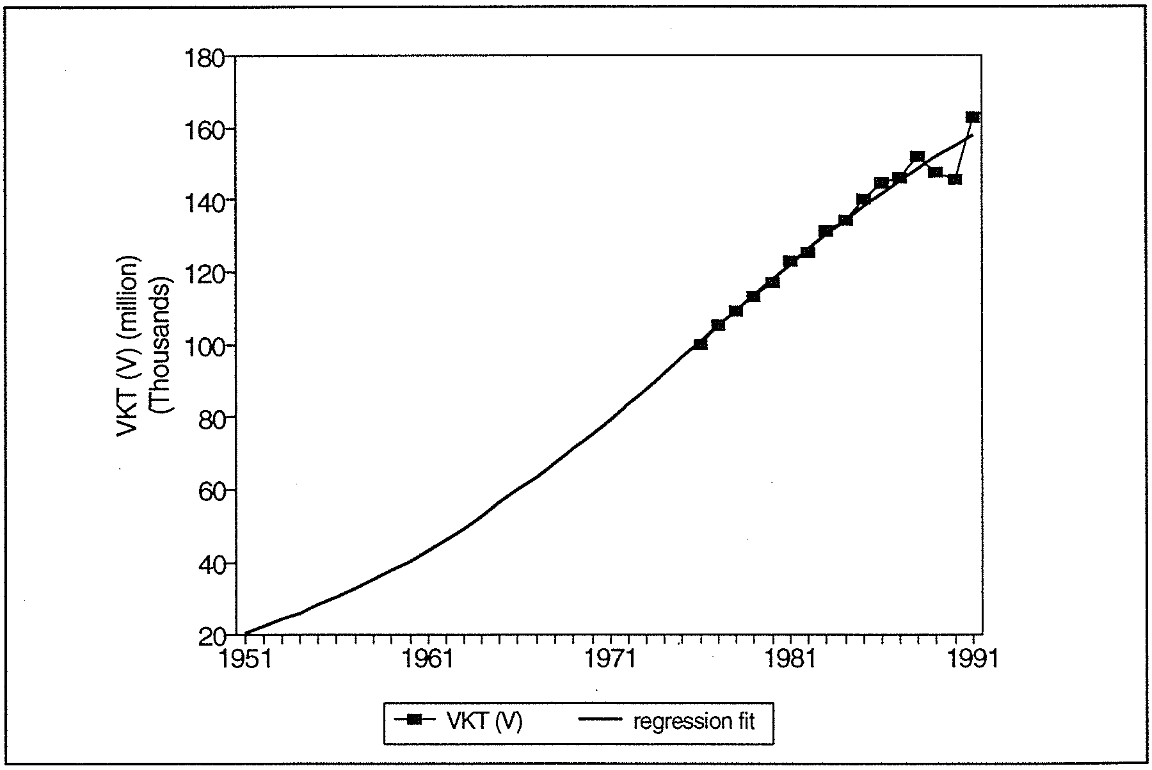

Figure A3.4 Vehicle kilometres travelled (V) between 1975-1991.

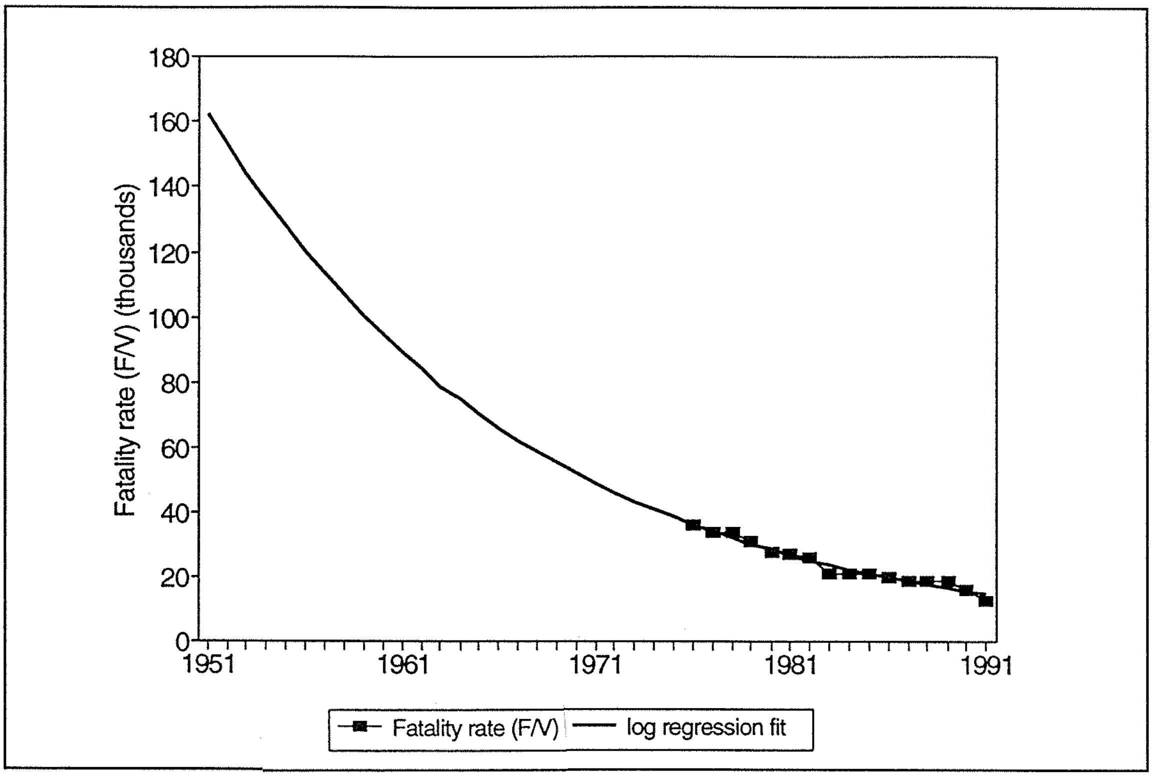

Figure A3.5 Fatality rate (F/V) between 1975-1991.

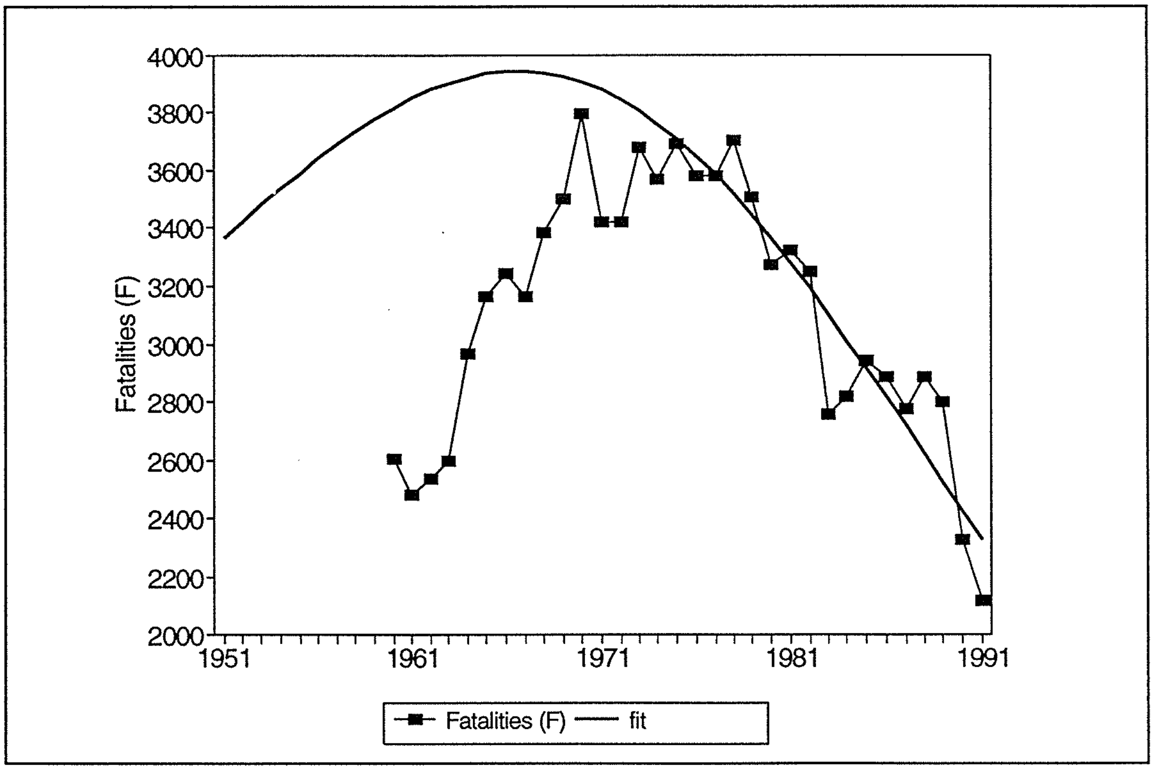

Figure A3.6 Fatalities (F) between 1960-1991.