SAFETY BENEFITS OF MEDIAN BARRIERS ON NEW ZEALAND MOTORWAYS

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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.

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David Harte, Applied Statistics Group, Ministry of Agriculture & Fisheries, Wellington (now at School of Mathematical & Computing Science, Victoria University of Wellington), refereed the report, then analysed the data using multiplicative modelling. His results and conclusions are Chapter 7.3 of this report.

CONTENTS

EXECUTIVE SUMMARY

This report details research carried out to measure the safety benefits of the installation of median barriers on the New Zealand motorway system. A decision in 1985 by the National Roads Board (NRB, which is now Transit New Zealand) to accelerate the construction of motorway median barriers using an installation warrant meant that barriers were installed without the normal evaluation procedures being carried out. To decide if this warrant was appropriate, the research was used to consider if median barrier installation had been a success.

Before & After analyses, using log-odds, multi-linear regression and multiplicative models, were carried out, in 1992, on accident data obtained from the Ministry of Transport (now Land Transport Safety Authority) database of accident records for motorways. The analysis of the data was difficult because the size of the data set was limited, the median barriers were installed at different times, accident reporting rates changed after 1985, and because the accident database coding did not specifically identify cross-median accidents.

The log-odds model was used to provide initial evidence that median barriers had reduced accident severity and accident frequency. The multi-linear regression model showed that the installation of median barriers reduced fatal accidents by 0.25 fatal accidents per kilometre per year (approximately 75% reduction). The reduction in serious injury accidents estimated by the regression model was 0.07 accidents per kilometre per year (approximately 7% reduction).

Two multiplicative models were then fitted to the motorway accident data. Model 2 was a refined version of Model 1 as it accounts explicitly for the AADT (average annual daily traffic), median width and number of lanes. Both models give consistent results for Fatal accidents with an estimated 75% decrease. The two models are not so consistent for the All and Non-Fatal accident categories, though the differences are barely significant. Model 1 predicted no increase or decrease and Model 2 predicted a 19% reduction.

Using the results obtained from the log-odds and regression models, and values for the installation and maintenance costs of median barriers, an economic analysis was carried out on the safety benefits of median barrier installation. The analysis showed that, applying figures from the standard 1986 methods used in New Zealand for evaluating the benefit/costs of roading projects, there had been no economic benefit in installing median barriers on motorways. However, using economic values from updated 1991 methods (Transit New Zealand Project Evaluation Manual, 1991), a benefit/cost ratio between 12 and 16 had been achieved.

The research shows that the cost of providing the existing median barriers on motorways is likely to be repaid many times in a 25-year design life. Data also show that motorway accident patterns on motorway sections with no median barriers differ from those on motorway sections with median barriers installed between 1985 and 1990. These data are used to recommend that developing a Median Barrier Installation Warrant based on previous experience for New Zealand motorways is inappropriate, and that each median barrier installation proposal should be judged on its own merits.

ABSTRACT

The report details the safety benefits achieved by the installation of median barriers on the New Zealand motorway system. Before & After analysis, using log-odds, regression and multiplicative models, was applied to determine the safety benefits.

Each of these models produced evidence of similar reductions in fatal accidents of around 75%. The estimated reduction in non-fatal accidents was inconclusive, with analysis showing the possibility of either a major increase or minor decrease in the number of non-fatal accidents.

Benefit/cost calculations were performed by applying both the 1986 and the 1991 methods for evaluating the benefit/costs of roading projects used in New Zealand. Median barrier installation on average had a benefit/cost ratio between 12 and 16. Because of changing accident patterns the recommendation is that, rather than developing a Median Barrier Installation Warrant based on previous experience for New Zealand motorways, each median barrier installation proposal should be judged on its own merits.

1. INTRODUCTION

1.1 Background

In 1986 the National Roads Board (NRB, which is now Transit New Zealand) decided to accelerate a programme of median barrier installation. The programme had already been started in conjunction with the widening of sections of the Auckland motorway. In early 1985 public pressure had been heavy for the installation of median barriers on motorways following some particularly horrendous cross-median accidents. Because of the NRB decision to accelerate the programme, the normal evaluation procedures were not applied.

At the same time the NRB adopted a warrant for the installation of median barriers. This was based on the National Cooperative Highway Research Program Report 118 titled *"Location, Section and Maintenance of Highway Traffic Barriers"*, published by the USA Highway Research Board. The warrant indicates the need for median barriers where the traffic volume exceeds 20,000 vehicles per day (vpd) with a median width less than 6 metres. As traffic volumes rise in excess of 40,000 vpd median barriers are justified where the median width is less than 15 metres. A median barrier is not considered necessary where the median width exceeds 15 metres.

The Road Research Unit (RRU) of NRB at that time had also produced their Technical Recommendation TR9 (Bone 1986), *"The Economic Appraisal of Roading Improvement Projects"*. The TR9 document lists recommendations for economic appraisals of roading works, prescribes standard methods of data collection, calculation and presentation, with New Zealand costs (as at 1986) for construction and road users. References to TR9 are labelled *"TR9 1986"* in this present report.

At the time that this present report was being researched (1990-92), TR9 was being updated to be published in 1991 as the *"Project Evaluation Manual"* (Transit New Zealand 1991, and referred to as *"PEM 1991"* in this report).

Before & After analyses, first using log-odds and regression models, were carried out to determine accident patterns. The results of these models were then compared with those given by a multiplicative modelling approach.

1.2 Objective

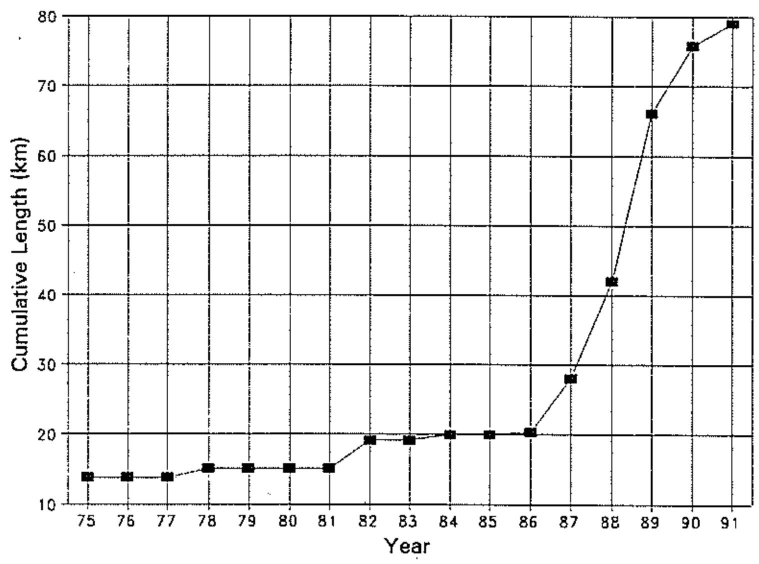
The objective of this study was to measure the safety benefits that have been achieved by the installation of median barriers on the New Zealand motorway system. This measure has been achieved by analysing the Ministry of Transport (MOT, now the Land Transport Safety Authority or LTSA) database of reported injury accidents, after enhancing it by the addition of roadway data including the type and date of installation of median barriers.

2. INSTALLATION OF MOTORWAY MEDIAN BARRIERS

Data on the installation of motorway median barriers was obtained from Transit New Zealand. These data included the date of installation (month and year for the period, 1975-1991), the type of barrier, the Route Positions (RP) of the beginning of the installation, and the length (in metres) of median barrier installed.

Based on the Transit New Zealand data, about 80 kilometres of motorway median barrier had been installed between 1980 and 1991. The cumulative kilometres of installed motorway median barriers are displayed in Figure 2.1.

Figure 2.1 Cumulative length (km) of motorway median barriers installed between the years 1975 and 1991.



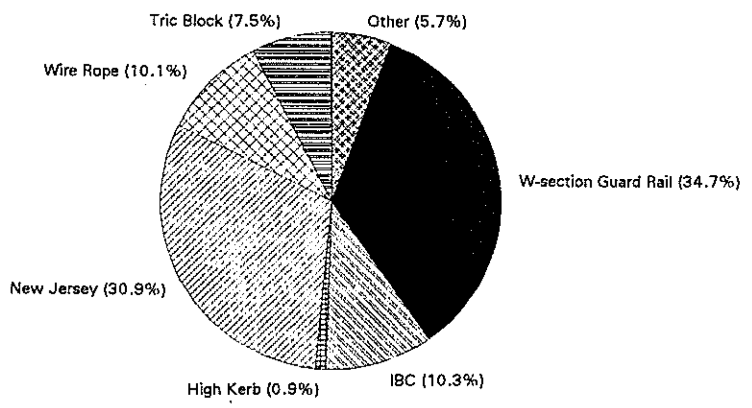
In 1975, just 14 kilometres of motorway median barriers had been installed. This total rose to only 20 kilometres in the following 11 years. However in the 5 years between 1986 and 1991, about 60 kilometres of median barrier, of various types, were installed.

Before 1986, motorway median barrier types were typically New Jersey concrete barriers or W-section Guard Rail. In recent years however, alternative barrier types have been installed, notably:

- Tric Block (a jointed concrete barrier)
- IBC (gravel or sand enclosed by a sheet steel sheathing)
- Wire Rope

The proportions of each type of motorway median barrier installed, as at 1991, is given in Figure 2.2. New Jersey and W-section guard rail make up the largest proportion of median barriers.

Figure 2.2 Use of different types of median barrier as % of total length of median barrier installed on New Zealand motorways.



3. STUDY METHODOLOGY

The prime objective of this study is to identify the changes in accident patterns resulting from the installation of motorway median barriers. In particular, this project seeks to quantify any decrease or increase in the frequency of different accident types resulting from the implementation of motorway median barriers. The methodology used to undertake this study is outlined.

3.1 Accident Data

A database of reported injury accidents occurring on the motorways was obtained from the MOT including all accidents from 1975 to 1990.

Transit New Zealand provided details of motorway median barrier* installation, as well as traffic volume details, the number of lanes, and the median* widths. Because all the data were identified by Route Position it allowed the accident database and the road environment database to be merged. This merging allowed the following additional fields to be added to each reported accident:

- whether a median was installed at the time of the accident;
- the type of median installed or eventually installed at the location (if a median had never been installed a blank was inserted in this field);
- the width of median between the opposing carriageways;
- and its form (i.e. paint or kerb);
- the roadway AADT (annual average daily traffic);
- the number of traffic lanes.

This database was accessed and tabulations were obtained using PC SAS (Statistical Analysis System computer package).

3.2 Analysis Methodology

The effects of the installation of median barriers, and evaluation of the existing installation warrants, were analysed for Before & After effects using three modelling approaches. This analysis involved first a log-odds model and regression (or additive) model. To check the validity of these models, the motorway accident data was then fitted to two types of multiplicative models, subsequently named Model 1 and Model 2.

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* *Median:* strip of road not normally used by traffic, which separates carriageways.
Median Barrier: device used on multi-lane roads to keep opposing traffic in prescribed carriageways (Definitions from Armitage (undated))

3.2.1 Log-Odds Model

This analysis involves attempting to identify accident types which have been unaffected by the installation of median barriers. The unaffected accident types can then be used as a 'control' for effects not related to median barriers for the Before & After analysis.

3.2.2 Simple Regression Model

The second method has been to partition sections of motorway into homogeneous sections where environment and traffic features remain constant, i.e.

- traffic volume;
- type of median installed (including no median);
- median width;
- number of traffic lanes.

The accident rate for different classes of accidents on each section was evaluated (i.e. accidents per kilometre per year). From this a multi-linear regression was undertaken to relate the accident rate to the above parameters as well as to whether a median was installed or not.

This regression (or additive) model allows for a further evaluation of the effectiveness of median barriers, and provides a potential tool for the investigation of median barrier installation warrants.

3.2.3 Multiplicative Models

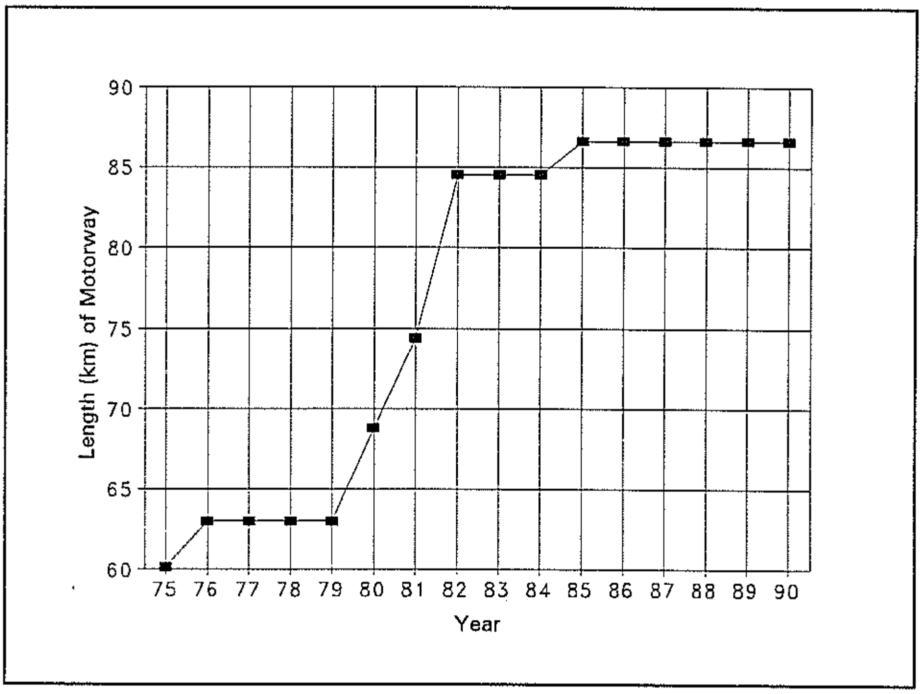
Two types of multiplicative models were fitted to motorway accident data. Both models were fitted to All accident data, Fatal accident data, and Non-fatal accident data.

The two models consider the accident counts for each month for each individual section of motorway. Model 2 is a refined version of Model 1, and excludes those sections where one of the factors, AADT, median width, or number of lanes, is missing.

4. ACCIDENT TRENDS ON NEW ZEALAND MOTORWAYS (1975-1990)

The overall accident trends during the 16 years between 1975 and 1990 are outlined. The data are based on the Motorway Districts Accident files provided by the MOT, but excluded the Hutt Motorway (State Highway 2) and the Mangere Motorway (State Highway 20). Figure 4.1 displays the length of motorway used in the data file for the period 1975 to 1990. Because the length of motorway was changing with time, the initial analysis considered accidents per kilometre of motorway studied.

Figure 4.1 Length (km) of motorway existing in years 1975-1990, used in the data files.

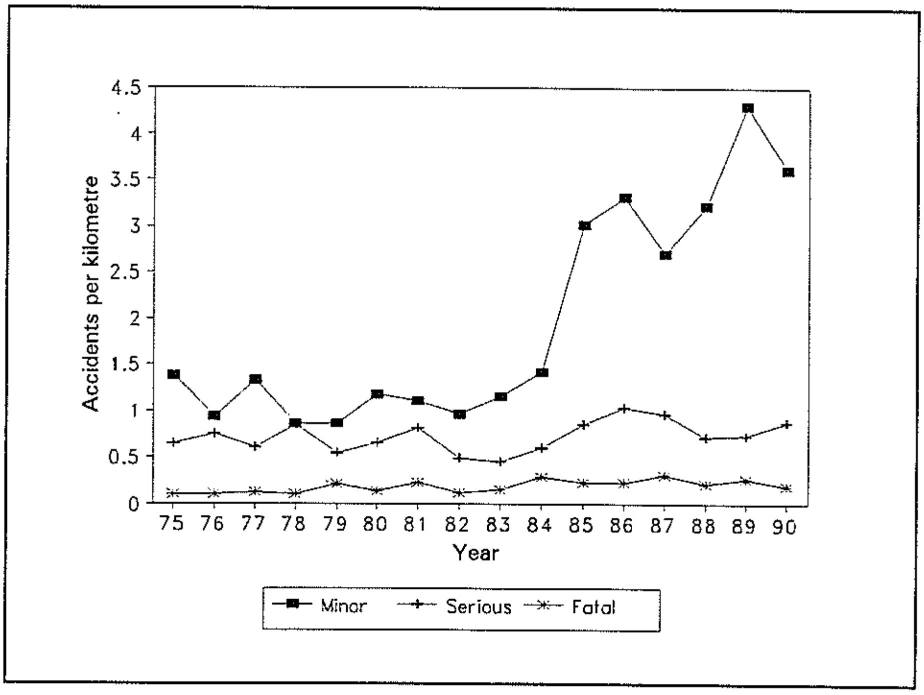


4.1 Changes in Accident Frequency and Severity over Time

Figure 4.2 displays the annual rates of injury accidents per kilometre reported to the MOT. These annual totals are also disaggregated into injury severity (i.e. fatal, serious and minor).

Figure 4.2 quite clearly demonstrates that in 1985 a quantum leap in accident numbers occurred on the New Zealand motorway system. However this increase was not uniform across accident severity in that, from 1984 to 1985, minor injury accidents per kilometre increased by 112% from 1.42 to 3.01, serious injury accidents per kilometre increased by 44% from 0.59 to 0.855, while fatal accidents per kilometre reduced 19% from 0.28 to 0.23.

Figure 4.2 Annual reported injury accidents per km according to severity, on the New Zealand motorway system from 1975 to 1990.



This change can be explained by changes to the reporting rate by Traffic Officers from the then MOT. In 1984, checking by MOT staff revealed large discrepancies in the number of accidents attended by officers and the number of completed Traffic Accident Report (TAR) forms filled in, particularly on the Auckland Motorway System.

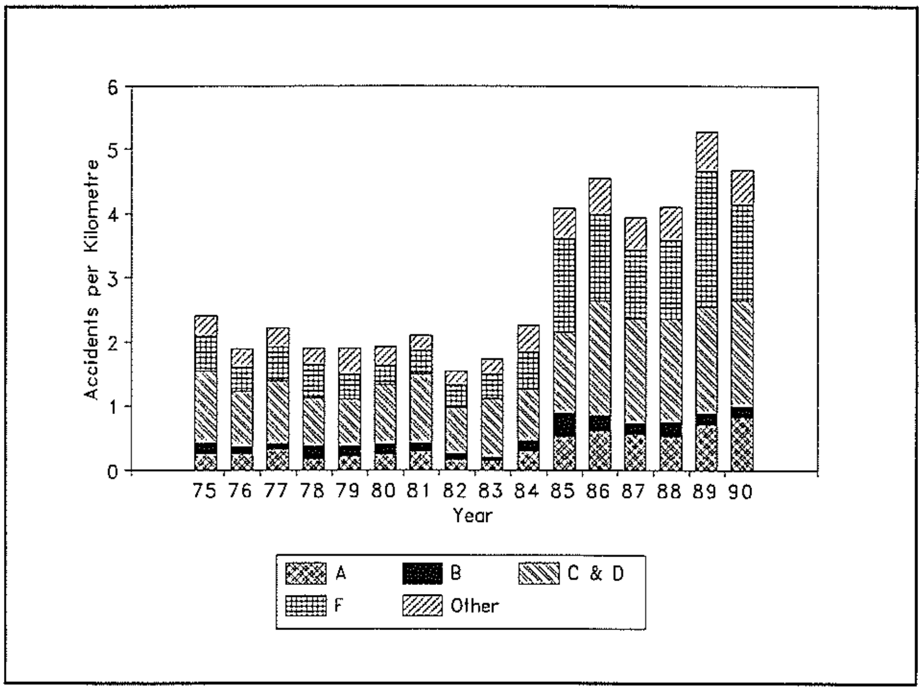
As a consequence, measures were implemented to improve the reporting rate so that by 1985 the reporting rate had increased. For example, the minor injury accidents had increased the most, because these accidents had tended to be most under-reported before 1985. This change in reporting rate has also caused the relative proportions of different accident types to change. For example those accidents associated with minor injuries (e.g. rear-end accidents) have increased relative to those accidents associated with more serious injuries (e.g. head-on accidents).

Such changes make the use of comparing pre- and post-1985 accident data more difficult. However as most median barriers were installed after 1986, this project will confine the statistical analysis principally to the years 1985 to 1990.

4.2 Changes in Accident Type over Time

Figure 4.3 displays annual reported injury accidents per kilometre disaggregated according to accident movement type (A - changed lanes, B - head on, C & D - lost control, F - rear-end, Other).

Figure 4.3 Changes from 1975 to 1990 in accident movement type against accident rates (accidents per km) on New Zealand motorways.



Accident Movement Types:
A - changed lanes; B - head on; C & D - lost control; F - rear-end; Other - other types

From 1984 to 1985 the pattern of reported injury accidents showed a considerable change when the reporting rate increased. For example the proportion of lost control accidents (types C & D) reduced from 36.1% to 31.3%, while the proportion of rear-end accidents (type F) increased from 25.3% to 35.5%.

4.3 Overall Accident Characteristics

Overall accident characteristics for the years 1975 to 1990 on the New Zealand motorway system are shown in Figures 4.4 to 4.7. The breakdown of total accidents during this period is by:

- Accident Movement Type (Figure 4.4)
- Objects Struck (Figure 4.5)
- Causes of Accidents (Figure 4.6)
- Vehicle Type, and Pedestrians, Involved in Accidents (Figure 4.7).

Figure 4.4 shows that lost-control accidents (Type C&D) and rear-end accidents (Type F) accounted for most (67.9%) motorway accidents. The high profile head-on accident has accounted for only 5.6% of all accidents (i.e. 209 out of 3,738 accidents).

Figure 4.4 Accident movement types occurring on motorways.

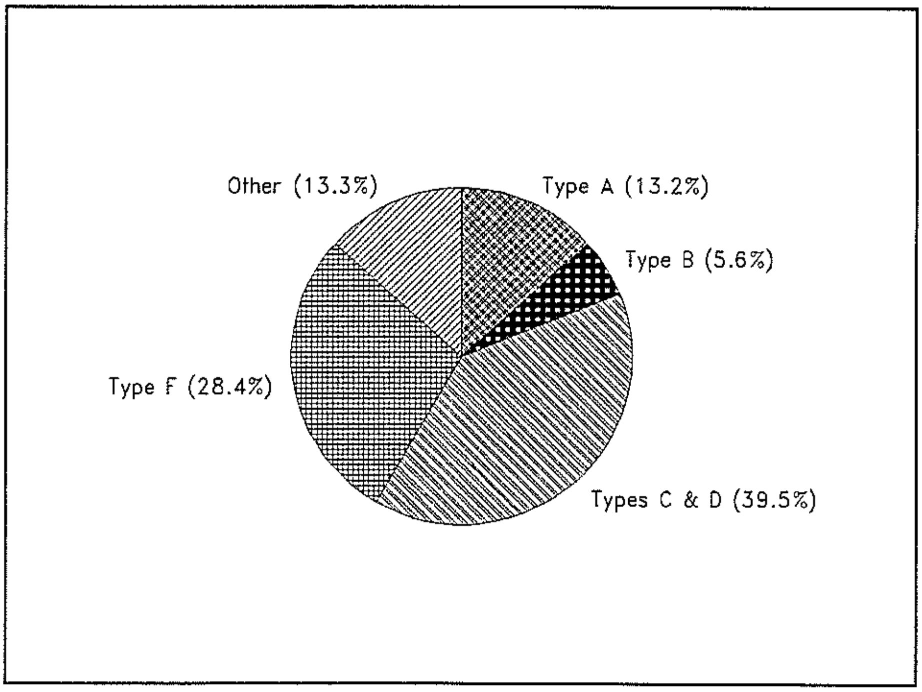


Figure 4.5 Objects struck in accidents on motorways.

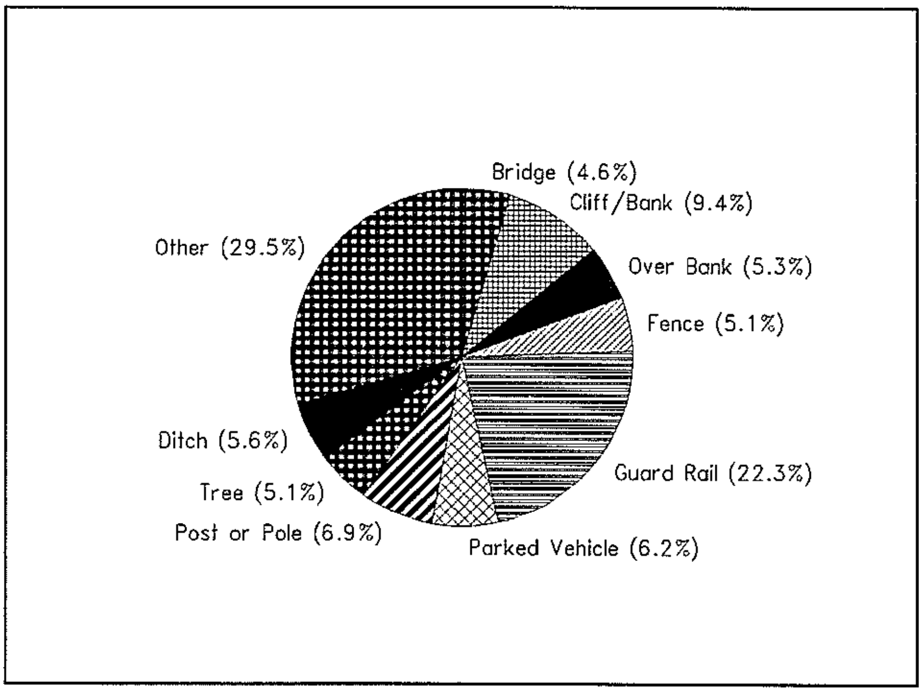


Figure 4.6 Causes of accidents on motorways.

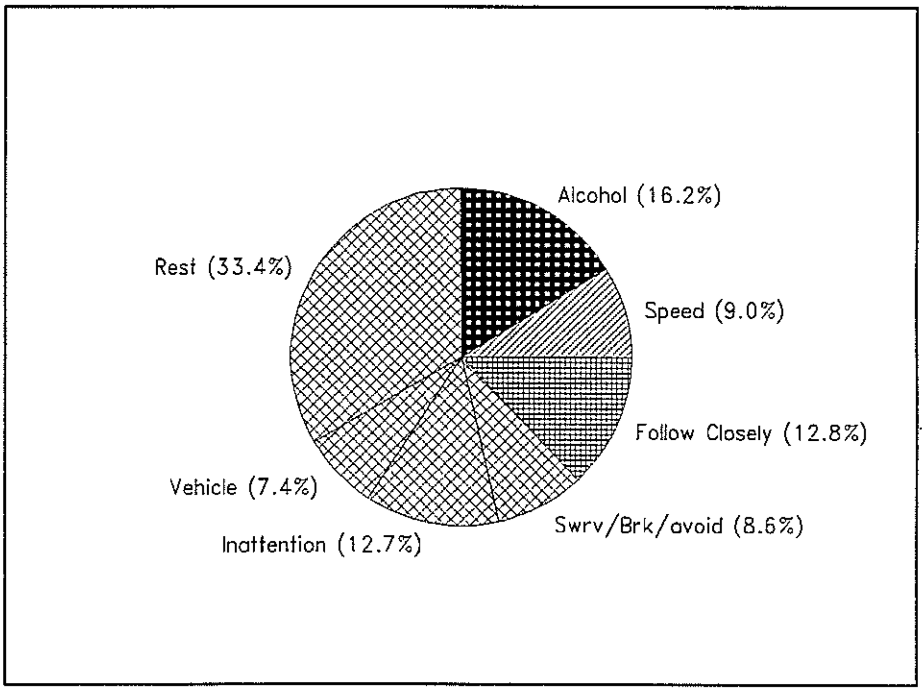
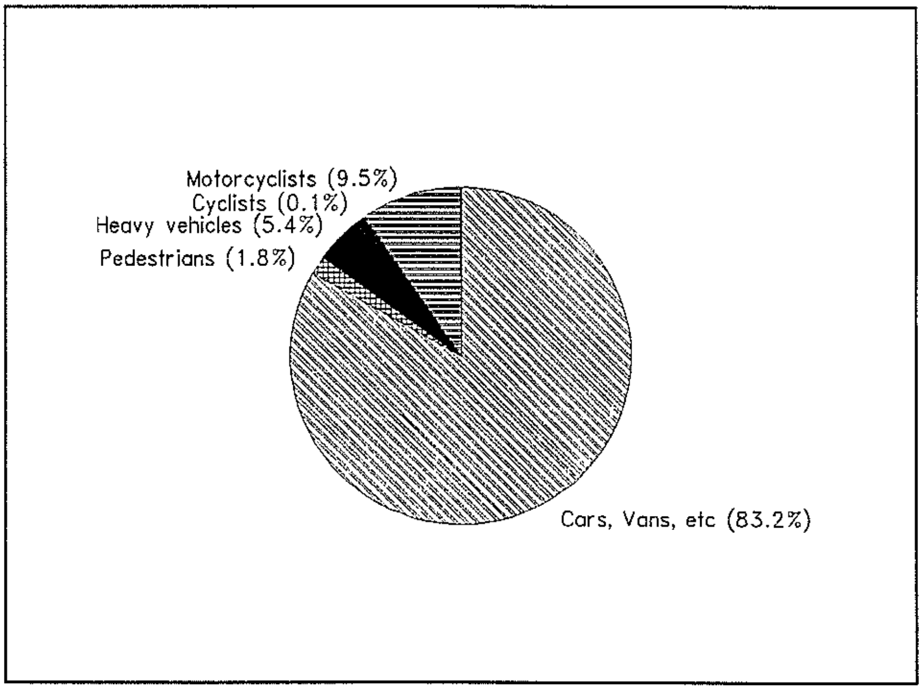


Figure 4.7 Vehicle types, and pedestrians, involved in accidents on motorways.



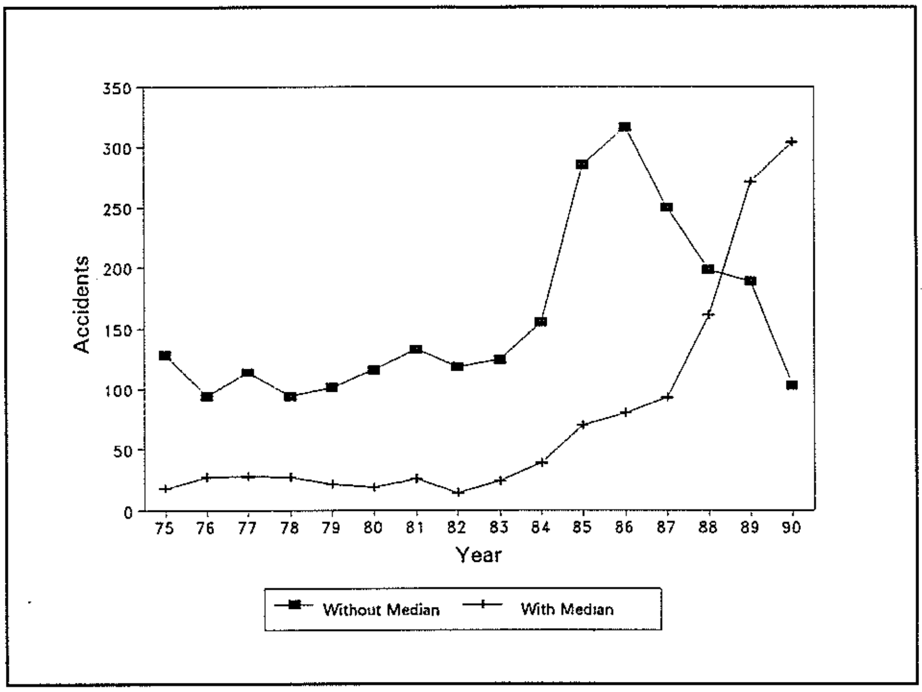
5. EFFECTS OF MEDIAN BARRIERS

5.1 Effect of Presence or Absence of Median Barriers

Because most of the motorway system did not have median barriers installed before 1987, most accidents occurred on sections of motorway with no median barriers. As the total length of motorway with median barriers increased, so did the number of accidents occurring on motorways having median barriers.

This change is demonstrated on Figure 5.1 in which the annual reported injury accidents on sections of motorway with and without median barriers installed are compared.

Figure 5.1 Annual reported all-injury accidents on sections of New Zealand motorways without and with median barriers.



Because the increase in accident reporting rate made substantial changes to the relative frequencies of the different accident types, the focus was on the six years 1985 to 1990. To compare pre-1985 accident data with the post-1985 data could confound any aggregate analysis attributing changes of accident patterns, resulting from the increase in reporting rate, by attributing them to the installation of the median barriers. The use of only 1985 to 1990 data does not seem to present a major obstacle, as most median barriers on the motorway system were installed after 1986 which gives reasonable 'before' periods that can be used for Before & After analysis.

5.2 Effect of Median Barriers on Accident Severity

Motorway median barriers are expected to result in a reduction in accident severity as, after installation of median barriers, the highest severity head-on accidents could no longer occur (Figure 5.2). When median barriers are installed, accident severity (Table 5.1) was reduced, with accidents involving fatalities reducing from 7.2% of accidents to 2.8% of accidents.

Figure 5.2 Relative occurrence of accidents by severity (i.e. fatal, serious injury, minor injury) on motorways without and with median barriers since 1985.

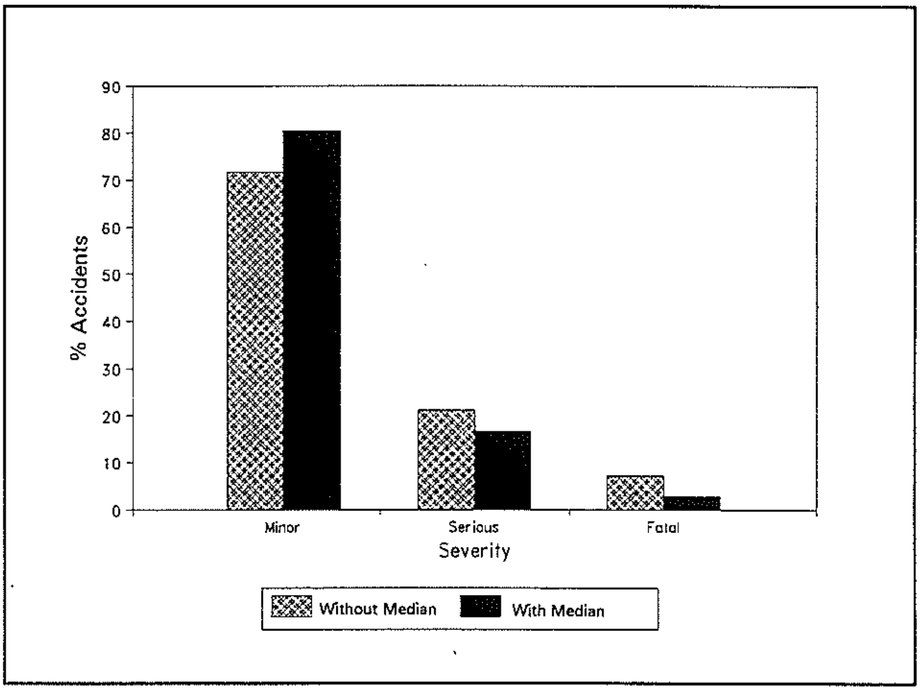


Table 5.1 Accidents (number, %) by accident severity occurring on motorways without and with median barriers, between 1985 and 1990.

Median Barrier	Type of Accident						
	Fatal		Serious		Minor		Total
	No.	%	No.	%	No.	%	No.
Without	97	7.2	284	21.2	960	71.6	1341
With	27	2.8	163	16.6	787	80.6	977
Significant Change at 95% level	Yes		Yes		Yes		

A Chi-Square Test confirms that the reduction in accident severity on motorways where median barriers are placed is significant.

5.3 Effect of Median Barriers on Accident Movement Type

Median barriers are installed to separate opposing flows of traffic. As such the implementation of the policy for their installation would be expected to affect accident patterns in two ways:

- Totally prevent or at least drastically reduce those accidents (usually fatal or serious) which, before median barrier installation, involved head-on accidents by vehicles travelling in opposing directions on the motorway.
- Possibly increase accidents (of lesser severity) where, before median barrier installation, vehicles went into the opposing traffic lanes but did not impact an opposing vehicle but, after median barrier installation, collided with the barrier itself.

However one problem in determining the effect of median barriers on accident type is that a cross-median head-on accident was not consistently coded as one accident movement type (say Type B - head-on). Rather the movement coded was the first movement involved in the accident which eventually resulted in the head-on. For example, a lane change (type A) or a lost control (Type C or D) led then to the head-on. The accident database includes relevant contributing factors where they were identified. A limited number of such factors are defined for inclusion in the database.

A Contributing Accident Factor (lost control - head-on) in the accident data could also help identify the target accident group but again would not identify all the relevant accidents. Thus the difficulties are to identify specific accident movements which are only associated with cross-median accidents. The Contributing Accident Factor Code (crossed median) would also help but it was not introduced until 1984 and thus would only be relevant for accidents reported after 1984.

Table 5.2 Changes in relative frequency of accident movement type.

Median Barrier	Type of Accident									
	A		B		C & D		F		Other	
	No.	%	No.	%	No.	%	No.	%	No.	%
Without	146	10.9	96	7.1	512	38.2	402	30.0	185	13.8
With	181	15.5	21	1.8	421	36.0	426	36.4	121	10.3
Significant Change at 95% level	Yes		Yes		Yes		No		Yes	

Figure 5.3 shows the percentages of different accident movement types for all accidents occurring on motorways without and with medians. It shows that some accident movement types have increased as a proportion of total accidents and some have decreased following the installation of median barriers. Most notably, head-on accidents (Type B) have decreased from 7.1% of all reported accidents without median barrier to 1.8% of all reported accidents with median barriers. Table 5.2 shows these changes in relative frequency of accident movement type.

Figure 5.3 Distribution of accident movement types on motorways without and with medians. (Key to Types A,B,C&D,F: see Figure 4.4)

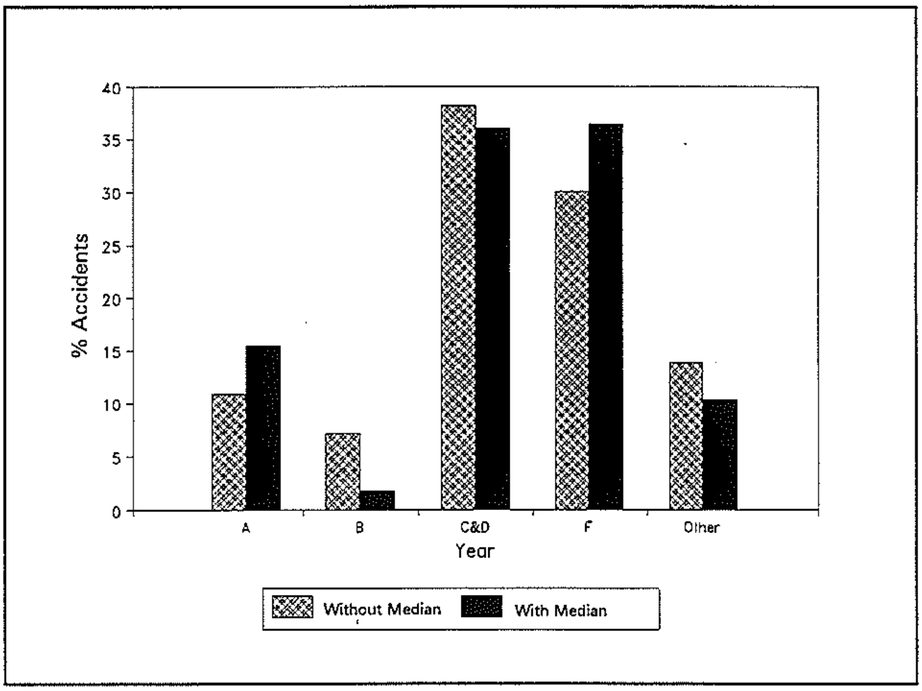


Figure 5.4 Percentage of fatal accidents for accident movement types on motorways without and with median barriers. (Key to Types A,B,C&D,F: see Figure 4.4)

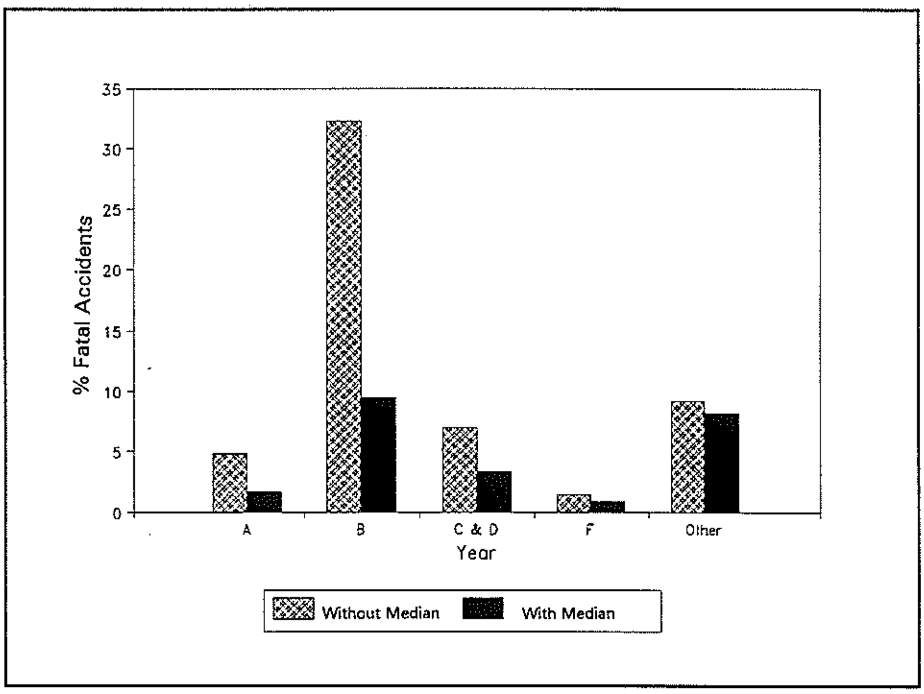
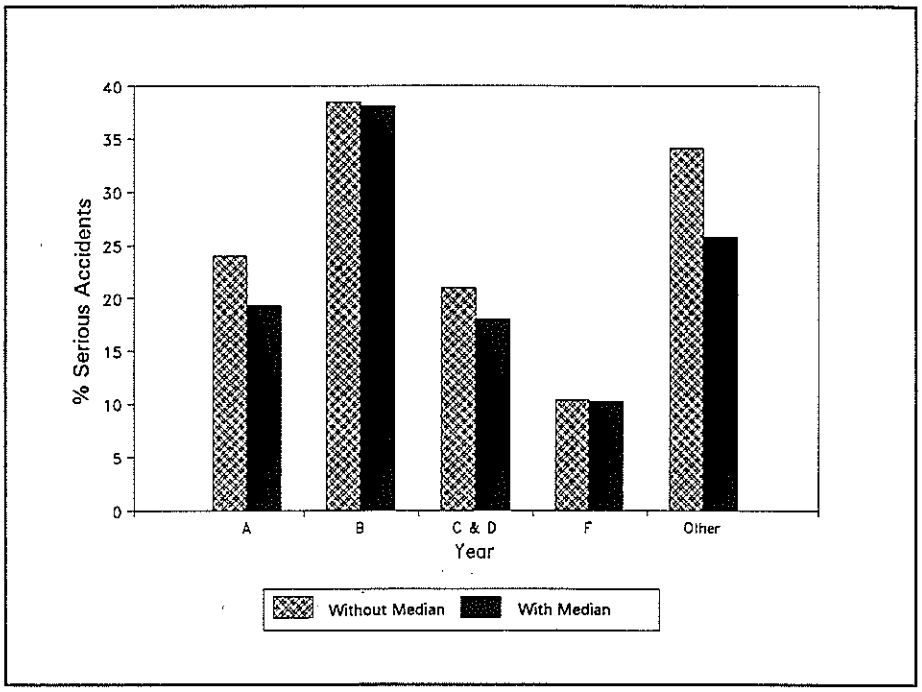


Figure 5.5 Percentage of serious injury accidents for accident movement types on motorways without and with median barriers.

(Key to Types A,B,C&D,F: see Figure 4.4)



Because the median barriers are expected to reduce head-on accidents resulting from accident types other than just Type B, the patterns of accident severity associated with other accident movement types are also worth examining for changes occurring after the installation of median barriers. Figures 5.4 and 5.5 display relative accident severity by accident movement type without and with median barriers. The information contained in Figures 5.4 and 5.5 is displayed in Table 5.3.

The installation of median barriers, as shown in Figures 5.4, 5 5 and in Table 5.3, has substantially reduced the percentage of Type A, B, C & D accidents which result in fatalities. However most of these reductions are not statistically significant. There is also a trend to reduce the percentage of accidents which are serious injury across all accident types.

However, because this analysis does not enable overall accident rates to be determined before and after median barriers are installed (i.e. total reported injury accidents per vehicle-kilometre per year, without and with barriers), it cannot be used to determine the accidents savings associated with median barriers.

The accident movement type which seems to be least affected by the installation of medians is rear-end accidents (Type F).

Table 5.3 Changes in accident severity by accident movement type on motorways with and without median barriers.

Accident Severity	**Median Barrier**	**Accident Movement Type**									
		A		**B**		**C & D**		**F**		**Other**	
		No.	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Fatal	Without	7	4.8	31	32.3	36	7.0	6	1.5	17	9.2
	With	3	1.7	2	9.5	11	3.4	3	0.9	8	8.3
	Significant to 95%	No		Yes		No		No		No	
Serious Injury	Without	35	24.0	37	38.5	107	20.9	42	10.4	63	34.0
	With	35	19.3	8	38.1	59	18.0	36	10.2	25	26.1
	Significant to 95%	Yes		Yes		No		No		No	
Minor Injury	Without	104	71.2	28	29.2	369	72.1	354	88.1	105	56.8
	With	143	79.0	11	52.4	257	78.6	313	88.9	63	65.6
Total	Without	146	100	96	100	512	100	402	100	185	100
	With	181	100	21	100	327	100	352	100	96	100

Note: See Appendix 1 for explanation of unexpected accident types

6. TIME TRENDS FOR DIFFERENT ACCIDENT TYPES

To estimate the effect of median barriers on accidents, a form of Before & After study using a control group of accidents was appropriate. Because median barriers were installed at different times, a particular time could not be chosen to perform a Before & After analysis using before and after periods. Rather the accident data would need to be disaggregated by each median installation to combine all the before and after periods. A simple form of this exercise is conducted in Section 7.2 of this report utilising a multivariate linear regression.

Another approach is to select an accident movement type which is unaffected by the installation of median barriers. Then this movement (or combination of movements) can be used to control for changes in other accident movement types resulting from the presence of median barriers.

Rear-end accidents did not appear to be affected by the presence of median barriers (see Section 5 of this report). Time patterns of accident movement types are now examined in this Section to further assess unaffected accident types.

To do this, graphs of accident movement type by year have been produced, as Figures 6.1 to 6.5. These graphs show the total accidents by movement per year as well as those accidents occurring on motorways where median barriers have been installed at some time in their history up until 1991, and on motorways where median barriers have never been installed.

When interpreting the graphs in Figures 6.1 to 6.6, consider that the bulk of median barriers were installed after 1987, as stated in Section 5.1 of this report. Thus any change in the frequency of an accident type as a result of the installation of median barriers should be seen in the accident frequency for motorways having median barriers installed between 1985 and 1990. For example, Figure 6.2 shows the reduction in head-on accidents from 1985 because median barriers had been introduced. In comparison, lane-change and overtaking accidents appear to have increased.

Ideally accidents on motorways where median barriers have not been installed could be used as a control for comparing such changes. However the accident frequency on these sections of motorway was too low to allow any statistically significant conclusions to be drawn.

For example, for all the accident type categories displayed in Figures 6.1 to 6.6, Chi-Square tests do not allow the hypothesis – that accidents on motorways where median barriers have and have not been installed follow the same trends – to be rejected. Obviously Type B accidents have reduced, but the treatment group is too small to show if this change is significant.

Figure 6.1 Overtaking and lane-changing accidents (type A) on motorways without and with median barriers, between 1975 and 1990.

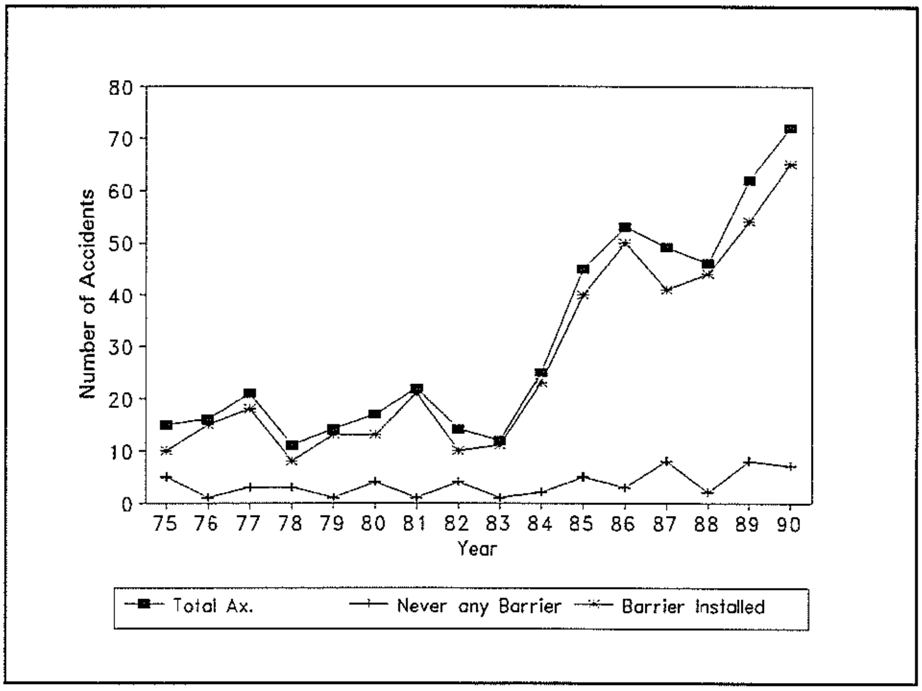


Figure 6.2 Head-on accidents (type B) on motorways without and with median barriers, between 1975 and 1990.

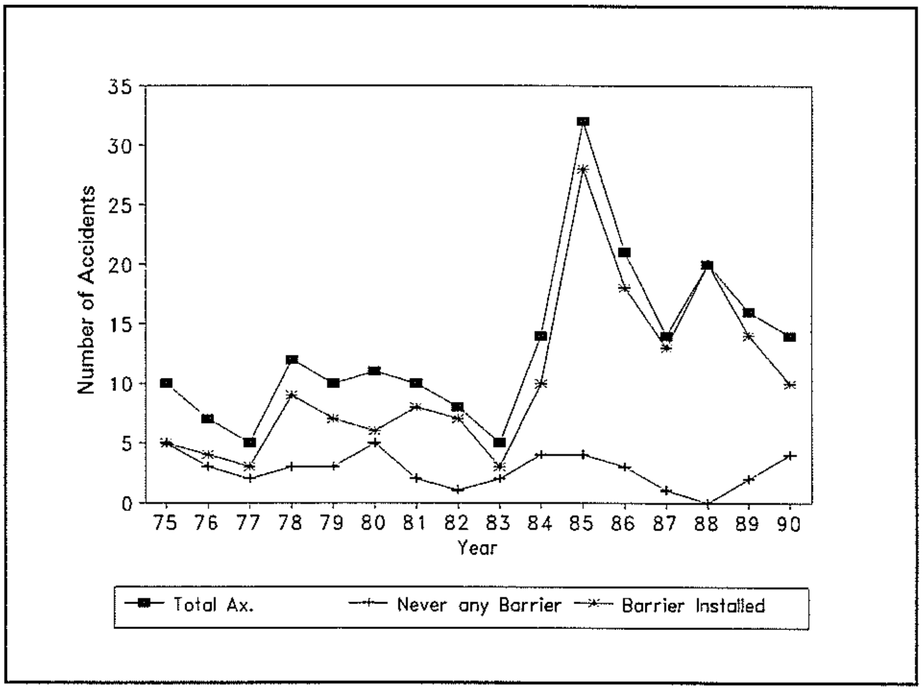


Figure 6.3 Lost control accidents (types C & D) on motorways without and with median barriers, between 1975 and 1990.

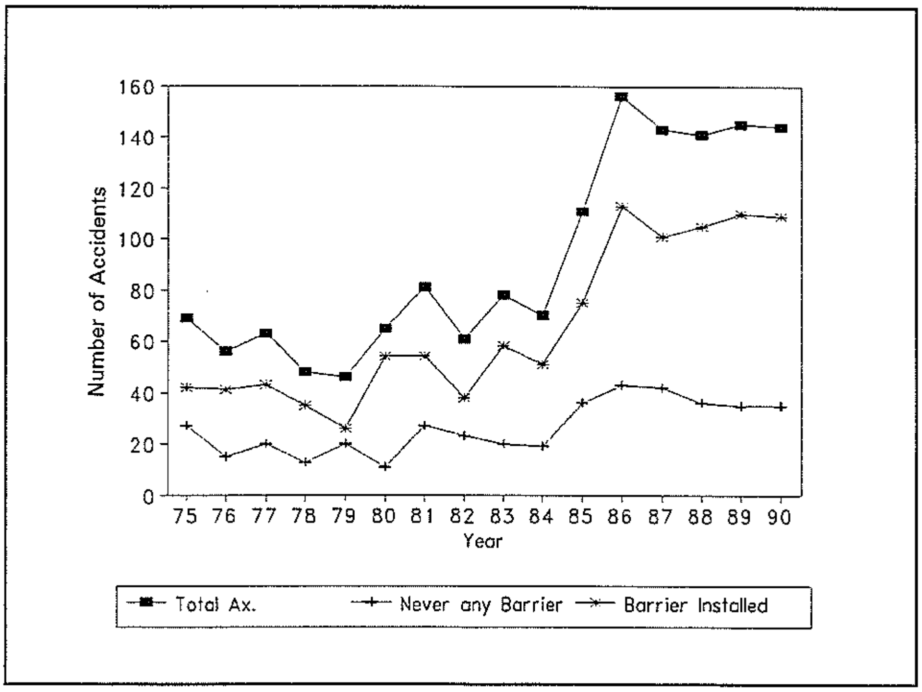


Figure 6.4 Rear-end accidents (type F) on motorways without and with median barriers, between 1975 and 1990.

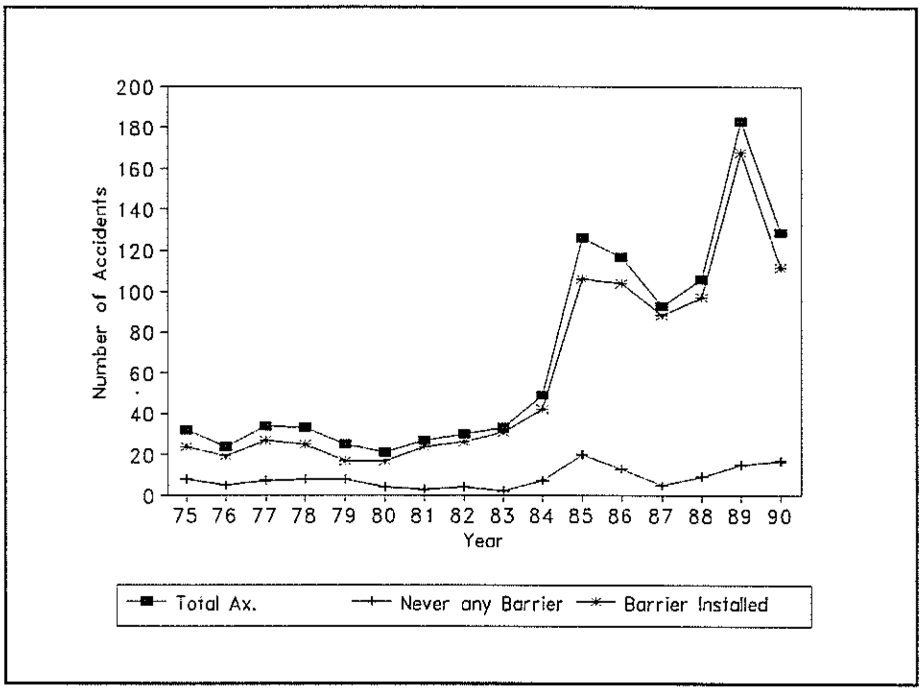


Figure 6.5 Other accident types (type Other) on motorways without and with median barriers, between 1975 and 1990.

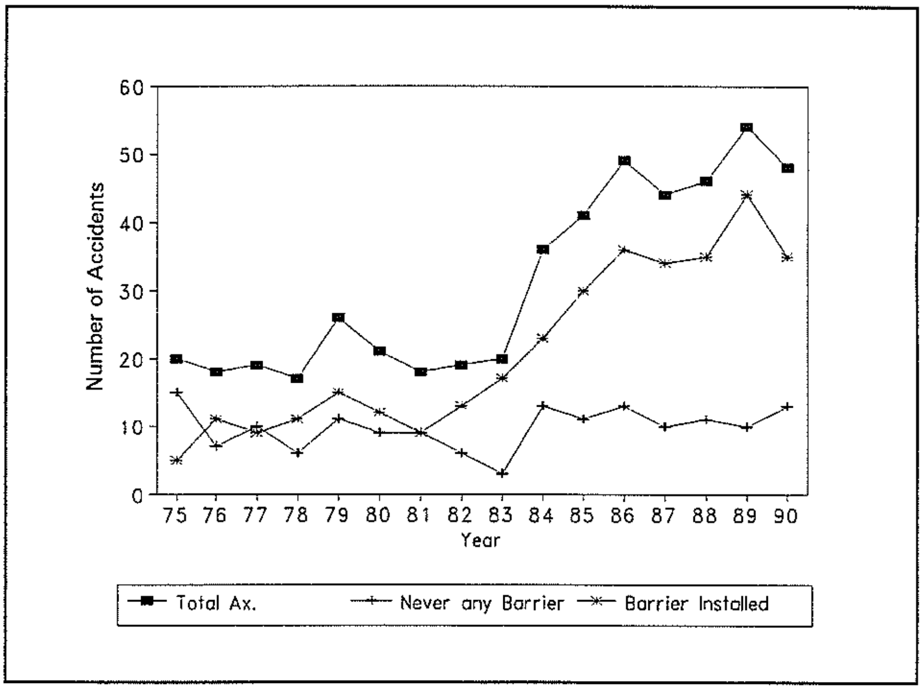
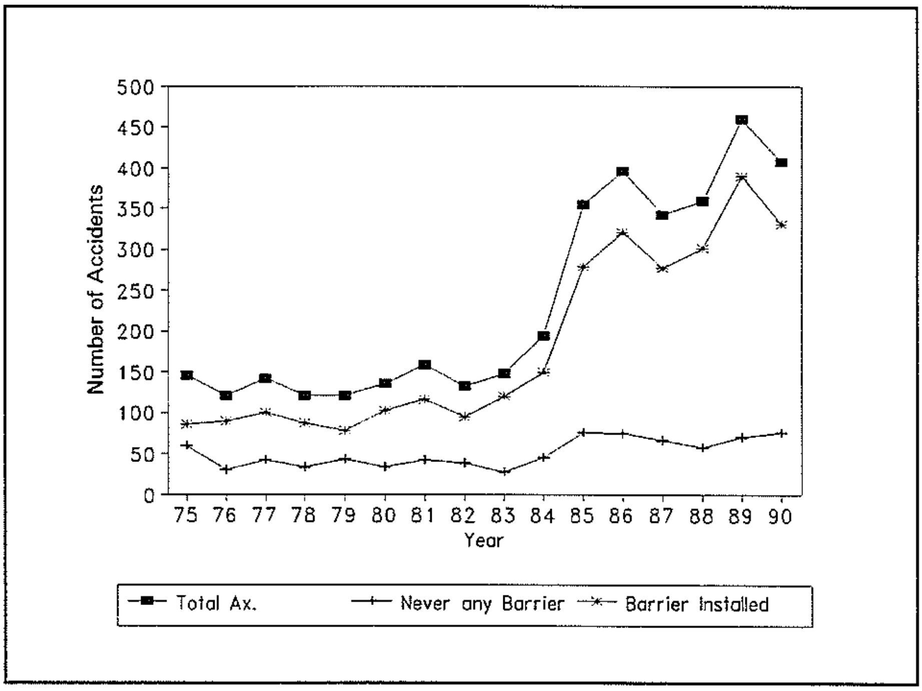


Figure 6.6 Total accidents (all types) on motorways without and with median barriers, between 1975 and 1990.



However a visual examination of the information in Figures 6.1 to 6.6 does indicate that the installation of median barriers has not markedly altered accident trends for accidents overall, with an apparent decrease in head-on accidents being balanced by an increase in lane-change and overtaking accidents.

As the results of Sections 5 and 6 of this report indicate that rear-end accidents patterns have remained relatively unchanged as a result of median barrier installations, rear-end accidents will be used as the control group in the Before & After analysis described in Section 7 following. However no rigorous validation of the use of this accident type as a control has been possible.

7. BEFORE & AFTER ANALYSIS OF ACCIDENT TYPES

Because median barriers could affect a range of accident types, as established in Sections 4 to 6 of this report, undertaking a Before & After study thoroughly would require assessing the original TARs for a large number of accidents to determine whether a cross-median incursion had actually occurred. This would take considerable effort and is beyond the scope of this study.

Accordingly an attempt to identify an accident type which is independent of whether a median barrier was installed or not was made instead. The most likely accident type on motorways with median barriers is rear-end accidents. The presence of median barriers could increase the number of rear-end accidents if breakdowns in the outside lanes are not able to park clear of other traffic lanes. However the previous analysis shows no significant difference in rear-end accidents as a proportion of total accidents without or with barriers, and the time trend of rear-end accidents with barriers follows the time trend of rear-end accidents without barriers. Hence for the Before & After analysis by Log-Odds, it will be assumed that rear-end accidents (Type F) have remained unaffected by the installation of median barriers.

Accidents for the years 1985 to 1990 can be classified according to movement and severity, and also if a median barrier was present when they occurred (see Tables and Figures in Section 5 of this report). As most median barriers were installed after 1987, most of the motorway system between 1985 and 1990 would have been without, and then with, median barriers at certain periods. Therefore Before & After analysis, using the Log-Odds model, and rear-end accidents as the control group, can be conducted.

7.1 Log-Odds Model

A Log-Odds test has been performed for the example of motorway accident data given in Table 7.1, and others can be formed in an analogous way. (Accidents in the before and after periods are drawn from the same sections of motorway over the same time periods.)

Table 7.1 Example of motorway accident data used for a Before & After test, using Log-Odds model.

Accident Type	**Before Period** (No Median Barrier Installed)	**After Period** (Median Barrier Installed)
Test Group Accident (Head-On) Type B	96	21
Control Group (Rear-End) Type F	402	352

The method of Log-Odds allows the determination of whether the change in accidents in the test group was indeed significant together with estimates of this change and the 95% confidence bounds for this change. The assumptions made are based on rear-end accidents as the control group.

Table 7.2 displays the results of the Log-Odds modelling using this control group of rear-end accidents. The accident types in Table 7.2 are disaggregated by accident severity. However as accident totals become smaller with increasing severity, significant results are less likely to be obtained.

Table 7.2 Results of using Before & After Log-Odds model of accident types, using rear-end accidents as a control.

Accident Severity	Before-&-After Change	Accident Movement Type			
		A (Lane Change)	**B** (Head-On)	**C & D** (Lost Control)	**Other**
ALL ACCIDENTS	**Significant Change**	Yes	Yes	Yes	Yes
	Estimated Change	+42%	-75%	-27%	-40%
	Upper Bound	+76%	-63%	-14%	-24%
	Lower Bound	+14%	-83%	-38%	-53%
MINOR INJURY ACCIDENTS	**Significant Change**	Yes	Yes	Yes	Yes
	Estimated Change	+55%	-56%	-21%	-32%
	Upper Bound	+99%	-21%	-15%	-9%
	Lower Bound	+22%	-75%	-34%	-49%
SERIOUS INJURY ACCIDENTS	**Significant Change**	No	Yes	No	Yes
	Estimated Change	+17%	-75%	-36%	-54%
	Upper Bound	+99%	-49%	+11%	-21%
	Lower Bound	-32%	-88%	-59%	-73%
FATAL ACCIDENTS	**Significant Change**	No	Yes	No	No
	Estimated Change	-14%	-87%	-39%	-6%
	Upper Bound	+360%	-47%	+96%	+320%
	Lower Bound	-80%	-97%	-81%	-72%
All tests at 95% level of confidence					

These results tend to validate the results that median barriers have reduced accident severity. They also suggest that accident frequency has not increased following the installation of median barriers. However such a conclusion is only tentative because of the assumptions made by selecting rear-end accidents as the control group.

7.2 Simple Regression Model

Because median barriers were installed in small lengths over an extended period of time, the classic Before & After survey has been difficult to apply. Also the Before & After analysis using a Log-Odds model (Section 7.1 in this report) has relied on the assumption that rear-end accident characteristics have remained unaffected by the installation of median barriers, both in frequency and severity.

An alternative approach, described in this Section, is using a simple regression or additive model. The motorway network is divided into homogeneous segments, each of which has the same:

- traffic volume,
- median width,
- median barrier type (if a median barrier was installed),
- number of lanes.

Reported injury accidents between 1985 and 1990 have been assigned to each of these segments.

If the median barrier was installed between 1985 and 1990 this fact has been added to the database associated with each segment and the accident database divided according to whether the accidents occurred before or after the median was installed. The accidents have then been counted by severity to give fatal, serious, minor, and total injury accident rates (in accidents/kilometre/year).

This disaggregation has then allowed a multi-linear regression to be conducted to predict accident rate as a function of the following independent variables:

- traffic volume,
- number of lanes,
- median width,
- median barrier installed.

This regression equation then allows the accident rate to be related to whether a median barrier was installed or not.

The traffic volume and number of lanes data were tested for independence. The correlation coefficient was 0.27 which indicates that, in terms of these data, the traffic volume is independent of the number of lanes.

In the regression the *y*-intercept was constrained through the origin and the results of this regression analysis are shown in Table 7.3.

Table 7.3 Results of multi-linear regressions of accident rates on motorways without and with median barriers (for period 1985-1990).

Accident Rate (accidents/ km/year)	Independent Variables							
	Median Barrier Installed		Traffic Volume		Number of Lanes		Median Width	
	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error
Fatal	−0.25	0.14	0.00	0.00	0.004	0.06	0.001	0.03
Serious Injury	−0.07	0.38	0.00002	0.00000	−0.06	0.17	−0.027	0.077
Fatal & Serious Injury	−0.32	0.47	0.00002	0.00001	−0.05	0.21	−0.03	0.09
Minor Injury	2.42	1.73	0.00018	0.00004	−1.16	0.77	−0.63	0.35
Total Reported Injury	2.10	2.10	0.0002	0.00004	−1.21	0.92	−0.65	0.42

These linear regressions indicate the following trends:

1. Fatal and Serious Injury accidents are reduced after the installation of motorway median barriers.

   The regression coefficients indicate that the magnitude of this reduction is estimated to be:
   Fatal Accident Rate : 0.25 fatal accidents / kilometre / year.
   Serious Injury Accidents : 0.07 serious injury accidents / kilometre / year.

2. Minor Injury accidents are increased after the installation of motorway median barriers.

   The magnitude of this increase is estimated to be:
   Minor Injury Accident Rate : 2.4 minor injury accidents / kilometre /year.

This analysis could be taken further by looking at individual accident movements and median barrier types separately. However as median barriers seemed to have only reduced the relatively rare (but the most severe) fatal and to a much lesser extent serious injury accidents, actual accident numbers in any analysis are consequently relatively small. Thus to disaggregate further by accident movement type and median barrier type at this stage will provide such small samples of the affected accident groups that meaningful comparisons will be impossible.

Also apparent from this regression analysis is that accident rate tends to increase with increasing traffic volume and decrease with increasing median width.

7.3 Multiplicative Models

To test the robustness of model assumptions of the log-odds and regression models, two multiplicative models were fitted to the motorway accident data. Both models have been fitted to All accident data, to Fatal accident data, and to Non-fatal accident data.

7.3.1 Multiplicative Model 1

Let Y_{ijkm} be the accident count on the ith motorway section, in the jth month (j=1...12), in the kth year with mth status before or after (m=1,2). Then:

$$E[Y_{ijkm}] = exp(\alpha + \beta_m + \gamma_i + \eta_j + \lambda_k)$$

where
α Constant
β_m Status parameter, $\beta_1=0$
γ_i Location parameter (for each section of motorway)
η_j Month parameter, j=1,...12
λ_k Year parameter, k=1985,...,1990
E Expected value or long-term mean

Y_{ijkm} is assumed to be Poisson, so $E[Y_{ijkm}] = Var(Y_{ijkm})$.

7.3.2 Multiplicative Model 2

Using the same notation as in Model 1, Model 2 postulates that the expected number of accidents is given by:

$$E[Y_{ijkm}] = \frac{V_i L_i}{N_i} \exp(\alpha + \beta_m + \eta_j + \xi_n + \lambda_k + \rho \log(W_i + 1) + \psi \log(N_i))$$

$$= \frac{V_i L_i}{N_i} (W_i + 1)^{\rho} (N_i)^{\psi} \exp(\alpha + \beta_m + \eta_j + \xi_n + \lambda_k)$$

where
$V_i =$ Volume (AADT) on the ith section of motorway
$N_i =$ Number of lanes on the ith section of motorway
$L_i =$ Length of the ith section of motorway
$W_i =$ Median width on the ith section of motorway
$\xi_n =$ Motorway parameter, if ith section of motorway is contained within nth motorway (i.e. N, S, NW, Porirua, Hutt, Wellington Urban)
$\rho =$ Median width parameter
$\psi =$ Number of lanes parameter

and

$$E[Y_{ijkm}] = Var(Y_{ijkm}).$$

Both models 1 and 2 account for an overall trend with the year parameter (λ_k) and seasonality with the month parameter (η_j).

Model 1 explicitly includes a parameter for each different section of motorway to account for the particular accident rate on that particular section. It is therefore quite like a paired t-test. Numbers of accidents on the particular sections may be influenced by such factors as AADT, length of each particular section, number of lanes, median width, etc.

Model 2 excludes the parameter relating to the individual motorway section, and attempts to model the accident rate explicitly according to:

- Vehicle kilometres per lane,
- Number of lanes,
- Median width, and
- Motorway parameter.

The motorway parameter (each motorway being the accumulation of many sections) may account for differences related to reporting biases and other effects intrinsic to the particular motorway system.

7.3.3 Results and Conclusions

Accident rate reductions are described by the parameter β_2. Since the models are multiplicative, an estimate of the accident rate after median installation relative to before is $exp(\beta_2)$. These estimates are listed in Table 7.4. Further details of the results are held on files at Transit New Zealand.

Table 7.4 Summary of estimates of accident rates after median barrier installation.

Accident Severity	Model 1	Model 2
All Accidents	$\beta_2 = -0.0677$ $exp(\beta_2) = 0.93$ $T = -0.77$ $\sigma^2 = 0.89(1.07)$	$\beta_2 = -0.2727$ $exp(\beta_2) = 0.76$ $T = -4.72$ $\sigma^2 = 1.06(1.25)$
Non-Fatal Accidents	$\beta_2 = -0.0038$ $exp(\beta_2) = 1.00$ $T = -0.04$ $\sigma^2 = 0.89(1.08)$	$\beta_2 = -0.2124$ $exp(\beta_2) = 0.81$ $T = -3.58$ $\sigma^2 = 1.05(1.28)$
Fatal Accidents	$\beta_2 = -1.3263$ $exp(\beta_2) = 0.26$ $T = -3.04$ $\sigma^2 = 0.24(0.88)$	$\beta_2 = -1.3807$ $exp(\beta_2) = 0.25$ $T = -4.50$ $\sigma^2 = 0.25(0.98)$

Note: σ^2 = Mean Deviance (Mean Pearson Residual Sum of Squares)

Both Models 1 and 2 give consistent results for Fatal Accidents, with an estimated 75% decrease. Model 1 predicted no increase or decrease and Model 2 predicted a 19% reduction.

Model 2 relies on the functional form of the accident risk being correct. The model assumptions for Model 1 are not as stringent. This is possibly why Model 1 gives a slightly better fit, as indicated by the mean deviance, σ^2 (with the Pearson residual variance in brackets), in Table 9.1. If the accident counts are Poisson, then these values should be approximately one.

Model 2 provides other interesting results. Because $\rho<0$, the accident rate (accidents/vehicle km/lane) appears to decrease with increasing median width by a factor of $(W_i+1)^\rho$. Similarly, the accident rate (i.e. accidents/vehicle km/lane) seems to increase with increasing number of lanes by a factor of N_i^ψ. The parameter estimates for ρ and ψ are fairly consistent for all accident severities, being approximately $\rho = -0.5$ and $\psi=1.5$.

There also appear to be differences in accident rates (i.e. accidents/vehicle km/lane) between different motorways, and these estimates are fairly consistent for all accident severities. It also shows that the Auckland motorway system appears to have a greater number of accidents/vehicle km/lane than the Wellington motorway system.

8. BENEFIT/COST EVALUATION OF MOTORWAY MEDIAN BARRIER PROGRAMME

Benefit/cost evaluations for the programme for median barrier installation that was implemented between 1987 and 1990 have been calculated, and are described in this Section 8 of the report.

8.1 Costs of Median Barriers

Transit New Zealand provided details on the sections of motorway median barriers installed between 1986 and 1990. From the data supplied the lengths of barrier installed have been estimated, together with their costs (in April 1990 NZ$). The aggregated estimates of barrier length and cost are shown in Table 8.1.

Table 8.1 Costs (1990 NZ$) of installing motorway median barriers over the period 1985 to 1990.

Motorway	Length (km)	Cost (NZ$ 000)
Auckland *	37.1	10,728
Wellington	19.6	4,580
Total	56.7	15,308

* Does not include Auckland Harbour Bridge.

Transit New Zealand also provided estimates of annual maintenance costs associated with motorway median barriers. From these values and an estimate of the annual maintenance of IBC barriers, the annual estimate listed in Table 8.2 was produced.

Table 8.2 Estimate of annual costs (1990 NZ$) of maintaining median barriers.

Barrier Type	Length (km)	Cost $/km	Total Annual Cost
Guardrail	21.7	$3,450	$75,000
Concrete	18.9	$50	$1,000
Wire Rope	8.0	$1,250	$10,000
IBC	8.1	$6,200	$50,000
Total	**56.7**	–	**$136,000**

8.2 Values of Accident Savings

A significant change in the patterns of reported injury accidents has occurred following the installation of motorway median barriers (see Section 5 in this report).

To ascertain the benefits accruing from these changes, two separate approaches have been adopted. One uses estimates of the total accidents on motorways before and after median barriers were installed, and the other uses the linear regression parameter estimates obtained in Section 7.2 of this report.

In addition, two accident values have been used: the TR9 (Bone 1986) accident cost valuations updated to April 1990 NZ$; and the accident costs proposed in the PEM 1991 (TNZ 1991).

8.2.1 Values Based on Changes in Accident Numbers

This assessment of values looks at the change in accident numbers between 1985-86 and 1990 on sections of motorway where barriers were installed at some time, and on sections where barriers were never installed. Table 8.3 shows these annual accident numbers. As most median barriers were installed between 1987-1989, the before years for accident numbers are taken as 1985-86, and the after year as 1990.

Table 8.3 Annual accident numbers for the 'before' years 1985-1986 on motorways without median barriers, and for the 'after' year 1990 on motorways with median barriers.

Years	Never Any Barrier	Barrier Installed
1985-86 (before)	300	75
1990 (after)	100	305

Thus for this exercise, it is assumed that accidents on the 56.7 km of the motorway, where median barriers were installed in the 1987-89 period, accidents increased from 75 per year to 305 per year.

It is assumed that the 75 accidents per year before barriers were installed followed the patterns of accident types for the years 1985-1990 of all sections of motorway which did not have barriers installed. The percentages of accidents by severity and movement are given in Table 8.4. For example, the percentages of fatal accidents have reduced from around 7% before median barriers were installed, to around 2.5% after they were installed.

In a similar way the 305 accidents per year after barriers were installed follow the overall patterns of accident types on motorways where median barriers were always installed, as also shown in Table 8.4.

Table 8.4 Types of reported injury accidents (% of all accidents) on sections of motorway between 1985-1990.

Accident Severity	Accident Movement Type											
	A		B		C & D		F		Other		Total	
	No Barrier	Barrier	No Barrier	Barrier	No Barrier	Barrier	No Barrier	Barrier	No Barrier	Barrier	No Barrier	Barrier
Fatal	0.5	0.3	2.3	0.2	2.7	1.1	0.5	0.3	1.3	0.8	7.3	2.7
Serious	2.6	3.6	2.8	0.8	8.0	6.0	3.1	3.7	4.7	2.5	21.2	16.6
Minor	8.1	14.6	2.1	1.2	27.5	26.3	26.4	32.0	7.8	6.3	71.9	80.4
Total %	**11.2**	**18.5**	**7.2**	**2.2**	**38.2**	**33.4**	**30.0**	**36.0**	**13.8**	**9.6**	**100**	**100**

Accident costs for each movement type and severity can now be estimated from TR9 1986 data and PEM 1991. The relevant values are those given in Table 8.5. As suggested in those documents, reporting rates of 1, 1.9 and 4.0 have been used for fatal, serious injury and minor injury accidents respectively to assess the total number of accidents occurring in each case.

Table 8.5 Estimated accident costs (NZ$ 000) per reported accident using TR9 (1986) data updated to 1990 and PEM 1991 data.

Accident Severity	Accident Movement Type									
	A		B		C & D		F		Other	
	TR9	PEM	TR9	PEM	TR9	PEM	TR9	PEM	TR9	PEM
Fatal	264	2326	373	2950	273	2326	264	2451	264	2200
Serious	83	159	100	237	74	183	83	166	86	165
Minor	66	38	60	87	36	61	66	63	60	38

TR9 - Bone 1986, TR9 updated to 1990
PEM - TNZ PEM 1991

By combining the contents of Tables 8.4 and 8.5, an estimate of the average cost per reported injury accident can be made before and after the installation of median barriers. These costs are given in Table 8.6.

Table 8.6. Average cost (1990 NZ$ 000) per reported injury accident on motorways with and without median barriers.

Median Barriers	TR9* (NZ$ 000)	PEM 1991 (NZ$ 000)
Without	78.5	262.7
With	66.0	137.5

* Factor of 1.51 used to update to April 1990 NZ$

From these estimates the annual accident savings can now be estimated, and they are given in Table 8.7.

Table 8.7 Annual accident cost savings (1990 NZ$) obtained from average costs of reported injury accidents on motorways with and without median barriers.

Median Barrier	**Reported Injury Accidents Per Year**	**Total Costs (NZ$ 000)**	
		TR9	**PEM 1991**
Without	200	15,700	52,540
With	230	15,180	31,625
Savings	-30	+520	+20,915

TR9 - Bone 1986, updated to 1990
PEM - TNZ PEM 1991

8.2.2 Values Based on Regression Model

The regression equations of Section 7.2 provided estimates of accident rate by severity on motorways with and without median barriers. In particular the coefficient of the median barrier term can be used to estimate the reduction in different classes of accidents following the installation of median barriers. The estimates of accident cost have been estimated as before, based on the distribution of accident types without median barriers installed. The annual expected accident savings over the 56.7 kilometres of motorway where median barriers were installed between 1985 and 1990 are given in Table 8.8.

Table 8.8 Estimated accident savings using regression coefficients (1990 NZ$ 000).

Accident Severity	**Median Barrier Length (km)**	**Coefficient**	**Cost Per Accident (NZ$ 000 1990)**		**Change In Accident Costs (NZ$ 000)**	
			TR9	**PEM 1991**	**TR9**	**PEM 1991**
Fatal	56.7	- 0.25	302	2,506	- 4,281	- 35,523
Serious Injury	56.7	- 0.07	83	181	- 329	- 718
Minor	56.7	+ 2.42	54	57	+ 6,780	+ 7,821
Total					**+ 2,170**	**-28,420**

8.3 Benefit/Cost Ratio Calculations

Over a 25-year period the benefit/cost ratio of the 1985 to 1990 motorway median barrier installations can be estimated. The results are given in Table 8.9.

Table 8.9 Benefit/cost ratio calculation of the median barrier installations of 1985-1990 (benefit/cost ratios in 1990 NZ$ 000).

Accident Value	**Costs**			**NPV* Benefits**		**Benefit/Cost Ratio**	
	Installation	Maintenance	NPV 25 Years	Proportions	Regression	Proportions	Regression
TR9	15,308	136	16,608	4,971	-20,475	0.3	**
PEM	15,308	136	16,608	199,947	271,695	12.0	16.4

TR9 - Bone 1986, TR9 updated to 1990
PEM - TNZ PEM 1991
* NPV - Net Present Value
** no net benefits

It is clear that, with the TR9's low valuation of life, the apparent increase in accidents of lesser severity offsets the significant reduction in fatal accidents. This leads to benefit/cost ratios which are considerably less than 1. However using PEM 1991 values, the benefit/cost ratios become very respectable and of a similar order if both methods of estimation are used.

Thus, depending on the accident cost data used (i.e. TR9 or PEM 1991), the installation of motorway median barriers has been either a failure or highly successful from an economic viewpoint.

8.4 Evaluation of Existing Median Barrier Installation Warrants

The median barrier installation warrant used by Transit New Zealand made allowance for both traffic volume and median width to be used in determining whether median barriers should be installed. The regression model applied in this study confirmed that accident rate decreases with decreasing volume and increasing median width. However the form of regression model used in this analysis, i.e. an additive model, separates out the effect of median barriers from the effect of median width and traffic volume.

Thus any change in the magnitude of benefit of median barrier installation with increasing traffic volume or decreasing median width cannot be identified from the log-odds or regression models. However such effects were quantified by the multiplicative model, where the accident rate was related to the product of the traffic volume, median width and with a coefficient identifying whether or not a barrier is in place (see Section 7.3.2 of this report). Using such a model it will be possible to comment on the validity of the existing median barrier installation warrant in cost-efficiency terms, and perhaps even improve the warrant.

Unfortunately such an improved installation warrant, developed on the basis of accident experience at sites where median barriers had been installed by 1990, might not be applicable to future installation proposals. Experience cannot be compared because the accident types associated with motorway sections lacking median barriers in 1990 are different from those generally associated with sections of motorways without median barriers before 1985 (but having median barriers installed between 1985-1990). This comparison is shown in Table 8.10.

Table 8.10 Accident patterns (% accidents) on motorways without median barriers in 1990 and on motorways without median barriers before 1985 (but installed between 1985-1990).

Accident Severity	**Accident Movement Type**											
	A		**B**		**C & D**		**F**		**Other**		**Total**	
	No Barrier	Barrier 1990	No Barrier	Barrier 1990	No Barrier	Barrier 1990	No Barrier	Barrier 1990	No Barrier	Barrier 1990	No Barrier	Barrier 1990
Fatal	0.2	0.5	0.7	2.3	4.8	2.7	0.5	0.5	1.0	1.3	7.1	7.3
Serious	2.1	2.6	1.4	2.8	11.6	8.0	1.7	3.1	5.5	4.7	22.3	21.2
Minor	5.5	8.1	1.2	2.1	37.5	27.5	16.6	26.4	9.7	7.8	70.5	71.9
Total	**7.8**	**11.2**	**3.3**	**7.2**	**53.9**	**38.2**	**18.8**	**30.0**	**16.2**	**13.8**	**100**	**100**

This comparison suggests that the results of installing median barriers on these sections where they are still lacking would be somewhat different to the results of installing median barriers between 1985-1990.

For this reason it would not be appropriate to develop a New Zealand barrier installation warrant that is based on past experience. Rather it would be more appropriate to judge each new barrier proposal on its own merits.

9. CONCLUSIONS

The analysis of the effects of median barriers on accidents has been made difficult by a number of factors, such as:

- Median barriers have reduced the number of only one small subset of accidents (i.e. fatal and serious accidents). From this small subset, actual numbers of affected accidents were small.

- Median barriers were progressively installed over a number of years, making a simple log-odds model difficult to apply. In this situation regression-type models (both additive and multiplicative) are more appropriate.

- The change in accident reporting rate between 1984 and 1985 fundamentally changed the nature of the accident database making the use of combined before and after 1985 data unwise.

- Ministry of Transport coding, before 1985, did not allow cross-median accidents to be specifically identified by accident movement type. Thus it is impossible to isolate cross-median accidents without actually looking at copies of individual TARs (an extremely time-consuming task).

Recognising these problems, conclusions on the effect of the installation of 56.7 km of median barriers on the motorway system between 1985 and 1990 are as follows.

- Median barriers have significantly reduced the percentage of reported injury accidents resulting in a fatality, from around 7% to 2.5%. This translates to an annual saving in fatal accidents of between 10 and 15 per year on the 56.7 km of motorway where median barriers had been installed between 1985 and 1990.

- Median barriers seem to have reduced serious injury accidents from around 21% of all reported accidents to around 17%. The installation of the motorway median barriers has been estimated to have saved between 4 and 8 serious injury accidents per year.

- Median barriers seem to have increased the incidence of minor injury accidents for all accident movement types. This increase has been estimated at between 30 and 137 accidents per year on the 56.7 km of motorway where median barriers were installed between 1985 and 1990.

- Because median barriers have reduced only the numbers of fatal and serious accidents, the benefit/cost estimates vary widely according to whether the TR9 or PEM 1991 accident costs are used. Given the previous low value of life used in TR9, the benefit/cost ratio was less than 1, but with the updated value of a life and the corresponding accident costs in PEM 1991, the benefit/cost ratio of the 1985 to 1990 median installations has been estimated to be between 12 and 16.

- Low numbers of accident types (i.e. fatal) affected by the installation of median barriers, and the lack of information on the distribution of cross-median accidents by accident movement type, has made an evaluation of the differences between individual median barrier types impractical. Any such future study should wait until additional after-data are available and should entail the examination of individual TARs and the use of non-injury data.

- The accident patterns of motorway sections without barriers in 1990 is quite different from the patterns observed on sections where barriers were lacking in 1985 but then had barriers installed between 1985-1990. For this reason extreme caution must be taken if attempting to extrapolate earlier accident experience to cases after 1990. In view of this, future proposals for installing median barriers each need to be considered on their own merits.

10. REFERENCES

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APPENDICES

APPENDIX 1
OCCURRENCE OF UNEXPECTED ACCIDENT TYPES

Because of the limited access and uninterrupted flow nature of a divided motorway, certain accidents should not occur. These include type N (pedestrian), type L (right turn against), type M (manoeuvring), type B (head-on), and type H (crossing) accidents.

The accident database revealed that a number of these accidents had nevertheless occurred on divided motorways where medians had been installed according to the records. Between 1975 and 1990, 63 accidents were recorded in these categories. The TARs for a number of these accidents were studied to determine why and how these accidents occurred.

Twelve head on, four pedestrian, and one manoeuvring accidents were investigated. TARs of seven of the head-on accidents described the vehicles crossing the median strip, which indicates that no barrier could have been in place suggesting an error in coded location. Of the remaining five head-on accidents investigated, two involved vehicles crossing the median barrier, two involved vehicles in the same lane, and one involved only the wheel of a vehicle crossing the median barrier.

The four pedestrian accidents involved pedestrians who had attempted to cross the motorway in various stages of intoxication. Presumably they had attempted to climb over the median barrier.

The manoeuvring accident involved an intoxicated driver attempting a u-turn on the motorway despite the presence of a barrier. This could also be an error in coded location. From these investigations, it can be assumed that most of the "unexpected" accidents were coded incorrectly, with a small number occurring despite the presence of barriers.

APPENDIX 2
SECTIONS OF MOTORWAY CONSIDERED FOR ANALYSIS

Identification Number	Region	Motorway	Location	State Highway	Route Station	Start Postion
1	Wellington	Hutt	Petone - Ngauranga	2	962	12.0
2	Wellington	Hutt	Ngauranga - Aotea	2	979	0.0
3	Wellington	Hutt	Aotea - Hobson	2	981	0.0
4	Wellington	Hutt	Hobson - Aurora	2	981	1.0
5	Wellington	Hutt	Aurora - Boulcott	2	981	2.3
6	Wellington	Porirua	Ramp - Mungavin	1	969	3.8
7	Wellington	Porirua	Mungavin - Tawa	1	969	4.4
8	Wellington	Porirua	Tawa - Jville Nth	1	979	0.0
9	Wellington	Porirua	Jville Bypass	1	979	4.3
10	Wellington	Porirua	Jville Sth - Newlands	1	979	5.4
11	Wellington	Porirua	Newlands - Ngauranga	1	979	5.7
12	Wellington	Porirua	Ngauranga Bench	1	979	7.3
13	Wellington	Wgtn Urban	Ngauranga - Aotea	1	987	0.0
14	Auckland	Northern	Grenville - Sunset	1	312	5.6
15	Auckland	Northern	Sunset - Tristram	1	312	7.8
16	Auckland	Northern	Esmonde Rd Underpass	1	326	1.2
17	Auckland	Northern	Esmonde - Onewa	1	326	1.9
18	Auckland	Northern	Onewa - Akl Harbour Br	1	326	4.1
19	Auckland	Northern	Akl Harbour Br	1	326	4.4
20	Auckland	Northern	Akl Harbour Br - Fanshawe	1	326	6.0
21	Auckland	Northern	Victoria Park Viaduct	1	326	7.3
22	Auckland	Northern	Victoria Park - Hobson St	1	326	8.0
23	Auckland	Southern	Hobson St - Grafton Rd	1	335	0.0
24	Auckland	Southern	Grafton - Khyber Pass	1	335	1.4
25	Auckland	Southern	Khyber Pass Viaduct	1	335	1.7
26	Auckland	Southern	Mountain - Gilles Ave	1	335	2.1

Identification Number	Finish Position	Route Length	Barrier Type	Installation Month	Installation Year	Median Width	Traffic Volume	Number of Lanes
1	17.0	5.0	B	12	1982	2.4	59,400	4
2	2.0	2.0	I	7	1988	3.0	.	6
3	1.0	1.0	W	3	1989	4.0	71,500	6
4	2.3	1.3	N	12	1978	2.0	47,600	6
5	2.9	0.6	N	11	1989	1.0	35,600	3
6	4.4	0.6	N	9	1989	0.0	57,200	4
7	10.0	5.6	B	2	1990	5.8	57,000	4
8	4.3	4.3	B	4	1989	2.7	36,000	4
9	5.4	1.1	N	0	1900	.	.	4
10	5.7	0.3	G	12	1988	1.7	.	4
11	7.3	1.6	W	11	1988	1.4	.	6
12	8.0	0.7	B	12	1987	.	.	4
13	2.0	2.0	I	7	1988	3.5	.	6
14	7.8	2.2	T	3	1991	0.0	25,000	2
15	10.6	2.8	R	4	1988	0.0	43,000	4
16	1.9	0.7	G	0	1900	6.0	60,000	6
17	4.1	2.2	N	7	1988	6.0	95,000	7
18	4.4	0.3	N	7	1988	6.0	114,000	8
19	6.0	1.6	N	11	1990	0.0	114,000	8
20	7.3	1.3	G	0	1900	5.8	100,300	8
21	8.0	0.7	K	0	1900	1.2	61,000	4
22	9.0	1.0	N	0	1900	4.3	52,900	4
23	1.4	1.4	G	0	1900	9.9	97,500	6
24	1.7	0.3	G	0	1900	6.9	130,000	7
25	2.1	0.4	N	7	1989	4.4	130,000	7
26	2.5	0.4	N	9	1986	2.8	119,000	6

Installation Year = 1999 indicates that no barriers were in place during the study period
Installation Year = 1900 indicates that barriers were in place for the whole study period

APPENDIX 2 (continued)

Identification Number	Region	Motorway	Location	State Highway	Route Station	Start Postion
27	Auckland	Southern	Newmarket Viaduct	1	335	2.5
28	Auckland	Southern	Newmarket - Greenlane	1	338	0.0
29	Auckland	Southern	Greenlane - Tecoma	1	338	2.5
30	Auckland	Southern	Tecoma - Ellerslie	1	338	3.2
31	Auckland	Southern	Ellerslie - Mt Wellington	1	338	4.4
32	Auckland	Southern	Mt Wellington Interchange	1	338	7.1
33	Auckland	Southern	Mt Wgtn Inter - Panama	1	338	7.9
34	Auckland	Southern	Panama - Trenwith	1	338	8.7
35	Auckland	Southern	Trenwith - Tamiki Br	1	338	10.4
36	Auckland	Southern	Tamiki - Bairds Rd	1	338	11.1
37	Auckland	Southern	Bairds - Papatoetoe	1	338	12.2
38	Auckland	Southern	Papatoetoe - Wiri	1	338	13.3
39	Auckland	Southern	Wiri - Hill Rd	1	355	0.0
40	Auckland	Southern	Hill Rd - Takanini	1	355	3.1
41	Auckland	Southern	Takanini Interchange	1	355	4.7
42	Auckland	North-Western	Hobson St - Newton Rd	16	0	0.0
43	Auckland	North-Western	Newton Rd - Bond St	16	0	1.2
44	Auckland	North-Western	Bond St - Western Springs	16	0	2.5
45	Auckland	North-Western	Western Sp - Carrington	16	0	3.7
46	Auckland	North-Western	Carrington - Waterview	16	0	5.2
47	Auckland	North-Western	Waterview - Rosebank	16	0	6.0
48	Auckland	North-Western	Rosebank - Patiki	16	7	0.0
49	Auckland	North-Western	Patiki - Whau	16	7	2.6
50	Auckland	North-Western	Whau - Te Atatu	16	7	3.7

Identification Number	Finish Position	Route Length	Barrier Type	Installation Month	Installation Year	Median Width	Traffic Volume	Number of Lanes
27	3.0	0.5	C	11	1988	2.8	119,000	6
28	2.5	2.5	N	0	1900	4.0	126,000	6
29	3.2	0.7	G	7	1988	3.6	114,300	6
30	4.4	1.2	G	0	1900	1.8	110,900	6
31	7.1	2.7	N	12	1975	3.6	91,300	6
32	7.9	0.8	N	3	1989	3.0	60,100	6
33	8.7	0.8	N	3	1984	3.0	79,100	4
34	10.4	1.7	N	3	1987	3.0	79,100	4
35	11.1	0.7	N	2	1989	3.0	79,100	4
36	12.2	1.1	N	10	1988	3.0	79,100	4
37	13.3	1.1	N	6	1987	3.0	79,100	4
38	17.0	3.7	T	6	1989	3.0	69,100	4
39	3.1	3.1	G	11	1989	6.4	58,200	4
40	4.7	1.6	G	3	1990	6.4	46,900	4
41	6.5	1.8	G	3	1990	3.7	31,800	4
42	1.2	1.2	N	0	1900	1.2	24,300	4
43	2.5	1.3	G	12	1987	9.9	74,000	4
44	3.7	1.2	N	11	1990	9.9	74,000	4
45	5.2	1.5	N	1	1989	2.0	67,700	4
46	6.0	0.8	G	0	1900	4.0	67,700	4
47	7.0	1.0	N	9	1989	4.0	59,000	4
48	2.6	2.6	G	3	1987	3.0	59,000	4
49	3.7	1.1	N	3	1991	3.0	60,800	4
50	4.2	0.5	G	2	1989	3.0	60,800	4

Installation Year = 1999 indicates that no barriers were in place during the study period
Installation Year = 1900 indicates that barriers were in place for the whole study period