Safety Implications of Flush Medians in Auckland City, New Zealand

Transfund New Zealand Research Report No. 233

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Transfund New Zealand Research Report No. 233

ISBN 0-478-25092-4
ISSN 1174-0574

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Segedin, T.[1], Jurisich, I.[1], Smith, M.[2], Dunn, R.[2] 2002. Safety implications of flush medians in Auckland City, New Zealand. *Transfund New Zealand Research Report No. 233.* 118 pp.

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Keywords: accidents, analysis, Auckland, before & after, crashes, flush medians, medians, New Zealand, pedestrian islands, roads, safety, traffic

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Abbreviations & Acronyms

ADT	Annual Daily Traffic
ASD	Approach Stopping Distance
AUSTROADS	National Association of Road & Traffic Authorities in Australia
B/C	Benefit / Cost Ratio
BIC	Bayesian Information Criterion
CAS	Crash Analysis System
CSD	Crossing Sight Distance
GIS	Geographical Information System
GLM	Generalised Linear Modelling
ITE	Institute of Transportation Engineers
LTSA	Land Transport Safety Authority
NAASRA	National Association of Road Transport & Traffic Authorities in Australia
rrpm	raised reflectorised pavement marker
RTM	Regression to Mean
SCATS	Sydney Co-ordinated Adaptive Traffic System
TCR	Traffic Crash Report
TWLTL	Two-Way Left-Turn Lane

Acknowledgments

Significant assistance in undertaking the research was provided by the following people. David Croft, Safety Engineer at the Land Transport Safety Authority (LTSA), provided the required crash data. His guidance was also invaluable in analysis of historical crash trends in Auckland City. The project peer review was completed by Anatole Sergejew, Adviser for Infrastructure Services, Ministry of Transport, who is a traffic safety expert. Additional help was also provided by Jocelyn Carr and Fraser Harvey with data collection and analysis of crashes.

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Executive Summary

Introduction

This report details research into the safety implications of flush medians in Auckland City, New Zealand, carried out between September 2001 and June 2002. Guidance is given to ensure that flush medians are used where they are most likely to produce safety benefits.

Crash Analysis Methodology

To investigate safety of flush medians, an observational 'before' and 'after' study was undertaken. This type of study was chosen because preliminary research had identified it as the best analysis method for assessment of traffic safety devices. As this research also found that no one statistical method for this type of analysis has been dominant, two separate methods of analysis were used. The first method used a basic 'traditional' analysis comparison or control group as a 'before' and 'after' study. 'After' crashes at sites were compared to 'before' crashes where time-trend variations were accounted for by using such a comparison or control group. The second analysis method was undertaken through Generalised Linear Modelling (GLM) of crash rates. Here the effect of implementing flush medians was calculated by comparing proportions of crashes occurring in 'before' and 'after' periods at treatment and control sites. Both methodologies analysed data broken up into the four crash severity classifications.

Data Collection

The raw data was obtained from a crash database (as reported to Police) of Auckland City flush median sections. This had been formed by the LTSA in 1998. Crash data were taken from 50 sites for five-year 'before' and 'after' periods where implementation dates for these sites had occurred between 1988 and 1994.

Crash Analysis Findings

Overall, the 50 flush medians have achieved good savings in crash costs. Both methods of analysis resulted in high crash cost savings of NZ$35 million and a benefit/cost ratio of 30 for the 50 sites.

When the analyses were based on frequency instead of costs, flush medians resulted in only an overall decrease of 2% in crash numbers, implying that flush medians provide few safety benefits. The recommendation therefore is that severity analysis of crashes to assess cost savings should be analysed in any future 'before' and 'after' studies of traffic safety devices to ensure accurate assessment of their benefits.

Flush medians were found to decrease fatal, serious and non-injury crashes while minor injury crashes had increased at the sites studied. This may be related to the difference in changes between crash types. Rear-end crashes at queues, which are typically less serious crashes, increased dramatically. However, the more serious 'loss of control' and 'pedestrian' groups of crashes did decrease.

Flush medians have greatly reduced fatal crashes in these crash types. Eighteen of the total 24 fatal crashes in the 'before' implementation period were in these groups while only six resulted in the 'after' period.

Rear-end crashes involving right-turning vehicles also achieved large cost savings. Right-turning crashes, on the other hand, were generally observed to increase. The increases observed in turning crashes could be addressed through investigation into improving visibility at problem locations and possible installation of high-friction grip surfacing.

Investigation was also made into effects of flush medians on different time periods. Higher crash cost savings were achieved with night-time crashes compared to those during the day. The peak and off-peak analyses showed a slight increase in crash cost for peak periods, while the off-peak periods produced large savings.

Flush median width was analysed by dividing the database into flush medians with widths greater than, and less than, two metres. Both groups gained positive B/C ratios, though flush medians less than two metres wide achieved double the B/C ratio of the wider medians. This highlights the benefit of installing narrower medians where the available carriageway width restricts the preferred wider flush medians. Further work should be undertaken to identify the optimum flush median width for traffic safety.

Overall, similar results were produced by the two analysis methods. However, the GLM (Generalised Linear Modelling) analysis method using Poisson modelling of crash rates provided the more accurate method of assessment. It also allowed for statistical inference to be made regarding the findings. Therefore the recommendation is that a review be undertaken in order to assess the most appropriate methodology for 'before' and 'after' study analysis in New Zealand. Further development of this GLM method should be undertaken and an observational 'before' and 'after' study guideline should be developed.

Regression Analysis

Regression analysis was also undertaken using crash data from the 50 investigation sites to form crash-prediction models. Flush median implementation, densities of access points and intersections, section lengths and traffic flows were used as explanatory variables. The resulting models showed promising results, but produced some difficulties, and therefore the recommendation is that further research work is required in this area.

Pedestrian Refuge Islands

As part of the study, crashes relating to all current pedestrian refuge islands on flush medians were also investigated in Auckland City. Pedestrian refuge islands have been found to cause both vehicle- and pedestrian-related crashes. To address these, efforts should be made to educate both drivers and pedestrians on the function of pedestrian refuge islands.

Design of the islands should also be improved, and raised reflectorised pavement markers (rrpms) be installed on approaches to the islands.

It is also recommended that the design guide be developed further to aid in placement of pedestrian refuge islands on flush medians to improve safety.

Recommendations for Use of Flush Medians

The final recommendation is that use of flush medians should be continued in New Zealand as a traffic improvement facility to reduce crashes. However, crash analysis should be undertaken at potential sites before flush medians are implemented, in order to properly assess any possible benefits that may be gained and to maximise crash savings. This is important as a number of sites with flush medians in Auckland City have experienced crash increases. The preliminary guidelines included in the appendices should be used as an aid in this process. The individual recommendations follow.

- This study should be distributed to all controlling authorities as improved crash savings are most likely to result from the guidance given in this report.

- Flush medians should continue to be used in New Zealand as a traffic control device to improve safety and operational efficiency. However, assessment of crash types should be used to analyse the potential benefits of flush median implementation at potential sites.

  The findings of this study should be used to identify the likely savings and increases in crashes by crash type. In anticipation of likely increases in certain types of crashes, investigation should be made into possible problem locations, and to implement the counter measures suggested in this report.

- Efforts should be made to educate both drivers and pedestrians on the function of pedestrian refuge islands. These efforts should be focused on school children. Design of the islands should also be improved to increase sight lines for drivers and pedestrians. Raised reflectorised pavement markers should be installed on approaches to pedestrian refuge islands to increase driver awareness through their visual and physical impact.

- Designers of flush medians should use the 'Preliminary Guidelines for Safer Flush Medians' supplied with the report as Appendix F, as this could result in substantial crash savings. It is also recommended that these guidelines should be developed further.

- Severity analysis of crashes should be analysed in any future 'before' and 'after' studies of traffic safety devices.

- A review should be undertaken to assess the most appropriate methodology for 'before' and 'after' study analysis in New Zealand. Further development of the Generalised Linear Modelling method described in this report should be undertaken and an observational 'before' and 'after' study guideline be developed. This will enable economic evaluation of devices through benefit/cost analysis.

- Further analysis should be undertaken to identify improved models for crash prediction of flush medians.

Abstract

Between September 2001 and June 2002, research was carried out to determine the safety implications of flush medians at 50 sites in Auckland City, New Zealand. 'Before' and 'after' crash data were analysed using both traditional methodology and Generalised Linear Modelling (GLM). Results showed that large crash-cost savings have been achieved by implementing flush medians despite small overall savings in accident frequency. Flush medians decreased fatal, serious and non-injury crashes while increasing minor injury crashes at the study sites. Crash types were affected differently by flush medians, with major savings seen in turning versus same direction, 'pedestrian' and 'loss of control' crashes, and large increases seen in some rear end crashes and the turning crashes.

Crash reductions were observed to be greatest during night-time periods, with increases in crash costs observed in peak periods. Both narrow and wide medians produced crash savings, which highlights the benefit of installing narrow medians where carriageway width restrictions apply. Regression analysis of the crash data has been used to form preliminary prediction models for sections of road where flush medians are to be implemented. Preliminary guidelines have been developed to ensure flush medians result in crash savings, as half the sites in Auckland City have experienced crash increases. Remedial measures have been included to address crashes at pedestrian refuge islands on flush medians.

1. Introduction

1.1 Project Brief

The research brief for this project, carried out between September 2001 and June 2002, was:

- To assess the safety implications of the introduction of flush medians in Auckland City, New Zealand; and
- To provide guidance that will ensure crash savings for all future sites where flush medians are implemented.

The research falls within Transfund New Zealand's key topic area of safety: "to reduce road crashes and related social costs through improvements to the road environment/ architecture" by:

- Identifying factors related to the safety performance of flush medians;
- Identifying how specific crash severity classes and types have been affected through implementing flush medians; and
- Improving the allocation of funds to flush median projects, through accurate benefit/cost analysis.

The project comprised three phases:

1. Preliminary crash analysis and formation of crash database, completed 1st October 2001;
2. Crash analysis, completed 15th March 2002;
3. Reporting on findings, completed 30th June 2002.

1.2 Historical Overview

Flush medians have been introduced extensively in Auckland City and throughout the rest of New Zealand over the last 10 years. This widespread implementation followed their perceived successful introduction in Australia in the early 1990s. However, no crash statistics were available at the times of implementation to support any claims regarding safety improvements.

Flush medians were not introduced in Auckland City specifically as a treatment for problem crash sites, but rather they were installed at sites where it was believed operational and safety improvements would result. These flush medians therefore were not the result of black spot, crash route, or other detailed studies into crash history or capacity.

The first national study on the safety of flush medians was undertaken by the Land Transport Safety Authority in 1995 (LTSA 1995). The flush medians in the LTSA database were all installed as a result of crash studies where they had been recommended as a remedial measure. This LTSA study suggested that injury crash savings of 19% could be obtained through implementation of flush medians on undivided roadway sections. Based on this, therefore, the use of flush medians was further encouraged in Auckland City.

In 1998 however, *CITY* DESIGN produced a report showing much lower crash savings for the 54 Auckland City sites where flush medians had been implemented (Jurisich 1998). Injury crash savings of only 1% were found to have been achieved, with up to 50% of sites having crash increases. This was the first significant study on the safety of flush medians for Auckland. The difference observed in the two studies may be explained by the method by which flush medians were introduced in Auckland City. Sites in Auckland City were chosen without detailed crash analysis, whereas the LTSA sites were problem crash routes where flush medians had been suggested as part of the remedial measures to be implemented.

Significant national and international interest was generated by the findings of the *CITY* DESIGN report (Jurisich 1998), with various local authorities seeking quantified information regarding crash statistics. This investigation follows on from where the Jurisich study (1998) finished, and addresses a number of questions that it raised.

1.3 Investigation Approach

To investigate flush median safety, this project used an observational 'before' and 'after' study of the vehicle and pedestrian crashes. The crash data was obtained from the LTSA Crash Analysis System (CAS) and transferred to a Microsoft Excel spreadsheet for analysis. The historical data for the 54 flush median sites previously studied by *CITY* DESIGN (Jurisich 1998) were collected and grouped into periods of 'before' and 'after' flush median implementation. The raw crash data was then 'cleaned' of anomalies such as: sites where road marking had changed, and crashes where patterns had developed for reasons other than flush median implementation. This left 50 sites at which 1560 injury and 3199 non-injury crashes had occurred.

Two methods of crash analysis were undertaken. The first used historical crash trends to convert crash counts from the period 'before' implementation into estimated crash counts for the 'after' implementation period.

This estimate of crashes that would have occurred had no flush median been installed, was then compared to the actual counts. A second method used Generalised Linear Modelling (GLM) of crashes where sites were grouped according to implementation date and compared to a historical control. Differences in trend from 'before' to 'after' provided estimates of the safety effects.

The analysis of crashes was broken up into six categories:

1. Assessment of the impact that the implementation of flush medians has had on crash severity;
2. Assessment of the impact that the implementation of flush medians has had on night-time, daytime, peak and off-peak crashes;
3. Assessment of the impact that the width of flush medians has had on safety;
4. Identification of the types of major crash changes;
5. Investigation of the effects of implementation of pedestrian refuge islands on flush median safety; and
6. Investigation of crashes in relation to traffic flows at flush median sites.

1.4 Limitations of Analysis

Several difficulties arose in the statistical assessment of the crash data. The most significant involved the formation of a crash control. The choice of control has a significant impact on crash reductions observed, therefore careful consideration of the regression to mean phenomena, road class selection, and remedial site omission was required. In this undertaking, a balance was required between refinement of control and maintaining significant numbers of crashes.

Hauer (1997) reported that observational 'before' and 'after' studies also have inherent uncertainties involved. Unlike a designed experiment, no control can be exercised in data collection techniques, maintaining an unchanging environment, and treatment application to sites. Therefore careful consideration of influencing factors was required and the associated uncertainty recognised.

1.5 Report Outline

The main body of this report is divided into five sections (chapters 2-6).

Chapter 2 reviews some of the national and international research on the safety impacts of flush medians. It also highlights statistical methods that can be used for evaluating highway safety projects.

Chapter 3 outlines the data collection process undertaken for the formation of the crash database used in the study. Site and period selection are explained, as is the process of cleaning the LTSA crash database. Cost estimate formation for the study sites is also detailed.

Chapter 4 describes the crash analysis undertaken for the investigation into safety impacts at the flush median study sites. Two crash analysis methodologies are described in combination with their respective results. The results of the analysis and their implications are then discussed.

Chapter 5 describes the development of crash prediction models formed for use on sections of road in urban areas.

Chapter 6 investigates the effects of implementing pedestrian refuge islands on flush medians. It also provides recommended minimum design details for two types of pedestrian refuge island designs.

The remaining sections are Chapters 7 and 8 which list the conclusions and recommendations resulting from the study, and Chapter 9 is the list of References.

2. Literature Review

2.1 Flush Medians

2.1.1 Introduction

This section of the report summarises the literature regarding crash analysis at sites where flush medians have been implemented. Both national and international findings on the safety of flush medians were studied. Terminology for physical markings and aspects of the operation of flush medians was found to vary internationally. In New Zealand the LTSA (1999) has described the flush median as follows: "A flush median is located in the centre of the road, and consists of white parallel lines with diagonal lines inside them. It provides a safe place for vehicles that are turning or have turned right".

Figure 2.1 illustrates how flush medians are used in New Zealand to separate conflicting streams of traffic and to assist in right turn manoeuvres. Vehicles may use the flush median when turning right onto another road or access way, or when turning right onto a road marked with a flush median (Smith 1986).

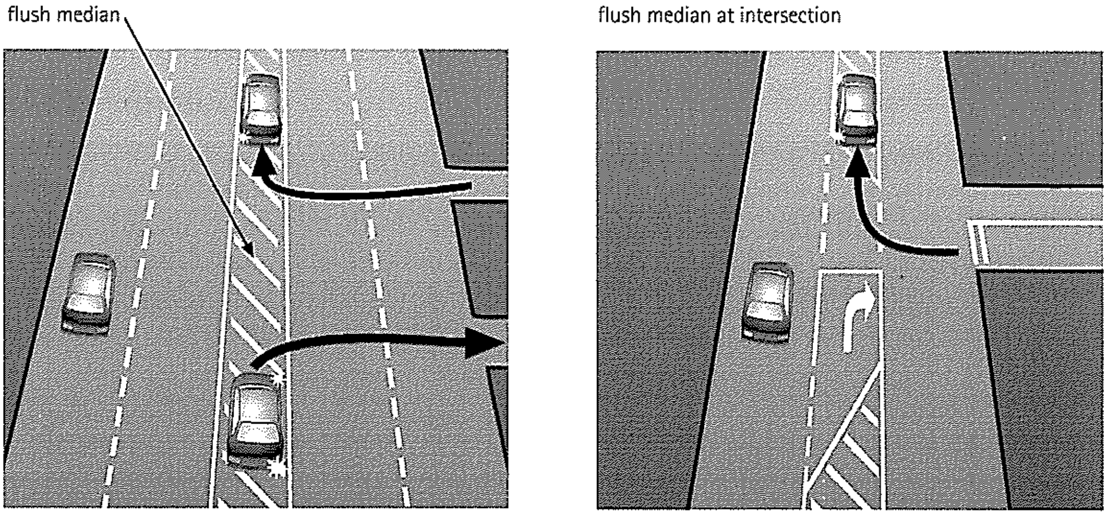


Figure 2.1 Use of flush medians to separate conflicting streams of traffic, and to assist right-turning manoeuvres (LTSA 2002a).

The United Kingdom (UK) refers to the medians as 'ghost islands' and, as shown in Figure 2.2, uses a dashed line instead of a solid edge line with the option of a coloured centre section. As with the New Zealand flush median, UK 'ghost islands' are used to separate traffic flows as an alternative to solid medians, and to assist centre lane turning. The UK ghost island incorporates marked turning bays at side road intersections (Highways Agency 1995).

Figure 2.2 Ghost island, as used in the UK, with dashed edge line to separate traffic flows.

Figure 2.3 Two-way left-turn lane, as used in the US, with two sets of lane-line markings, bordered by two yellow lines.

Figure 2.3 illustrates the US 'Two-Way Left-Turn Lane' (TWLTL) which provides the most significant change in design. It is marked with two sets of lane-line markings, bordered on either side by two yellow lines, of which the inner line is broken or dashed, while the outer line is solid. Pavement marking arrows may or may not be present.

Unlike its New Zealand, Australian and UK counterparts, the TWLTL is signposted on adjacent kerbs at regular spacing (FHWA 2000). The US TWLTL, like the New Zealand flush median, is used for turning movements from all side roads and driveways.

The AUSTROADS *Guide to Traffic Engineering Practice* manual (Part 9) (AUSTROADS 1988a) refers to flush medians and shows similar markings and operational descriptions to those used in New Zealand. However, it also describes the 'two-way centre-turn lane' as an alternative and shows road marking similar to the US TWLTL.

All these different adaptations of the flush median (in New Zealand, Australia, UK, US) serve to separate traffic streams and are used exclusively by centre-turning vehicles. Vehicles are not to use flush medians for passing or travel except when making a centre turn.

The number of published studies undertaken on the safety of flush medians has been very limited. Only two studies have been undertaken in New Zealand, one on a national level (LTSA 1995) and another for Auckland City (Jurisich 1998).

At the outset of this project a telephone survey was undertaken of a number of selected District Councils throughout New Zealand. The results of the survey showed that all the other investigations into flush medians had been observational only, involving a brief investigation of crashes on individual sections of road with no detailed statistical analysis. The District Council engineers surveyed stated that, in all cases of flush median implementation, crashes had been reduced.

Unlike New Zealand, where the flush median has been a relatively new development, the TWLTL has been in use in the US since the 1950s (Walton & Machemehl 1979), and has therefore been investigated more thoroughly. No significant safety studies on flush medians were identified in either Australia or the UK.

All studies identified in this review reported that roadways marked with flush medians or their equivalent have improved safety records when compared to undivided roadways (Brown & Tarko 1999, Bonneson & McCoy 1997, 1998, Jurisich 1998, LTSA 1995, Squires & Parsonson 1989, McCoy et al. 1988a, 1988b, Thakkar 1984, Walton & Machemehl 1979, Hoffman 1974). In a number of studies this increase in safety has been shown to be statistically significant (Stover 1996).

However, the crash reduction studies have shown a wide variation in the percentage of savings achieved. For example, in New Zealand, the Auckland City study revealed only a 1% reduction in injury crashes (Jurisich 1998). This contrasts significantly with the 19% obtained by the LTSA (1995) in their national study of 40 sites. Both studies involved identical analysis methodologies, significant numbers of sites, and the investigation of injury-only crashes. The variability in reduction claims has not been limited to New Zealand, with the US studies reporting a reduction ranging from 22% to 45% of total crashes (Stover 1996, Thakkar 1984).

Variability of claimed crash savings with flush median implementation is a concern. The importance of accurate crash-reduction predictions is essential for economic evaluation analysis (i.e. benefit/cost analysis) and thus allocation of funds for roading improvements. The variability in reduction has possibly been a result of the wide range of study design and analysis methodologies used, and these will be discussed in the following sections.

2.1.2 Analysis of Flush Median Sites

The most common analysis techniques used in the safety studies of flush medians are 'before' and 'after' studies and cross-sectional studies which include regression analysis, comparison and individual case studies, and performance-standard studies (Walton & Machemehl 1979).

The two New Zealand studies, by LTSA (1995) and Jurisich (1998), are the most recent examples of 'before' and 'after' studies of flush median safety. Both these studies involved analysis of injury-only crash data using a comparison group formed from total regional crashes. Study periods were five years before implementation with the partial year before implementation omitted. The study 'after' periods started immediately following implementation, including the partial year of implementation. The 'after' periods for the LTSA study ranged from one to three years while the range for Jurisich's study was two to five years.

'Before' and 'after' analysis studies have also been used to analyse the safety of TWLTLs in the US. These studies involved 'before' and 'after' observations using short time periods with no comparison or control group. For example, Hoffman (1974) used one year 'before' and 'after' implementation, while Thakkar (1984) and Welch (1999) used data from two years 'before' and 'after' implementation.

A more recent study of American TWLTLs was undertaken by Bonneson & McCoy (1998). This involved the formation of a safety model represented by a regression equation. This model was then calibrated using 6391 crashes from 189 street segments over a three-year period, before being used to determine the safety of flush medians. Others have also undertaken regression analysis when investigating crashes on TWLTLs, such as Squires & Parsonson (1989) and Walton & Machemehl (1979) who used different statistical packages to first determine significant variables and then to fit regression equations.

Another methodology used is to compare crash rates from sections of road with similar characteristics, with and without flush medians. This method was used by McCoy et al. (1988a) in a study of four-lane two-way sections in Nebraska. This study used four years of crash counts and resulted in a contradiction of most safety analysis work in this area, finding that crash severity was greater at sites where flush medians had been implemented. However, it was conceded by the authors that the comparative study had "confounded the effects of the TWLTL medians on crash severity with those of other factors not considered" (McCoy et al. 1988b).

These various studies have also used different statistical techniques to prove significance of observed reductions or increases. Such techniques have included Chi-square, Poisson, Wilcoxon, and Paired-t tests (McCoy et al. 1988b, Thakkar 1984) for the comparison of a difference of means, or a one-sided Student t-Distribution (Squires & Parsonson 1989) for a test of crashes for one section of road having a greater number of crashes than a control section of road.

None of the studies investigated accounted specifically for the "regression to mean" (RTM) phenomena, which is caused by the tendency of crashes at a site to fluctuate around a true crash mean. This can have a significant impact on studies, resulting in over-estimates in crash reductions (Hauer 1997). While not specifically addressing this problem, several studies have reduced the possible impacts of RTM by investigating a significant crash history (LTSA 1995, Jurisich 1998) and by ensuring that the crash experience at a location was not a factor in the selection of the study sites (Jurisich 1998, Thakkar 1984).

Flush median crash data has been assessed in a number of ways. Hauer (1997) favours the 'before'/'after' study for evaluating crash remedial measures, as less variability exists when compared to cross-sectional analysis. The US tendency to undertake cross-sectional analysis of TWLTL in recent years may have resulted from the limited 'before' period data available. The TWLTL has been used for over 40 years in the US and, therefore at most sites, 'before' data is difficult to analyse, resulting in cross-sectional analysis being chosen by default rather than preference.

2.1.3 Site Selection Criteria

In crash evaluation, site selection will influence all analysis and reflect assumptions made of cause and effect. Careful site selection can isolate and clarify observed reductions or increases of crash-remedial measures.

In most studies, site-selection criteria have been used to create uniformity of investigation, thus stratifying the wide variety of implementation options for flush medians (Walton & Machemehl 1979).

The actual section of roadway investigated has been different, with several studies omitting signalised intersections and a distance on their approaches (Bonneson & McCoy 1998, Jurisich 1998, LTSA 1995). These studies have assumed that the influence of flush median implementation does not affect signals. Welch (1999) also omitted non-signalised sections focusing on mid-block crashes, and several studies have limited selection criteria to specific road layouts with respect to numbers of lanes (Squires & Parsonson 1989, McCoy et al. 1988b, Hoffman 1974).

Other restrictions have also been placed on site selection to improve accuracy. Such restrictions include: no other significant works have been undertaken on the stretches of road other than the implementation of the flush medians or TWLTL (Jurisich

1998, LTSA 1995, Thakkar 1984); only sections with Annual Daily Traffic (ADT) within a given range are to be investigated (Squires & Parsonson 1989, Thakkar 1984); and that adjacent land use is to be consistent for the period of study (Thakkar 1984).

Finally, a wide range in the numbers of sites have been investigated in each study. For example Bonneson & McCoy (1998) investigated 189 sites, Squires & Parsonson (1989) 50 sites, Thakkar (1984) 31, and Hoffman (1974) only four sites.

Sites chosen for analysis have a significant influence on the clarity of crash reductions observed. Thus in site selection, changes in crashes that do not relate to flush medians need to be identified and removed.

2.1.4 Specific Crash Types

Certain crash types have been significantly affected by the implementation of flush medians. These targeted crashes have included turning, overtaking and pedestrian-related crashes (Jurisich 1998, LTSA 1995), rear-end, left-turn (US) and sideswipe crashes (Thakkar 1984), and head-on crashes (Hoffman 1974). Flush medians have also been reported to have an impact on crash severity (McCoy et al. 1988a, Thakkar 1984, Hoffman 1974).

These targeted crashes have been shown in several studies to be significantly reduced by the implementation of flush medians and TWLTL. Hoffman's (1974) study found head-on in combination with left-turn (US) crashes to be reduced by 45% and rear-end by 62%. Thakkar (1984) also found left-turn, rear-end and all sideswipe crashes reduced significantly (33%, 36% and 36% for 5 lane sections and 4%, 56% and 45% for 3 lane sections). These results again highlight the variability of crash frequency changes both between studies and between differing road sections.

The influence of flush medians can be seen to change for different crash types. Confirmation of changes by crash type is, therefore, required to guide future installation of flush medians.

2.1.5 Study Variables

Specific variables have been found to have a significant effect on the safety and operation of flush medians. These general roadway attributes have been found to contribute to the effectiveness of flush medians, and have been used in the formation of crash prediction models (Brown & Tarko 1999, Bonneson & McCoy 1997, Squires & Parsonson 1989, McCoy et al. 1988a, Walton & Machemehl 1979). Variables included:

- Access points
  - Driveway density;
  - Proportion of unsignalised public street approach density;
  - Proportion of signalised access points;
- Annual Average Daily traffic; and
- Adjacent development.

All these variables were found by Bonneson & McCoy (1998) to have a significant effect on crashes when used in a prediction model. Other variables like parking allowances, median widths, and pedestrian movements (Bonneson & McCoy 1998, Jurisich 1998, Walton & Machemehl 1979) have also been found to have an influence on median effect. For example, Jurisich (1998) found that for median widths less than 2.0 m, the injury crash saving was 15%, while a 3% increase was noted for widths 2.0 m and more. Thus these variables must obviously be taken into account when forming crash prediction models and guidelines for the appropriate use of flush medians.

2.1.6 Benefit/Cost Evaluation

Benefit/cost analysis is the most direct crash performance indicator (Nicholson 2002) as crash severity can be accounted for. Assessment of all costs provide a more useful tool for comparison of reductions than crash frequency alone.

Various studies have investigated how best to evaluate the cost-effectiveness of the implementation of flush medians. McCoy et al. (1988b) investigated this, accounting for both operational costs and crash costs. From this US data, a set of curves evaluating the cost effectiveness of TWLTLs for combinations of driveway density, ADT and left-turn percentage was formulated. The installation of a TWLTL consequently was found to be cost-effective only in certain situations.

Thakkar (1984) also undertook benefit/cost analyses for crash reductions at a series of US-TWLTL sites. Benefits were calculated using both the equivalent uniform annual benefits to costs, and present worth benefits to costs. Thakkar found that overall the US-TWLTL was both safe and cost effective.

Again, differences in method have possibly resulted in variation in the benefit of flush median implementation. However, these studies have identified the importance of converting savings in crash reductions to savings in crash costs. Thus allowing meaningful assessment of the effects of flush median installation and the calculation of the benefit/cost (B/C) ratio for funding guidance.

2.2 Statistical Evaluation

2.2.1 Introduction

During the course of this research, a frequent observation was that no statistical evaluation of crash studies had been undertaken and that, when it was, no one statistical method had been dominant. A survey undertaken by the Institute of Transportation Engineers (ITE) found that approximately 70% to 90% of all US agencies had no written procedure for traffic safety studies and research projects. Approximately one-third to one half stated that statistical techniques were not used at all in their analyses (ITE 1999). However, accurate use of statistical methods is critical in crash analysis (Hauer 1997) and appropriate tools should be identified to provide the strongest possible assessment. The following sections 2.2.2 and 2.2.3 describe some of the available methods for crash analysis.

2.2.2 Crash Frequencies v Crash Rates

The starting point in any analysis is defining the variables of interest. In the analysis of traffic safety, opinions vary as to whether crash frequencies or crash rates should be measured. AUSTROADS *Guide to Traffic Engineering Practice – Part 4* (AUSTROADS 1988b) highlights that, without a measure of exposure, "the interpretation of the results of evaluation studies and of research involving inter-relationships is very difficult and at times almost impossible". The Guide points out that, in the most basic of 'before' and 'after' studies, the best criterion to use is 'rate'. However, AUSTROADS has accepted that where more detailed analysis is undertaken, where traffic flows are accounted for in comparison groups or as a direct function, then this is not so critical (AUSTROADS 1988b). The preference for using rates is also argued on the basis that rates can be more readily translated into crash-cost savings for economic evaluation (Nicholson 1987).

However, Hauer (1997) illustrates that crash frequency, not rate, should be used for analysis, as crash occurrence is not directly proportional to traffic flow. Preliminary assessment of flows at study sites in the current investigation confirmed this finding. Hauer goes on to state that "This of course does not imply that changes in traffic flow from 'before' to 'after' should not be taken into account. It only implies that such change needs to be accounted for correctly, by modifying the crash frequency".

2.2.3 Before and After Studies

2.2.3.1 *Introduction*

Several statistical methods have been identified for use in evaluation of highway safety programmes. Two general types of analysis methods have been used in this evaluation process. The first is a 'before' and 'after' analysis of crash frequencies or rates of a safety measure. Alternatively, a cross-sectional approach can be used comparing similar locations with and without implementation of the treatment measure (ITE 1999). Hauer (1991) states that "although the threats to the validity of conclusions drawn from 'before'/'after' studies are many, they seem to be better known and easier to avoid than threats to the validity of conclusions drawn from cross-section comparisons."

Methods for evaluating highway safety programmes by 'before' and 'after' analysis can be classified as classical or empirical. Classical methods rely on the use of observed crash rates and frequencies while the empirical methods rely on estimated crash rates and counts (ITE 1999).

Hauer (1997) describes the basic building blocks of all 'before'/'after' studies:

> "The many ways of doing a Before – After study merely reflect the many possible ways for accomplishing two basic tasks:
>
> "The task of predicting what would have been the safety of the entity in the 'after' period had the treatment not been applied, and
>
> "The task of estimating what the safety of the treated entity in the 'after' period was.

> ".... the effect of a treatment on the safety of some entity consists of comparing the prediction of what safety would have been to the estimate of what safety was."

2.2.3.2 *Classical methods*

The 'before'/'after' study design with randomised control group provides the strongest evaluation technique available through randomised assignment of variables to a treatment group and a comparison group (AUSTROADS 1988b). This method is the equivalent of a planned experiment, although it is rarely used.

More often a simple or naive 'before'/'after' method is undertaken. This is the most common and simple to use method for the evaluation of a traffic safety measure (ITE 1999, Hauer 1997). This test assumes that the passage of time from the 'before' to 'after' period was not associated with changes that affected the safety of the entity. However, as has been proven, this is not a satisfactory assumption (Hauer 1997).

Comparison groups can be adopted to account for changes in the environment over study periods that may affect safety, such as: traffic volume, vehicle fleet, weather, and road user demography (Hauer 1997). Comparison sites are observed for the same time periods as study sites. They can be separate sections of road with similar characteristics or the actual study sections observed under different conditions (ITE 1999). The control group is then used to factor 'before' period crashes.

A statistical test that can be undertaken to test if a comparison group is valid is the test for comparability (ITE 1999). Hauer (1997) also justifies the use of comparison groups where it can be shown that a time series of past values for the comparison and the treatment groups are sufficiently similar.

Further refinement can be made to 'before'/'after' studies by accounting for the effect of traffic flow on the crash frequency explicitly through use of crash/flow functions (Hauer 1997). The comparison group is used only to account for implicit factors that are not easily measured or quantified.

Several general significance tests can be used to make statistical inference for 'before'/'after' studies. The ITE survey (1999) found that, of the traffic agencies which used statistical inference techniques, the most common were the 'test of two variances', 'T-test', 'analysis of variance', and the 'chi-square' test. The ITE (1999) has, however, recognised that the majority of current statistical approaches used in analysing crash statistics have numerous problems.

Another concern with the above methodologies is the 'regression to mean' (RTM) phenomena. Classical statistical methods assume that the 'before' crash history of a site is a suitable estimate of what the 'after' crashes would have been had the treatment not been implemented. However this may not be the case as a result of the RTM effect (ITE 1999).

Hauer (1997) points out that "one may not assume that the past crash history has not been considered when the decision was made to treat or not to treat an entity". It is this assumption which gives rise to RTM. Also if an entity has been selected because it had an unusually high number of crashes, the 'before' crashes would not be a good estimate of the 'after' crashes had the treatment not been implemented.

It would tend to over-estimate the true value, as crashes in the following period would tend to regress toward a likely lower true mean crash rate for the site. Hauer (1997) also notes that RTM may still be a concern for entities even if they were not selected for treatment because of high crash rates at the site.

Some engineers have indicated that RTM is reduced sufficiently through use of significant time periods. Nicholson (1987) stated that, for statistical reliability, a five-year time period is most appropriate for crash analysis. This period is thought to be an accurate estimate of the true mean value of crashes at a site. However, Hauer (1997) maintains, and has illustrated, that even longer time periods can be significantly influenced by RTM.

2.2.3.3 *Empirical Bayes Method*

The Empirical Bayes method requires a reference group or population that is similar to the treatment sites. This group is required to provide an estimate for the expected number of crashes that is not biased by site selection. The critical assumption with this method is that the reference and treatment group must be homogeneous with regard to factors that affect safety, i.e. they must be readily exchangeable. Such factors include traffic volume and geometric design (ITE 1999).

The essence of this method is that it uses two pieces of information to form the prediction of the estimate of 'after' crashes at a site.

There are two clues to safety of an entity:

1. Characteristics (e.g. traffic flow, road section length, roadside development); and
2. History of crash occurrence (Hauer 1997).

Clues of the first kind are based on characteristics of the entity, and on safety of the group of entities sharing these characteristics, i.e. a reference population. These clues are used to form a prediction model for sites using multivariate analysis. Clues of the second kind are determined by how much the actual crash history of an entity deviates from the mean of the entire group (Hauer 1997).

The Empirical Bayes method combines the two entities and in doing so accounts for RTM. The actual history is adjusted closer to the true population mean for such an entity.

ITE raises concern regarding the use of the Empirical Bayes method:

> "Several issues pertaining to the exchangeability assumption and reference group need to be addressed before the extended Empirical Bayes methodology is used further. Currently, the extended Empirical

> Bayes method has the potential to be misused given that a user can't easily determine if the exchangeability and distribution assumptions are appropriate for a given set" (ITE 1999).

The estimation of the true savings of an crash remedial measure is complex. Numerous changing factors must be accounted for in this estimation, requiring tailored analysis for different data sets. The analysis method chosen should be carefully considered and reflect the characteristics of the data available. It is also fundamental that suitable statistical inference is included in the analysis, which has historically been ignored.

2.3 Conclusions

The implementation of flush medians has been found almost conclusively to reduce crashes. However, the actual reduction has been significantly different, from one study to another, both nationally and internationally. The above discussion has highlighted that the various methodologies and statistical techniques used in the studies could have contributed to this variation. Good study design is, therefore, of obvious importance to ensure meaningful results.

3. Data Collection

3.1 Database Formation

A database of 54 Auckland City flush median sections was formed by the LTSA in 1998 and these data were used by Jurisich (1998). An updated version of this database has been investigated in this current study. The flush median sections chosen were some of the first sites converted in Auckland City and therefore provided the longest 'after' time periods. Implementation dates for these sites ranged from 1988 to 1994. Geographical Information System (GIS) aerial photographs of the study sites were reviewed to ensure that no significant road marking, civil works, traffic signal or lighting changes had been made since implementation. As a result of this, four of the original study sections and a portion of another were omitted because of road marking changes.

The 54 original undivided sections investigated in this study had not been changed to flush median roadmarking as a result of crash studies or high crash rates. Flush medians installed during this period were usually on main roads where operational and safety benefits were likely to result. This has therefore reduced any possible bias introduced by the regression to mean phenomena (RTM), which occurs where crashes at a site fluctuate around an underlying true crash rate. Sites selected for treatment because of high crash rates could be expected to regress toward a lower true crash rate in a following time period, thereby exaggerating any observed reductions.

Five year 'before' and 'after' periods were chosen for analysis based on previous LTSA studies. The LTSA (1995) considers that use of significant study periods is a satisfactory estimate of the underlying true crash rate, thus also reducing any possible RTM effect. All injury data for these periods were available, although some sites were restricted by the non-injury 'before' periods as the LTSA did not start recording non-injury crashes until 1989. Because of some uncertainty with the exact implementation dates, any partial year 'before' or 'after' implementation was omitted. This also made allowance for a post-implementation settling-down period when driver confusion or caution may have led to a distorted crash frequency (Nicholson 2002).

Only those crashes that could be affected by flush medians (i.e. targeted crashes) were required in the database. Therefore those crashes believed to be non-target were removed. The target crash group was defined by expert opinion and as a result only signalised intersections and their approaches were omitted from the database. No other crash type, period, or light condition could be isolated from the potential effects of flush medians. By accounting for only these target crashes, any distortion of the data by non-target crashes is avoided (Hauer 1997).

Further cleaning was undertaken in order to remove locations where problems developed as a result of influences other than flush median implementation. To do this, Crash Analysis System (CAS) reports and plots were obtained for all flush-median study sites. 'Before' and 'after' implementation periods were obtained separately, while injury and non-injury crashes for the respective periods were combined. Review of these crash reports was undertaken to identify any obvious inconsistencies in crashes. Individual crashes suspected of being recorded incorrectly or requiring omission were identified and the original Traffic Crash Reports (TCRs) were then referred to. Following these evaluations, any required corrections or deletions from the database were made.

3.2 Benefit/Cost Analysis

Cost estimates were prepared for the 50 sites, for the works required to remove the pre-flush median road marking and to install the current layout. No plans or aerials of the sections before implementation of the flush medians were available, therefore the previous road marking layout was based on typical Auckland City Council practice for the road widths. Investigation was also made into identifying any civil works associated with the implementation of the flush medians, such as road widening. The current council engineer in charge of road pavement marking was involved with a number of the installations and indicated that very little civil works had been undertaken in the implementation of the 50 study sites. Also note that the cost estimates have not included the cost of physical traffic islands added at later dates.

Using these cost estimates, benefit/cost analyses were undertaken for each aspect of the investigation. The analyses followed Transfund's procedures as outlined in the Transfund Project Evaluation Manual (Transfund New Zealand 1997). Evaluation was undertaken using a spreadsheet program developed by *CITY* DESIGN and accepted by Transfund New Zealand for B/C analysis.

4. Crash Analysis

4.1 Traditional Crash Analysis Methodology

4.1.1 Introduction

Previous New Zealand studies (LTSA 1995, Jurisich 1998) have used a basic comparison or control group 'before' and 'after' study to determine the safety implications of flush medians. This study has used a similar methodology. 'Before' crashes at a site are used to predict what the number of crashes would have been in the 'after' period had the flush median not been implemented (i.e. 'expected after'). This is then compared with what actually occurred in the 'after' implementation period and the difference is calculated. Time trend variations in environmental factors are accounted for by using a comparison or control group.

LTSA studies have focused on evaluation of the combined group of all injury crashes, with no distinction being made for severity classes. The current study has divided crashes into severity classes and included the non-injury crash class in the analysis. Changes in crashes were calculated separately for the different severity classes with the implementation of flush medians.

For the 50 sites investigated, crashes at each site were separated into severity classes and 'before' and 'after' periods. The expected number of 'after' crashes was then estimated for individual sites. 'Before' crashes at a site for a severity class were multiplied by a control factor accounting for time trends and time period differences. The observed 'after' crashes at individual sites were summed and the estimated expected 'after' crashes combined. The percentage change in crashes was then estimated for the group of sites.

The calculation involved is as follows:

$$\text{Percentage change in crashes} = -\frac{(\text{sum of 'expected'} - \text{sum of 'after'}) \times 100}{\text{sum of 'expected'}}$$

where:

expected	is the estimated number of 'after' crashes at a site during the 'after' period, assuming the treatment had no effect;
after	is the observed number of crashes that occurred in the 'after' period.

Calculation spreadsheets for the 'before' and 'after' analysis are in Appendix B.

4.1.2 Control Design

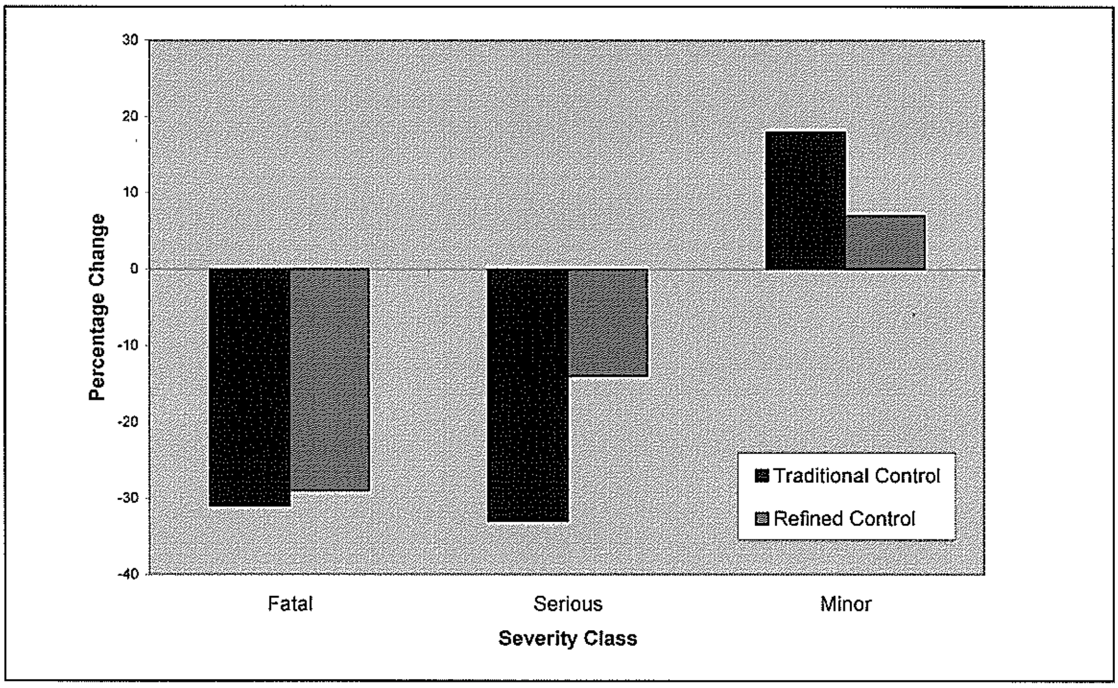
One of the most important tasks in crash analysis is to "separate the effect of the treatment from the effect of other factors" (Hauer 1997). Our study has attempted to achieve this through use of a control group. The most important assumption in the selection of a control group is that the change in the factors influencing safety is similar in the treatment and control groups (the compatibility assumption).

This study has made use of a modified LTSA control for crash analysis. In the LTSA control group, all crashes in Auckland City for individual months are summed. Total crashes are then calculated for a range of five-year 'before' and 'after' periods matching the study sites. 'After' crashes are then divided by the 'before' crashes to form a 'control' value. Thus the control value will change with different implementation dates. This control group excludes any traffic safety investigation sites, such as black spots, as these may significantly distort the control.

Modifications were made to this control group through the removal in the data of additional road sections. Local roads were excluded from the control group, as flush medians were almost exclusively implemented on collector or arterial roads. This will strengthen the compatibility assumption of the control group, as crash trends at arterial and collector roads could be significantly different to those on local roads. The Auckland City Road Assessment Maintenance & Management database (RAMM) of collector and arterial roads was used to identify control road sections. Sections of road where flush medians had been installed were also removed from the control group as their inclusion would minimise any differences observed from the 'before' to 'after' periods.

Further refinement of the control group was made by using crash severity to analyse the crash data. In previous LTSA studies, all injury crashes have been combined for controls. However when analysing crash severity, using an all or general injury type for the control group could lead to distortions. Historical trends have been shown to be different for the four severity classes (Appendix D). Therefore to further increase accuracy, separate control values were formulated for the three crash severity classes. Figure 4.1 illustrates the difference between the traditional LTSA control and severity-specific refined controls used (in this study). The LTSA method of control used for all injury crashes tends to over-estimate both the reduction in fatal and serious injury crashes, and the increase of minor injury crashes.

Figure 4.1 Effects of two types of controls on reductions in severity of crashes.



4.2 Generalised Linear Modelling Analysis Methodology

An alternative analysis to the traditional 'before' and 'after' study has been undertaken through modelling of the crash rates at treatment and control sites. Crash rates at treatment sites are compared with the crash rates at the control sites, which therefore allows for time trends. Differences in 'before' and 'after' crash proportions are used to estimate the effect of flush median implementation (Appendix C).

Under the assumption that no effect is related to the presence of a flush median the ratio of the crashes in the pre- and post-installation periods is calculated from the length of the periods, and the slope coefficient obtained from analysis of the control sites. The data for the flush median sites are accumulated by year of installation. All sites installed in the same year will have the same pre- and post-installation proportions.

A log-linear model, fitted using the GLM method, was adopted for each crash type. The form of model is described as follows:

y_{ib} is the number of crashes in the before installation period for all the sites installed in year i. It has a Poisson distribution with mean μ_{ib}.

y_{ia} is the number of crashes in the after installation period for all the sites installed in year i. It has a Poisson distribution with mean μ_{ia}.

The mean number of pre-installation crashes is modelled by

$$\begin{aligned}\mu_{ib} &= \theta_i p_{ib}\\ \log(\mu_{ib}) &= \log(\theta_i) + \log(p_{ib}) = \lambda_i + \log(p_{ib}),\end{aligned}$$

and the post-installation mean is given by

$$\begin{aligned}\mu_{ia} &= \theta_i p_{ia}\,\varphi\\ \log(\mu_{ia}) &= \log(\theta_i) + \log(\varphi) + \log(p_{ia}) = \lambda_i + \alpha + \log(p_{ia}),\end{aligned}$$

where:

θ_i = $\exp(\lambda_i)$ and is the mean total number of crashes in the pre- and post-periods for sites with installation year i assuming the flush median has no effect;

p_{ib}, p_{ia} are the pre- and post-period proportions of crashes assuming there was no effect due to the flush median ($p_{ib} + p_{ia} = 1$). They are estimated from the control data and are not part of the fitting of the test site data (see Appendix D).

φ = $\exp(\alpha)$ and is the multiplicative effect of the presence of a flush median.

All the components are multiplicative and hence are linear in the logarithm.

The log-linear Poisson models were fitted for each crash type using the GLM command in the statistical package ***R***. The effects were then estimated for different combinations of crash severity and type.

The same raw control data was used as for the traditional analysis in Section 4.1.2 (and given in Appendix D) of this report. Controls were formed using 1982 to 1999 crash data for fatal crashes, 1984 to 1999 for serious and minor injury crashes, and 1989 to 1999 for non-injury crashes. Reporting rates for serious and minor injury crashes showed some inconsistency before 1984 and were consequently omitted. Specific controls were used for night-time/daytime and peak and off-peak analysis (see Appendix D).

4.3 Results

4 3.1 Crash Severity

Before crash analysis was carried out, all crashes at the 50 sites were separated by severity class. The effect of flush median implementation was then assessed in each of these classes. The results of this analysis are shown in Table 4.1. Both the traditional analysis and the GLM generated very similar results for each severity class. Fatal, serious and non-injury categories all showed reductions in crashes, with the largest change seen in the fatal injury category. Minor injury crashes were shown to increase by 7%. The only result that was significant using the GLM method was the saving in non-injury crashes, which had a p-value of 0.004. The change in combined injury crash frequency has been calculated at 3% increase for the traditional analysis method. Frequency for all crashes shows a 2% reduction.

Table 4.1 Before and after crash changes by severity class.

Severity Class	**Before Crash**	**After Crash**	**Exp. After**	**% Change Trad.**	**NZ$M Change Trad.**	**% Change GLM**	**NZ$M Change GLM**	**GLM Sig.**
Fatal Inj	24	13	18.1	-28	-26.0	-28	-25.9	No
Serious Inj	226	120	131.2	-9	-10.4	-7	-8.6	No
Minor Inj	612	565	527.2	+7	+2.5	+7	+2.5	No
Total Inj	**862**	**698**	**676.5**	**+3**	**-33.5**	-	**-32.0**	-
Non-Inj	1324	1875	1951.3	-4	-1.2	-10	-3.2	Yes
Total	**2186**	**2573**	**2627.8**	**-2**	**-35.2**	-	**-35.2**	-

Inj – injury; Exp. – expected; Trad. – traditional; GLM – Generalised Linear Modelling; sig. – significance

An overall B/C ratio of 30.2 with 25-year crash savings of $35.2 million was calculated for the implementation of flush medians at the 50 study sites using the GLM reductions and the 5-year crash history before implementation. The traditional method generated a B/C ratio of 36.6 and 25-year crash savings of $35.2 million.

Most of the projected savings for the design life of the flush medians have been in the fatal injury class, for which both analysis methods gave estimates of $26 million savings. Large savings are also observed in the serious injury classes while only small changes are seen in the minor and non-injury classes.

4.3.2 Effects of Night-time and Daytime on Crashes

Crashes were separated into night and day classes in order to calculate the effect of flush medians on these sorts of crashes. Table 4.2 summarises the results of the analysis. Again, both methods demonstrated similar trends in results. Crash reductions were found in both fatal and serious injury categories, with higher savings seen in the night-time periods. Reductions were also found in both time periods for non-injury crashes, with the daytime non-injury saving having a p-value of 0.006 using the GLM method. No crash savings were found for the minor injury category upon implementation of flush medians.

Table 4.2 Changes in night-time and daytime crashes by severity class.

Severity Class	Time of Day	Before Crash	After Crash	Exp. After	% Ch. Trad.	$M Ch. Trad.	% Ch. GLM	$M Ch. GLM	GLM Sig.
Fatal Inj	Night	12	5	9.1	-45	-20.7	-37	-17.1	No
	Day	12	8	9.0	-11	-5.3	-18	-8.3	No
Serious Inj	Night	103	52	60.1	-13	-7.5	-19	-10.6	No
	Day	123	68	71.1	-4	-2.9	-12	-8.0	No
Minor Inj	Night	216	189	185.6	+2	+0.2	+5	+0.6	No
	Day	396	376	341.6	+10	+2.3	0	0	No
Total Inj	**Night**	**331**	**246**	**254.8**	**+3**	**-28.0**	-	**-24.9**	-
	Day	**531**	**452**	**421.7**	**+7**	**-5.9**	-	**-16.3**	-
Non-Inj	Night	431	612	633.3	-3	-0.3	-7	-0.7	No
	Day	893	1263	1318.0	-4	-0.9	-12	-2.6	Yes
Total	**Night**	**762**	**858**	**888.1**	**-3**	**-28.3**	-	**-27.8**	-
	Day	**1424**	**1715**	**1739.7**	**-1**	**-6.8**	-	**-18.9**	-

Inj – injury; Exp. – expected; Trad. – traditional; GLM – Generalised Linear Modelling; Ch. – Change; sig. – significance

The largest crash cost savings were observed in the night-time crashes despite total crashes in this group being much lower than those during the day. From the results, design life crash cost savings of $27.8 million are achieved for night-time crashes, and $18.9 million for daytime crashes using the GLM method of analysis. The corresponding values using the traditional analysis were $28.3 million for night-time and $6.8 million for daytime crashes. Again, the fatal and serious injury crashes have made up most of the crash cost savings observed in both periods, with minor and non-injury crashes contributing relatively low savings.

4.3.3 Effects of Peak and Off-Peak on Crashes

The effect of flush medians on peak and off-peak crashes was calculated after separating these two groups. The a.m. (morning) peak period was between 7:00–9:00 a.m. and the p.m. (afternoon) peak between 4:00–6:00 p.m., Monday to Friday. The results of this analysis are listed in Table 4.3. Savings are seen in both fatal and serious crashes apart from the fatal peak period, where low numbers contribute to the large increase (Table 4.3). Small savings are seen in the minor injury crashes during peak periods, however increased minor crashes are found off-peak. A discrepancy is found between the different methods for non-injury crashes.

Traditional analysis shows an 11% increase in peak crashes while the GLM method shows a 5% decrease for the same category. Non-injury crashes had a significant reduction of 11% with a p value of 0.003, and no other results were significant.

Table 4.3 Changes in peak and off-peak crashes by severity class.

Severity Class	Time of Day	Before Crash	After Crash	Exp. After	% Ch. Trad.	$M Ch. Trad.	% Ch. GLM	$M Ch. GLM	GLM Sig.
Fatal Inj	Peak	4	4	3.2	+24	+3.7	+41	+6.3	No
	Off	20	9	14.9	-40	-30.5	-38	-29.3	No
Serious Inj	Peak	46	26	26.5	-2	-0.5	-3	-0.7	No
	Off	180	94	104.7	-10	-9.9	-19	-18.6	No
Minor Inj	Peak	164	141	142.1	-1	-0.1	-8	-0.8	No
	Off	448	424	385.2	+11	+2.6	+4	+1.0	No
Total Inj	**Peak**	**214**	**171**	**171.8**	**0**	**+3.1**	-	**+4.8**	-
	Off-	**648**	**527**	**504.8**	**+4**	**-37.8**	-	**-46.9**	-
Non-Inj	Peak	299	485	437.0	+11	+0.8	-5	-0.4	No
	Off	1025	1390	1514.3	-8	-2.0	-11	-2.7	Yes
Total	**Peak**	**513**	**656**	**608.8**	**+7**	**+4.0**	-	**+4.5**	-
	Off-	**1673**	**1917**	**2019.1**	**-5**	**-39.8**	-	**-49.5**	-

Inj – injury; Exp. – expected; Trad. – traditional; GLM – Generalised Linear Modelling;
Ch. – Change; sig. – significance

Cost analysis shows significant savings occurring in the off-peak period, while the peak period is observed to increase. This may be distorted due to the low number of peak period crashes, particularly in the fatal injury class (i.e. only 4 recorded). Again, fatal and serious injury crashes assert the most influence on the results observed.

A crash increase of $4.5 million was obtained for peak crashes and savings of $49.5 million for off-peak using the GLM method of analysis. The traditional methodology resulted in an increase for peak crashes of $4.0 million and off-peak savings of $39.8 million.

4.3.4 Effects of Flush Median Width on Crashes

The effect of flush median width on crash savings was determined by dividing crash sites into widths narrower than 2 m (10 sites) and widths greater or equal to 2 m (40 sites). One of the study sites was omitted because it had significant variation in width over its length. Table 4.4 summarises the results of the 'traditional' analysis. GLM analysis has not been undertaken for investigation into median width. Median width had a large impact on non-injury crashes. A reduction of 20% was found in non-injury crashes with medians less than 2 m wide, compared to an increase of 2% with wider medians. Median width had no obvious impact on injury crashes, with both groups experiencing savings in fatal and serious injury crashes but not in minor injury crashes, which increased.

Table 4.4 **Effect of flush median width on crash changes by severity class,**

Severity Class	Median Width	Before Crashes	After Crashes	Expected After	% Ch. Trad.	$M Ch. Trad.
Fatal Inj	<2 m	7	3	5.4	-44	-11.9
	≥2 m	17	10	12.7	-21	-14.1
Serious Inj	<2 m	63	36	37.5	-4	-1.4
	≥2 m	163	84	93.7	-10	-9.1
Minor Inj	<2 m	149	136	126.7	+7	+0.6
	≥2 m	463	429	400.6	+7	+1.9
Total Inj	**<2 m**	**219**	**175**	**169.6**	**-3**	**-12.7**
	≥2 m	**643**	**523**	**507.0**	**-3**	**-21.3**
Non-Inj	<2 m	373	402	503.3	-20	-1.8
	≥2 m	951	1473	1448.0	+2	-0.4
Total	**<2 m**	**592**	**577**	**672.9**	**-14**	**-14.4**
	≥2 m	**1594**	**1996**	**1955.0**	**+2**	**-20.9**

Inj – injury; Exp. – expected; Trad. – traditional; GLM – Generalised Linear Modelling; Ch. – Change; sig. – significance

A B/C ratio of 55.8 is achieved where flush medians less than 2 m wide have been installed with 25-year crash savings of $14.4 million. A B/C ratio of 24.0 and savings of $20.9 million have been calculated where flush medians greater than 2 m have been installed.

4.3.5 Effects on Crash Types

Crash types with the most significant number of injury crashes were chosen for detailed investigation. To do this, a matrix was formed of 'injury' only crashes for all crash types. Of the 85 crash types, 14 made up 78% of the total 'before' injury crashes and 77% of the total 'after' injury crashes. These crashes were then individually assessed for crash severity. Low crash numbers in the different crash classes will have resulted in increased variability in the results. However, the assessment does provide some guidance as to trends between crash types. The results of the 'traditional' analysis undertaken are summarised in Figure 4.2. GLM analysis was not undertaken for the assessment of crash types.

Crash analysis found that the largest reductions occurred with turning versus same direction (GD[1]) crashes, where all three crash severity classes experienced very large savings (≥74%). Loss of control crashes (BF, CB, CC, DA, and DB) also generally showed reductions in frequency at flush median sites. Only CC and CB crashes showed some increases in the serious and non-injury classes respectively. Pedestrian crashes (NA and NB) were observed to have reduced in all but the minor injury class. A very large increase was seen in the minor injury category of the FD class (rear-end crashes at queues) and consistent increases were observed in all categories for some right turn manoeuvres (JA and LB). No obvious trends were found for the remaining crash types. Table 4.5 shows the crash statistics by type which are discussed next.

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[1] Codes for crash types are listed in Appendix A.

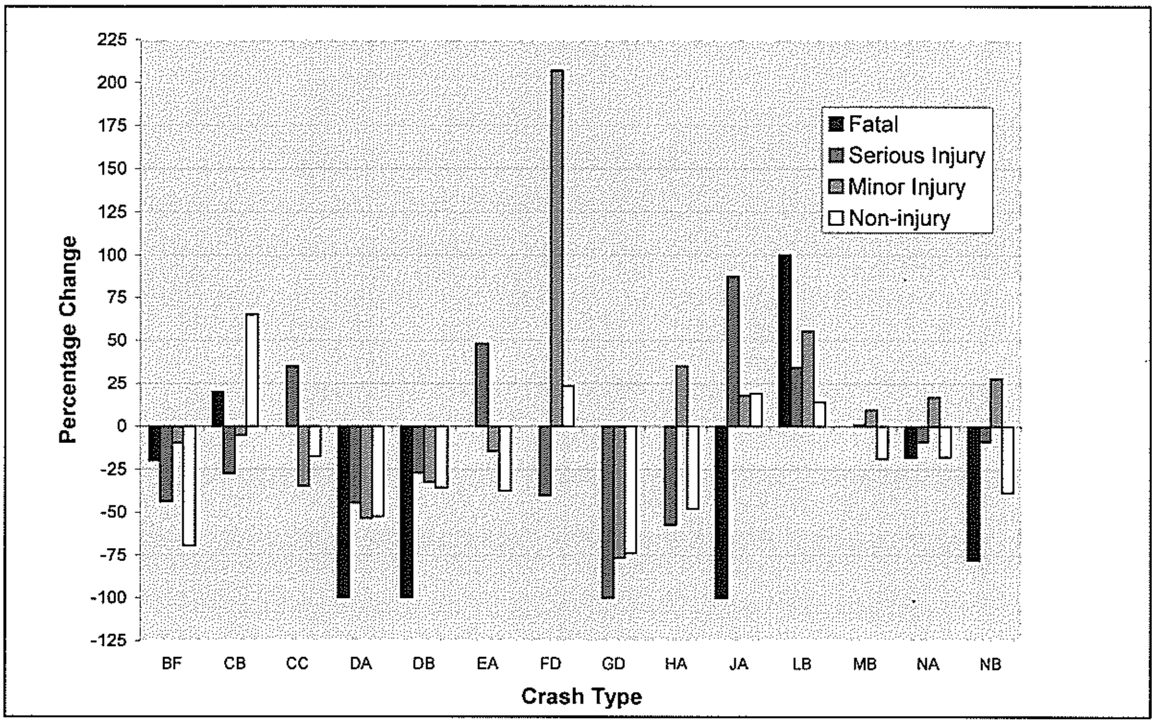

Figure 4.2 Percentage crash changes by crash type.

Table 4.5 Crash statistics by type.

Crash Group Savings NZ$M	Crash Type	Severity	Before Crash	After Crash	Exp. After	% Ch. Trad.	$M Ch. Trad.
Straight – Lost Control / Head On	CB Off roadway to left	Fatal	2	2	1.67	+20	+1.5
		Serious	14	6	8.3	-27	–2.2
		Minor	21	17	17.9	-5	–0.1
		Non-inj	32	77	46.7	+65	+0.5
Total changes +$0.1 million	CC Off roadway to right	Fatal	0	0	0	-	0
		Serious	5	4	3	+35	+0.9
		Minor	18	10	15.4	-35	–0.4
		Non-inj	21	25	30.3	-17	–0.1
Bend – Lost Control / Head On	BF Lost control on curve	Fatal	3	2	2.5	-20	–1.9
		Serious	12	4	7.1	-44	–3.6
		Minor	13	10	11.1	-10	–0.1
		Non-inj	21	8	26.3	-70	–0.6
Total change –$28.8 million	DA Lost control turning right	Fatal	2	0	-1.44	-100	–6.4
		Serious	12	4	7.2	-45	–3.1
		Minor	45	18	38.7	-53	–1.4
		Non-inj	90	56	117.6	-52	–1.2
	DB Lost control turning left	Fatal	2	0	1.39	-100	–7.3
		Serious	14	6	8.2	-27	–2.2
		Minor	26	15	22.2	-32	–0.5
		Non-inj	53	44	68.5	-36	–0.5

Crash Group Savings NZ$M	Crash Type	Severity	Before Crash	After Crash	Exp. After	% Ch. Trad.	$M Ch. Trad.
Rear End – Obstruction Total change –$1.9 million	EA Parked vehicle	Fatal	0	1	0	+100	+1.7
		Serious	7	6	4.1	+48	+1.6
		Minor	38	28	32.7	-14	–0.3
		Non-inj	103	95	151.3	-37	–0.4
	FD Queue	Fatal	0	0	0	-	0
		Serious	3	1	1.7	-40	–0.6
		Minor	18	49	16.0	+207	+2.3
		Non-inj	105	198	160.3	+23	+0.6
	GD Near centre line	Fatal	0	0	0	-	0
		Serious	6	0	3.4	-100	–3.0
		Minor	40	8	34.4	-77	–1.9
		Non-inj	93	38	145.2	-74	–1.9
	MB U-turn	Fatal	0	0	0	-	0
		Serious	12	7	6.9	+1	+0.1
		Minor	48	45	41.1	+10	+0.3
		Non-inj	112	141	173.7	-19	–0.4
Crossing / Turning Total change +$9.3 million	HA Right angle (70° to 110°)	Fatal	0	0	0	-	0
		Serious	4	1	2.3	-57	–1.2
		Minor	20	23	17.0	+35	+0.4
		Non-inj	52	36	69.0	-48	–0.6
	JA Right turn right side	Fatal	1	0	0.7	-100	–2.5
		Serious	13	14	7.5	+87	+6.0
		Minor	63	64	54.3	+18	+0.6
		Non-inj	160	289	242.5	+19	+0.6
	LB Making turn	Fatal	0	1	0	+100	+2.3
		Serious	13	10	7.4	+34	+2.2
		Minor	45	61	39.3	+55.3	+1.3
		Non-inj	81	135	118.2	+14	+0.2
Pedestrian v Vehicle Total change –$14.8 million	NA Left side	Fatal	5	3	3.66	-18	–3.2
		Serious	38	20	22.0	-9	–1.7
		Minor	56	56	48.0	+17	+0.4
		Non-inj	7	9	10.9	-18	0
	NB Right side	Fatal	6	1	4.57	-78	–9.7
		Serious	21	11	12.1	-9	–0.9
		Minor	27	30	23.5	+28	+0.3
		Non-inj	6	6	9.8	-39	0

Inj – injury; Exp. – expected; Trad. – traditional; GLM – Generalised Linear Modelling;
Ch. – Change; sig. – significance

Table 4.5 highlights the significance of the reductions in frequency through calculation of predicted crash cost changes. The major crash cost savings are seen in the group comprising of 'loss of control' on bends and 'head on' crashes on bends (DA, DB, and BF). Consistent reductions in these crashes resulted in a combined $28.8 million projected savings in fatal, serious, minor and non-injury crashes for the 50 sites studied.

The next largest saving was seen in pedestrian crashes (NA and NB) which resulted in combined projected savings of $14.8 million. The large savings observed has resulted from the reduction in fatal crashes. These two movements made up 11 of the 24 fatals in the 'before' period at the 50 sites.

Rear-end type crashes resulted in an overall decrease in crash cost. However some variability was observed within the group. Major savings were observed in the 'rear-end near-centre line' (GD) crashes with projected design life reductions of $6.8 million for the four severity classes. However both 'rear end hitting parked vehicles' (EA) and 'rear end at queues' (FD) showed increases in crash costs.

'Crossing and turning' crashes resulted in a combined projected increase in costs of $9.3 million. A $1.4 million saving was observed in HA 'right angle' crashes while a combined $10.7 million increase was observed in 'right turning' crashes (JA and LB).

4.4 Discussion

4.4.1 Differences between Methodologies

Generally, the two analysis methods used produced similar results, and this was especially evident with the larger data set of 'all crashes'. Once broken up into different time periods, for example night/day and peak/off-peak, the differences in the results became greater.

Deficiencies in the traditional analysis arise as the data sets become small. Breaking data into severity classes, and into specific types or classifications, can result in distortions, as zero numbers arise in some 'before' and 'after' columns. Differences in crash savings observed in the GLM method occur because the analysis models use rates, not averages. Also contributing to the difference is the use of specific controls for night/day and peak/off-peak periods.

The GLM method of crash analysis uses the underlying mean effect of crashes over periods of time, as opposed to the traditional method which uses actual numbers. If the study could be repeated a number of times for the same time periods and for the same influencing factors, the same crash frequencies would not be expected every time. The results would be expected to vary about an underlying true mean crash rate. The crash frequencies over a time period would have a Poisson distribution with mean μ. This is the mean crash rate that the GLM method models and uses to estimate the actual effect of the flush median implementation. The traditional method looks at one frame in time and assumes this is the true mean crash rate with no variability, i.e. if the study could be repeated the same result would be achieved. This assumption is incorrect and also restricts accurate application of statistical inference because the variables are treated as fixed.

The controls for the two methods have also been used in different ways. The traditional control uses short time periods, which may introduce bias. For the 10-year periods investigated (5 years 'before' and 5 years 'after'), control crashes fluctuate around what is believed to be a true mean population time trend (see Appendix D).

The GLM method fits a prediction function to a longer series of historical data estimating the true underlying mean rate and uses this to account for influencing environmental factors. This refinement was possible because of relatively consistent traffic growth and crash reporting in Auckland City over the past 20 years.

It is, therefore, believed that the GLM method of analysing the Poisson modelling of crash rates provided the most statistically accurate method of assessment. This method could be improved further by performing an analysis using year-by-year data for the test sites. Rather than fitting a slope to the control data and assuming that this has no error, the analysis could be undertaken so that both the control and the test site data are incorporated. The analysis would estimate all year effects (instead of a control slope) and would quantify all the error in both the control and test sites data. It is recommended that further investigation into this method be undertaken for use in future 'before' and 'after' crash studies.

4.4.2 Crash Severity

The implementation of flush medians at 50 Auckland sites has reduced fatal, serious and non-injury crashes by 28%, 7% and 10% respectively (using GLM), while resulting in a 7% increase in minor injury crashes. The associated B/C ratio of 1:30.2, and a predicted design life crash savings of $35.2 million illustrates that flush median implementation has achieved a very significant economic safety benefit.

Analysis of total crash frequency has resulted in an observed decrease of 2% and analysis of crash severity has found large savings of $35.2 million in crash costs. This highlights the importance of crash analysis by severity for assessment of traffic safety devices. Without severity analysis, the largest injury-crash group exerts a distorted influence over any result and perceived benefits. Concern is raised, therefore, that, without such analysis, traffic improvement devices could be discarded when real savings in crash costs are occurring.

One reason for the decrease in observed severity may be that flush median implementation has resulted in crash migration between severity classes. Their implementation have possibly created a calming effect and slowing of traffic. The increased separation of opposing flows and the constricting of lane widths resulting from flush median implementation may have shifted crashes that are usually serious and fatal injury into the minor injury class. Flush medians have also improved driver discipline, thus taking away uncertainty of drivers' actions.

The difference in crash reductions between severity classes with flush median implementation may also have resulted from the different observed savings in crash type. As seen in Section 4.4.6 of this report, 'rear end' (FD) crashes increased dramatically. Historically, a large proportion of these type of crashes have resulted in less serious crashes with the whole 'rear end' group of crashes making up only 2.8% of fatal crashes and 7.6% of injury crashes in New Zealand in 1999 (LTSA 2002b).

Crash migration between severity classes is also supported by the observed reductions in the historically more severe 'loss of control' group of crashes. Loss of control crashes on straight sections and loss of control when cornering made up a total of 32.5% of fatal crashes and 30.5% of injury crashes in New Zealand in 1999

(LTSA 2002b). This demonstrates that analysis of crash types along with severity analysis is important when investigating the benefits of traffic safety devices.

4.4.3 Effects of Night-time and Daytime on Crashes

Based on the GLM method of analysis, the implementation of flush medians has had more impact in reducing night-time crashes (crash savings of $27.8 million) than they do during the day (crash savings of $18.9 million) (Table 4.2). The difference in savings is significant as night-time crash numbers are approximately half that of those during the day.

The analysis of night and day crashes has again followed the general patterns observed in the severity analysis. The largest reductions were observed in fatal and serious crashes during the night periods. This could be attributed to high vehicle speeds at night being reduced upon flush median implementation related to constriction in lane width and increased delineation.

4.4.4 Effects of Peak and Off-peak on Crashes

The GLM analysis results show that flush medians are most beneficial in reducing crashes during off-peak periods. Predictive crash savings of $49.5 million were calculated for off-peak periods while a $4.5 million increase was observed for peak periods (Table 4.3). This is expected as it has already been established that flush medians are effective in addressing night-time (off-peak) crashes. This is again probably related to high vehicle speeds and alcohol being contributing factors in these crashes.

The increase in peak period crashes may have been distorted by very low fatal crash numbers which resulted in a predicted $6.3 million increase, according to the GLM analysis results (Table 4.3). All other classes in peak periods showed some savings. Difficulties also result in interpretation as the off-peak period represents three times the number of crashes compared to those in the peak periods.

The absence of significant savings of any class in the peak period is consistent with more congestion and slower moving vehicles. Auckland has considerable congestion in the peak periods with slow-moving vehicles along its roads. Queues not uncommonly extend the whole block length. This would then reduce the number of serious and minor injury crashes but probably increase ‘turning’ crashes and ‘rear end’ crashes, which are prevalent in peak periods.

4.4.5 Effects of Flush Median Width on Crashes

The width of flush medians influences the difficulty and speed with which vehicles can leave the adjacent through-traffic lane. The results show that median width causes no obvious difference in crash changes within the injury classes. The most obvious difference between median widths was in the non-injury class, with median widths less than 2 m showing a large crash reduction. As indicated in the B/C analysis, narrow medians achieve twice the B/C ratio of the wider medians. Most of this benefit is attributed to savings in fatal crashes.

These results, therefore, show that narrow medians are better to use than wider ones. The increased benefit at narrow medians is believed to be related to driver perception, as the driver perceives a narrow flush median to be more dangerous to use and, therefore, uses it with caution. Figure 4.3 illustrates that, even though turning vehicles can not be fully removed from the traffic stream in narrow medians, vehicles will still be able to pass on the inside. Encroaching on the traffic stream may result in more caution being taken by the passing driver, which may explain the large crash cost savings.

The difference in safety performance may also be related to an increase in turning JA and LB crashes at the wider flush median sites. This should be investigated further by reviewing Traffic Crash Reports (TCR) to confirm this. Further work should also be undertaken to identify the optimum flush median width.

Figure 4.3 Safe operation of narrow flush medians.

4.4.6 Effects on Crash Types

Observations from the results show that flush medians have different effects on different crash types. By highlighting the changes in the major crash types, assessment of future benefits from implementation at potential flush median sites can be achieved.

The largest increase in crash percentage has been observed in 'rear end' crashes at queues (FD). The FD group of crashes resulted in a $2.3 million increase in crash costs (Table 4.5). Implementation of flush medians has frequently resulted in a reduction in the number of lanes at a site, and this has therefore decreased headways and reduced capacity. As a result queues at major intersections may have been extended, providing more opportunity for rear-end crashes. The dramatic increase in crashes may also have resulted because, in the 'before' period, queues were contained within the approaches to signalised intersections and were consequently removed from the study cordon. Following flush median implementation and the resulting increase in queue lengths, rear-end crashes resulting from queuing at traffic signals may have been pushed into the study cordon.

In contrast, rear-end crashes involving right-turning vehicles (GD) have been observed to have the largest percentage reduction and achieved savings of \$6.8 million. With the implementation of flush medians, right-turning vehicles are removed from the through-traffic stream, therefore taking away the opportunity for such crashes.

The largest crash cost savings were seen in 'loss of control' crashes and 'head on' crashes on bends (\$28.8 million) (Table 4.5). Savings were observed in all crash severity classes for these crash types. Importantly, this category contained 7 of the 'before' period fatal crashes, and only 2 'after' crashes. This apparent reduction in fatalities has contributed to the larger crash cost savings observed. It is believed that the savings observed with flush median implementation could result from the increased constriction perceived by drivers, resulting in more caution and lower vehicle speeds. Flush medians also provide better delineation than a centre lane alone, and this may have also assisted in flush medians reducing these types of crashes. Flush median installation also moves the tracking path of vehicles further to the left where the camber may be better for vehicle stability. The increased separation of traffic flows probably accounts for the reduction in head on crashes.

Large savings were also achieved for the pedestrian-related crashes NA and NB (\$14.8 million) (Table 4.5). These categories observed 11 fatal crashes in the 'before' period while only 4 in the 'after' period. Implementation of a flush median provides protection to pedestrians and reduces the conflict area for potential crashes. Implementation of pedestrian-refuge islands would also have contributed to the observed savings. Again, reduction in severity may be attributed to lower vehicle speeds resulting from constriction in lane width and better delineation.

Finally, right-turning crashes (JA and LB) were observed to consistently increase over the three severity classes analysed, resulting in an increased crash cost of \$9.3 million. The JA type (right-turn right-side) may have resulted from a reduction in visibility, as the centre line and lane lines will have been shifted further toward the kerb side following flush median implementation. Flush median installation may also have encouraged previously undesirable manoeuvres, possibly increasing these types of crashes. Therefore if JA problems are identified, visibility should be investigated and increased if required through removing adjacent parking. If a number of JA or LB crashes are identified at an intersection, investigation should be made into installation of high-friction grip surfacing on the problem approach.

4.4.7 Future Implementation

The analysis of 50 Auckland City sites, where flush medians have been implemented, overall have achieved a significant economic benefit in safety. However, the concern still is that crashes increased at several sites.

- Fatal crashes increased at 11 sites;
- Serious injury crashes increased at 19 sites;
- Minor injury crashes increased at 27 sites; and
- Non-injury crashes increased at 18 sites.

Assessment of crash types provides the strongest means of ensuring successful implementation of flush medians. This study has identified several target crash types, which have been significantly influenced by their presence. Assessment of the numbers and proportions of these crashes should be undertaken at the preliminary assessment stage of flush median implementation in order to identify:

1. Whether a flush median is appropriate at a site; and
2. What should be incorporated in the design to ensure crashes do not increase?

In order to achieve this, a preliminary guideline for the safer use of flush medians has been included as Appendix F, which summarises the important findings of this study.

5. Regression Analysis

5.1 Introduction

Formation of accurate crash prediction models would provide quantitative guidance in the assessment of sites for potential flush median implementation. This investigation has provided a preliminary analysis of the potential of such models, and identified areas of concern that require further investigation.

Analysis has been carried out to investigate whether crash rates can be predicted from the values of certain variables for a section of road. Investigation sites were made up of the 50 sites identified in Section 3 of this report. For these sites several explanatory variables were obtained for use in the prediction analysis. Section length, traffic flow, access densities, and intersection densities were all used in the analysis. A time trend was also adopted for all the predictive equations.

The analysis undertaken was of a very preliminary nature and only log-linear models relating the response variables (crashes) to the explanatory variables were considered.

5.2 Methodology

5.2.1 Data Collection

For each of the 50 sites investigated, the number of crashes in a period before the installation of the flush median, and the number of crashes in a period after the installation of the flush median were recorded. These data are the same as that used in the earlier site analysis. Crash data for the calendar year in which the installation took place were not used in the predictive analysis.

Several explanatory variables were then calculated for each of the sites. Historical traffic flow data were collected from several sources to estimate representative flows for the 'before' and 'after' analysis periods. Tube counts were obtained from the Auckland City Council, and the RAMM databases. Sydney Co-ordinated Adaptive Traffic System (SCATS) counts were obtained from Auckland City, Traffic and Roading Services. Five-day average daily traffic (ADT) values were collected from 1985 to 2001, although availability of information for different sections differed significantly. All historical data in the vicinity of, or believed to be representative of, study sections were collected. Using these data, best estimate ADT values were then calculated for each of the individual flush median sites.

Investigation was then made into the seasonal variations of the traffic flow data. Several Auckland sites with continuous monthly traffic counts were obtained and monthly variations calculated for individual years. Only minor variations in the ADT were found to have occurred from February to November. However, January showed a significant decrease while December showed an increase. This finding is consistent with that observed by Douglass & McKenzie (2001) for metropolitan localities and suburban areas in a national study. Therefore January and December counts were adjusted accordingly so as not to distort historical trends.

The historical flow data collected for flush median sections were then graphed, a linear best-fit line applied and growth rates analysed for any anomalies. Where little data was available at a section, growth rates calculated for adjacent road sections were used to factor the counts. Following final adjustment, the graphs were used to interpolate representative flows for the 'before' and 'after' periods for each flush median section. These flows were taken at the midpoints of the 'before' and 'after' periods.

T-intersection, cross-intersection and private access points were estimated for each flush median section from GIS aerial photographs. These were then adjusted to densities by dividing by the section length.

For the purpose of the analysis:
Response variables
fat = Number of fatal crashes.
ser = Number of serious crashes.
min = Number of minor injuries.
non = Number of non-injury crashes.

Explanatory variables
date.adj.inj = Mid-point of the (fatal and injury crash) time period relative to mid-1990.
date.adj.non = Mid-point of the (non-injury crash) time period relative to mid-1990.
flush = Presence or absence of flush median (factor).
period.l = Length of time period for fatal and injury crashes.
t.flow = Mean traffic flow.
l.sect.l = Logarithm of the section length (km).
access.dens = Density of access ways (side road intersections, driveways) per unit length of road section.
t.dens = Density of T intersections per unit length of road section.
x.dens = Density of cross intersections per unit length of road section.

Preliminary analysis indicated that log of section length resulted in a better fit for the analysis. Initial investigation also identified that there were some high correlations between the section lengths, the number of access ways, number of T intersections, and the numbers of cross intersections. Therefore covariates access.dens, t.dens and x.dens were defined. Densities of these (obtained by dividing by section length) were used as covariates to reduce these correlations.

A high correlation (–0.883) between date.adj.inj and the flush factor was also a concern (Appendix E). This has resulted in difficulty in distinguishing between the effects of the flush median and the time reduction in crash rate in the models.

5.2.2 Predictive Models

The model used in the analysis was log-linear with Poisson errors. Therefore the effects in the model are multiplicative on the mean number of crashes in any observed period. The earlier analyses showed strong decreasing trends in crashes with time. These trends (in injury and fatal crashes) went against the trend of increasing traffic flows at the sites.

To allow for a time trend in the predictive crash rate, the mean rate of crashes is assumed to be approximately proportional to the length (l) of the observed time interval, multiplied by the discounting factor that is an exponential function of the distance (t) of the mid-point of the interval from the mid-point of the base year, which is taken as 1990.

$$\mu \propto l e^{\beta t}$$

where:

l is the length of the time interval,
t is the mid-point relative to mid-1990, and
β is a coefficient representing the trend in crash rate.

Equivalently this suggests that there is a linear trend

$$\log(\mu) = \text{const} + \log(l) + \beta t$$

Because log(l) has no unknown coefficient, it is treated in the analysis as an offset variable (one which is added to the model but for which the coefficient is fixed to be 1).

Assuming the effects of the other variables (t.flow, sect.l, t.dens, x.dens, access.dens) are linear in the logarithm of the mean, in the model, the mean μ is given by:

$$\log(\mu) = \log(\text{period.l}) + \beta_0 + \beta_1\text{flush} + \beta_2\text{date.adj} + \beta_3\text{l.sec.l} + \beta_4\text{t.flow} + \beta_5\text{t.dens} + \beta_6\text{x.dens} + \beta_7\text{access.dens}$$

The full model has 8 coefficients in all (β_0 is the intercept, β_1 is the flush median effect, β_2 is the exponential time trend coefficient, and log(l) is an offset variable with a predetermined coefficient of 1).

In the analysis, a backwards-stepwise method was used to check which, if any, coefficients added little or nothing to the model, from which a reduced model was formed. However, the mid-point (date.adj) and ‘flush’ variables were always included. As stated before, the variable and the mid-points of the observation intervals were highly correlated (in no case was a site observed for a period with a flush median, then the flush median was removed, and the site observed at a later period). For this reason, all models considered have both variables present. This has had the effect of increasing the standard errors of both variables.

5.3 Results

Overall comparison of the best-fit models shows some inconsistency between crash severity classes. The implementation of a flush median, while keeping all other explanatory variables the same, has resulted in decreases in crashes in the fatal and serious injury classes while increasing the minor injury and non-injury classes. Differences in models were observed as a reduced model obtained the best fit for both the fatal and serious injury crashes as shown below, while all explanatory variables were maintained for the minor injury and non-injury classes.

Analysis of the explanatory variables has shown that the 'log of the section length' has contributed to most of the deviance for all of the models, making it the most important variable in the prediction. For the serious injury model, the coefficient is very close to 1, indicating that the mean number of crashes is simply proportional to the length of the section. Access density (number of accesses to length) has been included in all models except for fatal injuries and has been assigned negative coefficients in each, thus indicating a saving in mean crash rate with increased number of accesses.

The serious, minor and non-injury models all showed evidence of over-dispersion as the residual deviance was much larger than the degrees of freedom for each.

The best-fit models for the four injury classes have been included below. Appendix E describes the full models and coefficients calculated, and the Bayesian Information Criterion (BIC) that was used to determine the model that best fits the data.

Fatal Crashes
BIC criterion-reduced model:

The mean number of fatal injury crashes:

$$= \exp(\log(\text{period l}) - 2.19628 - 0.51148 \times \text{flush} - 0.07579 \times \log(\text{sect.l}))$$

Note: 'flush' takes the value 1 when the flush median is present and 0 when it is not. For prediction purposes the length of the observation period (period l) is usually 1 year and so log(period l) = 0.

The predictive power of the model has been found to be limited as only 11.1% of the 'variation' is explained. By keeping all variables at their same values, a change from no median to a flush median results in a 40.0% reduction in fatal crashes. However, all these observations are only possible trends as apart from the 'log of the section length' variable, the model does not produce significant coefficients.

Serious Injury Crashes
BIC criterion-reduced model:

The mean number of serious injury crashes:

$$\begin{aligned} = \; & \exp(\log(\text{period.l}) - 0.3857 - 0.3041 \times \text{flush} - 0.06684 \times \text{date.adj} + \\ & 0.9525 \times \log(\text{sect.l}) + 3.685\text{e}{-05} \times \text{t.flow} - 4.960\text{e}{-03} \times \text{access.dens}) \end{aligned}$$

The BIC criterion analysis of serious injury crashes resulted in an explained deviance of 46.9%. The variables 'l.sect.l', 't.flow', and 'access.dens' were all found to have significant coefficients in the reduced model. The implementation of a flush median can be seen to have an effect of a 26.2% reduction in serious injury crashes.

Minor Injury Crashes
For the minor injury analysis all variables contributed to the fit, and the stepwise analysis showed that removing the variable explaining the least amount of deviance (traffic flow) increases the BIC. Therefore, the full model was used as described below.

The mean number of minor injury crashes:

$$= \exp(\log(\text{period.l}) - 0.3186 + 0.3820 \text{ x } \text{flush} - 0.08717\text{date.adj} + 0.9576 \text{ x } \log(\text{sect.l}) + 2.927\text{e}{-}05 \text{ x } \text{t.flow} + 0.05391 \text{ x } \text{t.dens} + 0.1780 \text{ x } \text{x.dens} - 6.487\text{e}{-}03 \text{ x } \text{access.dens})$$

The full model explains 59.3% of the deviance, representing a reasonable amount of predictive power. All variables had highly significant coefficients in the model. The prediction of flush median implementation results in a 46.5% increase in crashes, with all other factors kept the same.

Non-Injury Crashes
All variables contribute to the fit, and the stepwise analysis showed that removing the variable explaining the least amount of deviance (access density) increased the BIC value. The full model is therefore as follows.

The mean number of minor injury crashes:

$$= \exp(\log(\text{period.l}) + 1.532 + 0.2655 \text{ x } \text{flush} - 0.08178 \text{ x } \text{date.adj} + 0.8315 \text{ x } \log(\text{sect.l}) + 3.343\text{e}{-}05 \text{ x } \text{t.flow} + 0.04790 \text{ x } \text{t.dens} + 0.1448 \text{ x } \text{x.dens} - 3.861\text{e}{-}03 \text{ x } \text{access.dens})$$

The full model explains 63.5% of the deviance, which represents strong predictive power. Again, all variables were found to be significant. However, the installation of a flush median at a site where all other factors are kept the same, results in a 30.4% increase in crashes.

5.4 Discussion

Unless data is collected from a carefully designed experiment, cause and effect relationship may be difficult to determine. Traffic engineering data hardly ever arises from a designed experiment, as is the case for the flush median-site data. In any model developed from data collected where there are high correlations between the explanatory variables, the model may have good predictive power but the coefficients may not carry much physical meaning. This arises because correlated variables stand in for one another in the model. The correlations observed between most of the variables in the flush median models are quite modest. Therefore, one can put some emphasis on the coefficients given.

However, some correlation does exist between the time adjustment variable and the flush median variable. Therefore, although the proportion of deviance explained by some of the model indicates good predictive power, this would need to be established by assessing the performance of the model on a fresh set of sites (with and without flush medians).

In the process of fitting the models, the Poisson probability distribution was used for the variability of the data about the mean. This has resulted in a problem with over-dispersion for all crash types except fatal. Although further modelling involving a random effect can be done to allow for this, it usually does not affect the coefficients and therefore similar predictive values would be obtained.

More important though is whether the simple linear model could be improved. Plots of residuals against the various variables (those with more than 2 different values) could be examined for structure, and if this was confirmed a more complex model should be used. Searching among the broader class of generalised additive models might improve the fit and hence predictive power.

Another improvement might be to use the exact non-linear relationship between the length of the mid-point of the observation interval and the trend coefficient. Any improvement in that part of the model would only help with the estimate of a flush median effect.

Finally, the fact that in some of the crash severity classes, the presence of a flush median appears to increase the crash rate is almost certainly due to the inability of the model to distinguish between the time trend effect and the flush median effect. This arises because all flush median observation times are after the corresponding non-flush median observation times. There is also some correlation between the presence of the flush median and the traffic flows, which generally increase over time. To address this problem, a large number of control sites covering all the time periods could be included as was done in the earlier analysis.

6. Pedestrian Refuge Islands

6.1 Introduction

The analysis to this point has been of all flush medians in the study sample. A subset of this sample are those sections which have had pedestrian refuge islands installed. Analysis has been undertaken to isolate and assess the effects of their implementation on the operation of flush medians.

Pedestrian refuge implementation on flush medians in Auckland City began in the mid-1990s in an effort to improve pedestrian safety. Since then they have been installed in numerous locations throughout Auckland City. Pedestrian refuge islands have been installed for a variety of reasons which did not have a systematic or analytical basis. However suggestions have been made for future systematic implementation of these islands on all flush medians. This raises concerns because the impact of pedestrian refuge islands on pedestrian and vehicle safety is unknown. Therefore, a preliminary investigation has been made into crashes, following which possible remedial measures to address those crashes have been discussed. As a result of this research, preliminary guidelines were produced making suggestions on how to improve the safety of pedestrian refuge islands.

6.2 Procedure

Crashes relating to all current pedestrian refuge islands on flush medians in Auckland City were investigated. CAS-coded listing reports were obtained for injury and non-injury crashes for a 60-m radius around pedestrian refuge islands. Few implementation dates were available for the refuge islands, therefore crashes were investigated from the earliest flush median implemented date of 1988 through to 2000.

Crash types possibly related to pedestrian refuge islands were identified and the corresponding TCRs reviewed. The following target crash types (listed and defined in Appendix A) were investigated:

- F type crashes (Rear end);
- GD type crashes (Turning versus same direction);
- N and P type crashes (Pedestrian);
- JA, KB, LA and LB type crashes (Turning);
- AO, EC and EO type crashes (Collision with objects).

Pedestrian refuge island placement is restricted by the minimum vehicle turning curve allowed into or out of an adjacent access point. The minimum separation of pedestrian refuge islands from access points was investigated for several typical carriageway widths and for two refuge island design types (Appendix F), using the Auckland City District Plan 99 percentile car-turning circles. These were then site-tested to ensure accuracy.

6.3 Results

6.3.1 Pedestrian Refuge Crashes

A total of 23 crashes involving pedestrian refuge islands on flush medians have been identified. These crashes can be broken up into five general categories of crashes.

Vehicles hitting pedestrian refuge islands have been the cause of two crashes. Sun strike was identified as the contributing factor in one of these crashes, and the other involved a vehicle overtaking on a flush median. However this type of crash is believed to have a very low reporting rate. Maintenance records of RG-17 'Keep Left' signs that have been damaged by crashes at pedestrian refuge islands indicate a significantly higher under-reporting rate than is suggested in the Project Evaluation Manual (Transfund New Zealand 1997/2000). For example approximately 140 signs were replaced on the pedestrian refuge islands during 2001.

Vehicles stopping for pedestrians at refuge islands have resulted in seven reported crashes. Driver obligation at pedestrian refuge island, as opposed to zebra crossings, has created confusion in these crashes. Cars have stopped to allow or encourage pedestrians to cross the road. This has then created rear-end crashes, with following vehicles unable to stop (three crashes) or, in multilane situations, following vehicles passing on the kerbside lane have hit the pedestrians (four crashes). Three of the four crashes where pedestrians were hit involved children crossing the road.

Pedestrians walking in front of traffic without looking have resulted in 10 crashes at refuge islands. Five pedestrians have been hit moving off the central island and four moving from the kerbside to cross. A rear-end crash has also resulted from a pedestrian stepping in front of a car. Five of the crashes have involved child pedestrians, and four children have been hit moving off central refuge islands. Only one of the crashes has been at night.

Three crashes involving *vehicles right-turning to and from access points* may have involved substandard island design. GIS aerial photographs have shown that insufficient separation of raised islands from access points has not allowed right-turning vehicles to move onto the flush median. This has resulted in rear end crashes.

One crash has resulted where a child pedestrian has *walked off a refuge island through a centre-lane queue* and has been hit by a vehicle travelling in the kerbside lane. This highlights a more general concern of pedestrians walking through queuing traffic.

6.3.2 Minimum Separation from Access Points

Minimum separation distances were formed using turning circles. The minimum requirement for the distance from the furthermost kerbside of the access point to the end of the pedestrian refuge island was 11 m for type 1 pedestrian refuge islands and 10 m for type 2 islands (Appendix F, in which values for different carriageway widths are also found). The separations detailed there are minimum requirements only, and typical vehicle-through speeds and number of turning movements generated by access points should be considered in the design.

6.4 Discussion

Pedestrian inattention and driver confusion has caused most of the crashes identified at pedestrian refuge islands. The first step in addressing these crashes is through education, in order to help both parties better understand how pedestrian refuge islands operate. Children in particular must be taught the different obligations that apply to refuge islands and zebra crossings. The current school curriculum involving traffic safety should include the operation of pedestrian refuge islands.

Design improvements have also been identified that may help to address some of the crashes reported. Pedestrians walking in front of traffic have resulted in a number of crashes. These crashes may have been influenced by sight lines at the kerbsides and at the pedestrian refuge islands.

It is critical that Approach Site Distance (ASD) and Crossing Sight Distance (CSD) as described in AUSTROADS (1994) is achieved. Parking adjacent to the pedestrian refuge islands may need to be removed to achieve CSD. The AUSTROADS (1994) Guide also highlights that the line of sight should not be obstructed by "street furniture, such as poles, mailboxes, telephone booths, trees, decorative planters, etc. However minor obstructions, such as posts, poles and tree trunks, that are less than 200 mm diameter within the line of sight may be ignored". An audit of existing islands should be undertaken to ensure adequate sight distances have been achieved and remedial steps taken if islands are found to be substandard.

Most of the crashes involving pedestrians walking off central refuge islands have involved children. One possible reason could be that children may be hidden from the view of drivers by the RG-17 'Keep Left' signs on the islands. This concern is also highlighted by AUSTROADS (1994). It is therefore recommended that a 300 mm by 600 mm RG-17.1 'Keep Left' sign be used to replace the existing 600 mm RG-17 at islands with high child pedestrian use. These should be positioned at least 600 mm from the left kerb of the island (for approaching drivers), as this will maximise the visibility of pedestrians waiting to cross from the island.

Proximity of pedestrian refuge islands to access points has also been identified as a concern. Turning vehicles access to the flush median can be restricted by placement of the islands, causing the vehicles to encroach on the through-traffic lane. This can then result in rear-end crashes. Appendix F shows tables and diagrams detailing minimum distances that have been developed to address this problem. Vehicle tracking should also be investigated for all movements where pedestrian refuge islands are being implemented near intersections. Design should also ensure appropriate manoeuvre speeds can be achieved for the site environment.

Maintenance records have indicated that vehicles hitting refuge islands is also a concern. This is thought to be predominantly an overtaking problem possibly occurring with more frequency at night. In order to address these crashes, a yellow reflectorised no-overtaking line should be installed for a length on the approaches to pedestrian refuge islands. Lighting levels at the islands should also be in accordance with the values described in the Australian/New Zealand Standards for Road Lighting (AS/NZS 1158.1.1:1997 and AS/NZS 1158.3.1:1999).

To further increase the visibility of the pedestrian refuge islands at night, yellow mono-directional raised reflectorised pavement markers (rrpms) should be installed at 1-m intervals on the no-overtaking lines approaching the pedestrian refuge islands. Installation of rrpms at close spacings will also increase driver recognition during the night and day by their physical impact when vehicles cross the flush median edge line. At sites where high numbers of collisions are occurring, additional white bi-directional rrpms should be installed at 0.5-m spacings on the diagonal flush median bars to further increase driver recognition of the potential hazard. Figures 6.1 and 6.2 illustrate the visual impact of installation of rrpms on no-overtaking lines and diagonal flush median bar markings.

Education of drivers and pedestrians combined with the implementation of the described design measures should reduce pedestrian refuge island-related crashes. The measures recommended are low cost and can be implemented easily.

Figure 6.1 Standard pedestrian refuge island at night.

Figure 6.2 Pedestrian refuge island with no-overtaking line and rrpms on approaches, at night.

7. Conclusions

7.1 Crash Severity

- Overall saving of $35.2 million with a B/C of 30.2 has been achieved with the implementation of flush medians at 50 Auckland City sites studied using the GLM analysis method.
- Flush medians have clearly reduced the severity of crashes with reduction in fatal, serious and non-injury crashes of 28%, 7%, and 10% respectively, with an increase of 7% in minor injury crashes using the GLM method.
- Only a 2% saving in total crash frequency was observed with an increase of 2% in injury and a 3% decrease in non-injury crashes (using the traditional method).
- Flush medians appear to have had a calming affect that has reduced the severity of crashes. This could be related to a slowing down of vehicle speed with a better defined and constricted route, which has also resulted in improved driver discipline.
- Crashes at some of the 50 flush median sites have increased:
  - at 11 sites for fatal crashes;
  - at 19 sites for serious injury crashes;
  - at 27 sites for minor injury crashes; and
  - at 18 sites for non-injury crashes.

7.2 Effects of Night-time and Daytime on Crashes

- Flush medians have reduced the severity of crashes at night more than during the daytime. The reduction has been 37% and 19% in fatal and serious crashes at night, but only 18% and 12 % reduction during the day (GLM analysis method).
- Greater cost savings have been achieved by installing flush medians that reduce night-time crashes despite significantly less crash numbers than those during the daytime.
- The reduction in night-time crashes is thought to be mostly related to reductions in the 'loss of control' and 'head-on' crashes.

7.3 Effects of Peak and Off-peak on Crashes

- Flush medians appear to have reduced crashes in the off-peak periods, while resulting in an increase in crashes in the peak periods.
- An increase in the cost of crashes ($4.5 million using GLM analysis method) has occurred in the peak periods, with a significant saving in the off-peak periods ($49.5 million using GLM analysis method).

- In the peak period, crashes have decreased in all crash severity classes except for fatal crashes, where low numbers may have distorted the results.
- In the off-peak periods, crash frequencies have decreased in the fatal, serious and non-injury classes, while increasing in the minor injury.

7.4 Effects of Flush Median Width on Crashes

- Narrow flush medians have resulted in crash savings of $14.4 million (10 sites) with a B/C of 55.8, while wider medians have resulted in crash savings of $20.9 million and a B/C of 24.0 (using the traditional method).
- Narrow flush medians made up approximately 28% of crashes, but however resulted in 40% of the total cost saving (traditional method).
- Greater crash savings for narrow medians may be related to driver perception. Drivers may perceive them to be less safe and therefore use them with caution resulting in higher crash savings.

7.5 Effects on Crash Types

Flush medians resulted in major crash cost savings in 7 crash types.
The largest cost savings occurred as follows:

- Bend - lost control
  - turning right (DA) $12.1 million
  - turning left (DB) $10.5 million
  - head on (BF) $6.2 million
- Pedestrian
  - left side (NA) $4.5 million
  - right side (NB) $10.3 million
- Rear end / object
  - near centre line (GD) $6.8 million
- Crossing
  - right angle (HA) $1.4 million

Flush median implementation has greatly reduced fatal crashes in the 'bend – lost control' and 'pedestrian' crash types. Eighteen of the total 24 fatal crashes in the 'before' implementation period were observed in these groups while only 6 in the 'after' period.

The largest cost increases occurred in the following crash types:

- Turning
  - right turn right side (JA) $4.7 million
  - making turn (LB) $6 million
- Rear end obstruction
  - queue (FD) $2.3 million

7.6 Turning Crashes

- The greatest increase in crash cost occurred for turning crashes (JA and LB) type.
- The reduction in visibility by moving traffic lanes closer to the kerb, with the implementation of flush medians, could be contributing to the increase in turning crashes.
- By improving the friction of the pavement (e.g. friction grip), and improving visibility (e.g. removing obstructions, etc.), would reduce most of the turning problems.

7.7 Pedestrian Crashes

- Flush medians appear to have reduced the severity of pedestrian crashes.
- Pedestrian refuge islands may make it safer for pedestrians.
- Design guidelines have been developed for improved pedestrian refuge islands (see Appendix F).
- Maintenance records have shown that a significant number of non-reported crashes occur where signs have been knocked down at pedestrian refuge islands.

8. Recommendations

- This study should be distributed to all controlling authorities as improved crash savings are most likely to result from the guidance given in this report.

- Flush medians should continue to be used in New Zealand as a traffic control device to improve safety and operational efficiency. However, assessment of crash types should be used to analyse the potential benefits of flush median implementation at potential sites. The findings of this study should be used to identify the likely savings and increases in crashes by crash type. In anticipation of likely increases in certain types of crashes, investigation should be made into possible problem locations, and to implement the counter measures suggested in this report.

- Efforts should be made to educate both drivers and pedestrians on the function of pedestrian refuge islands. These efforts should be focused on school children. Design of the islands should also be improved to increase sight lines for drivers and pedestrians.

  Raised reflectorised pavement markers should be installed on approaches to pedestrian refuge islands to increase driver awareness through their visual and physical impact. It is also recommended that the design guide in Appendix F be used to aid the placement of pedestrian refuge islands on flush medians. The separations detailed there should be used as minimum requirements for safe operation.

- Designers of flush medians should use the 'Preliminary Guidelines for Safer Flush Medians' given in Appendix F as this could result in substantial crash savings. It is also recommended that these guidelines should be developed further.

- Severity analysis of crashes should be analysed in any future 'before' and 'after' studies of traffic safety devices.

- A review should be undertaken to assess the most appropriate methodology for 'before' and 'after' study analysis in New Zealand. Further development of the Generalised Linear Modelling method described in this report should be undertaken and an observational 'before' and 'after' study guideline be developed. This will enable economic evaluation of devices through benefit/cost analysis.

- Further analysis should be undertaken to identify improved models for crash prediction of flush medians.

- Further work should be undertaken as outlined in Appendix F in this report.

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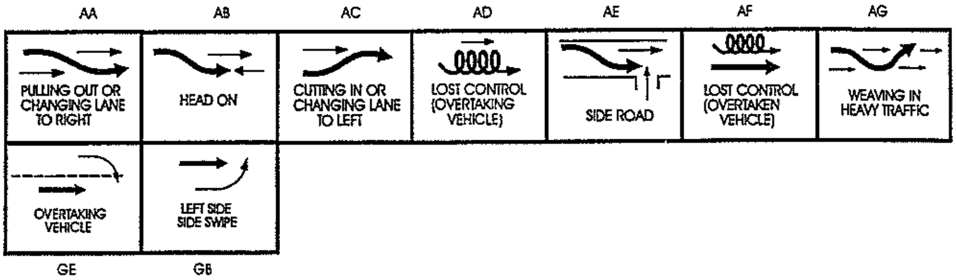
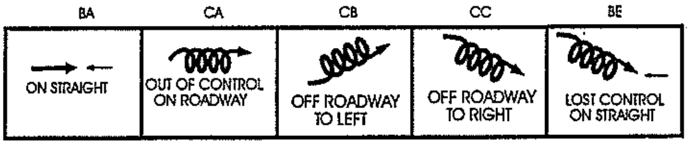
Appendices

Appendix A LTSA Vehicle Movement Coding Sheet

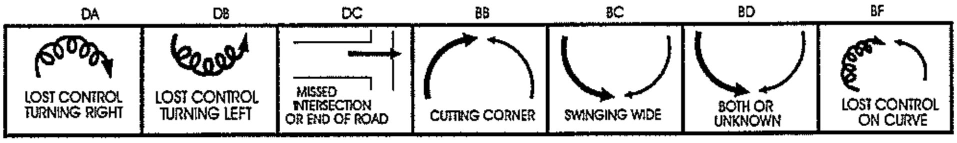
Overtaking



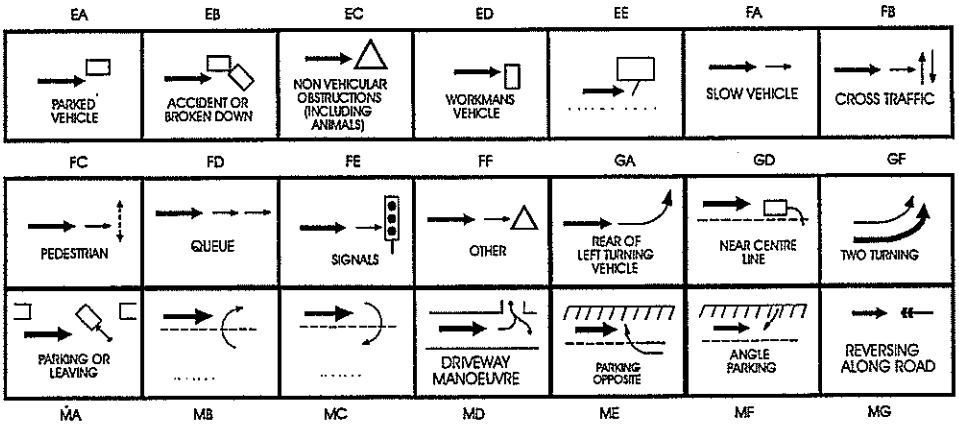
Straight - Lost Control / Head On



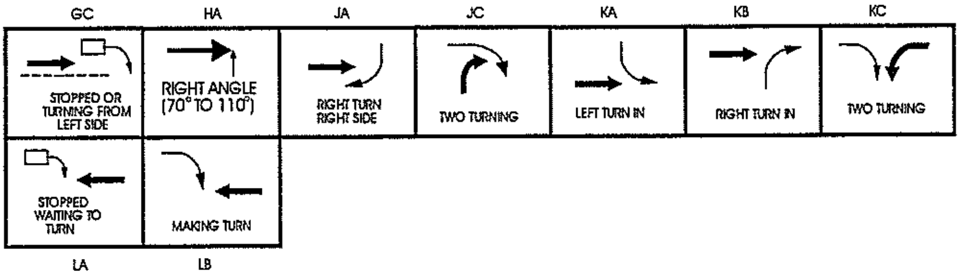
Bend - Lost Control / Head on



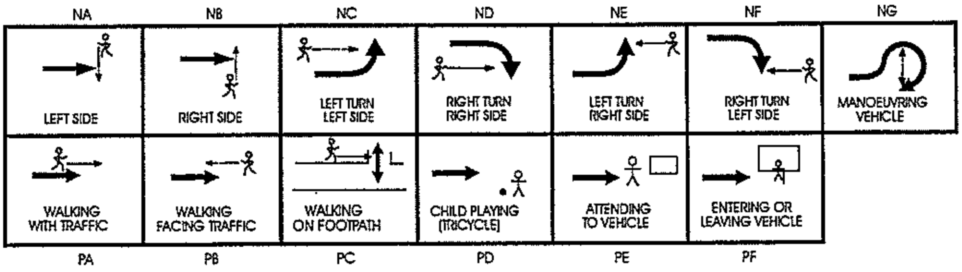
Rear End / Obstruction



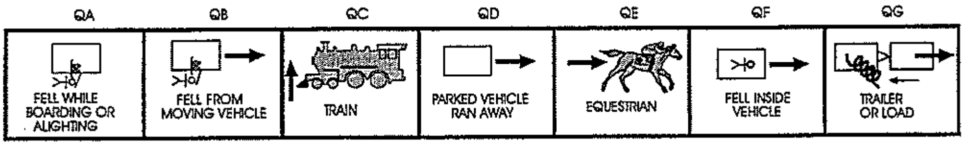
Crossing / Turning



Pedestrian vs Vehicle



Miscellaneous



Appendix B Traditional Analysis Results

Table B1. Flush Median Site List

Site Number and Site Name	Impl Date
Site: 1 BALMORAL:SANDRINGHAM-DOMINION	1992
Site: 2 BALMORAL:DOMINION-MT EDEN	1992
Site: 3 BALMORAL:MT EDEN-ST ANDREWS	1992
Site: 4 BROADWAY:DAVIS-KHYBER PASS	1993
Site: 5 DOMINION:BALMORAL-MT ALBERT	1992
Site: 6 GT NORTH:ST LUKES-HUIA	1990
Site: 7 GT SOUTH:GREENLANE-CAMPBELL	1988
Site: 8 GT SOUTH:CAMPBELL-ROCKFIELD	1988
Site: 9 GT SOUTH:KALMIA-MOTORWAY INT'CHANGE	1988
Site: 12 JERVOIS:WHARF-KELMARNA	1993
Site: 13 JERVOIS:WALLACE-CURRAN	1993
Site: 14 JERVOIS:WHARF-WEST END	1992
Site: 15 KOHIMARAMA:KEPA-ALLUM	1994
Site: 16 KOHIMARARA:ALLUM-ST HELIERS BAY	1994
Site: 17 MANUKAU:ALPERS-RANFURLY	1991
Site: 18 MANUKAU:RANFURLY-GREENLANE	1991
Site: 19 MANUKAU:NGAROMA-CAMPBELL	1992
Site: 20 MT ALBERT:NEW NORTH-SANDRINGHAM	1993
Site: 21 MT ALBERT:MANUKAU-CROWN	1989
Site: 22 MT EDEN:BALMORAL-DUKE	1989
Site: 23 MT EDEN:DUKE-MT ALBERT	1991
Site: 24 MT EDEN:BOSTON-VALLEY	1992
Site: 25 MT EDEN:GRANGE-BALMORAL	1993
Site: 26 MT SMART:MANUKAU-ONEHUNGA MALL	1992
Site: 27 MT WELLINGTON:MONAHAN-PANAMA	1989
Site: 28 MT WELLINGTON:PANAMA-PORTAGE	1989
Site: 29 MT WELLINGTON:ARANUI-HAMLIN	1992
Site: 30 NEW NORTH:BLOCKHOUSE BAY-RICHARDSON	1992
Site: 31 NEW NORTH:RICHARDSON-MT ALBERT	1992
Site: 32 NEW NORTH:MT ALBERT-ST LUKES	1992
Site: 33 NEW NORTH:ST LUKES-MORNINGSIDE	1992
Site: 34 NEW NORTH:MORNINGSIDE-SANDRINGHAM	1992
Site: 35 NEW NORTH:SANDRINGHAM-DOMINION	1992
Site: 36 PAH:ALBERT-ORAKAU	1993
Site: 37 PARNELL:ST STEPHENS-PARNELL RISE	1992
Site: 38 PONSONBY:FRANKLIN-POMPALLIER	1992
Site: 39 PONSONBY:PICTON-FRANKLIN	1993
Site: 40 PONSONBY:HEPBURN-PICTON	1993
Site: 43 PRINCES:WELLESLEY-WATERLOO	1991
Site: 44 PT CHEVALIER:MEOLA-GT NORTH	1994
Site: 45 QUEEN:MAYORAL-K ROAD	1991
Site: 46 REMUERA:LADIES MILE-UPLAND	1993
Site: 47 REMUERA:UPLAND-KELVIN	1993
Site: 48 SANDRINGHAM:BALMORAL-MT ALBERT	1993
Site: 49 SANDRINGHAM:BALMORAL-ROSSMAY	1993
Site: 50 SANDRINGHAM:ROSSMAY-NEW NORTH	1994
Site: 51 ST STEPHENS:PARNELL-GLADSTONE	1994
Site: 52 TAMAKI:NGAPIPI-RONAKI	1993
Site: 53 TAMAKI:RONAKI-VALE	1993
Site: 54 WILLIAMSON:POLLEN-COLERIDGE	1993

Table B2. Analysis of crash severity for all crashes.

	Implementation	Crash Controls CD				Fatal Injury Crashes				Serious Injury Crashes				Minor Injury Crashes				Non-Injury Crashes			
Site	Date	Fatal	Serious	Minor	Non	Before	After	Exp -Aft	%Change	Before	After	Exp -Aft	%Change	Before	After	Exp -Aft	%Change	Before	After	Exp -Aft	%Change
1	1992	0.72	0.59	0.86	1.62	2	0	1.44	-100.00	3	4	1.76	127.42	3	9	2.57	250.70	14	41	22.61	81.33
2	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	3	0	1.76	-100.00	17	14	14.54	-3.73	36	51	58.14	-12.28
3	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	4	2	2.35	-14.72	5	1	4.28	-76.62	14	11	22.61	-51.35
4	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	3	7	2.54	175.21	12	26	14.96	73.80
5	1992	0.72	0.59	0.86	1.62	1	1	0.72	39.29	10	8	5.86	36.45	52	36	44.48	-19.07	81	161	130.82	23.07
6	1990	0.69	0.52	0.87	4.98	0	0	0.00	-	9	2	4.65	-56.99	20	15	17.37	-13.65	9	55	44.81	22.74
7	1988	0.65	0.60	0.99	-	0	0	0.00	-	6	2	3.60	-44.38	8	19	7.95	139.06	-	-	-	-
8	1988	0.65	0.60	0.99	-	0	1	0.00	-	5	2	3.00	-33.25	8	5	7.95	-37.09	-	-	-	-
9	1988	0.65	0.60	0.99	-	0	0	0.00	-	5	0	3.00	-100.00	6	5	5.96	-16.12	-	-	-	-
12	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	2	0	1.20	-100.00	1	2	0.85	135.89	4	5	4.99	0.27
13	1993	0.83	0.60	0.85	1.25	1	0	0.83	-100.00	1	2	0.60	234.53	6	22	5.09	332.47	38	33	47.37	-30.34
14	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	2	0	1.17	-100.00	4	6	3.42	75.35	6	8	9.69	-17.44
15	1994	0.84	0.62	0.85	1.04	2	0	1.68	-100.00	2	0	1.25	-100.00	5	2	4.25	-52.90	21	26	21.83	19.11
16	1994	0.84	0.62	0.85	1.04	0	1	0.00	-	2	4	1.25	220.57	3	3	2.55	17.74	23	16	23.91	-33.07
17	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	7	2	3.72	-46.26	17	21	14.77	42.21	20	81	48.28	67.79
18	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	4	4	2.13	88.08	20	14	17.37	-19.41	16	59	38.62	52.77
19	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	6	5	3.52	42.14	18	8	15.40	-48.04	33	34	53.30	-36.21
20	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	4	5	2.39	109.08	11	12	9.33	28.67	51	66	63.58	3.81
21	1989	0.64	0.54	0.88	-	0	2	0.00	-	7	2	3.79	-47.19	7	7	6.17	13.42	-	-	-	-
22	1989	0.64	0.54	0.88	-	1	1	0.64	56.25	5	1	2.71	-63.04	22	14	19.40	-27.82	-	-	-	-
23	1991	0.68	0.53	0.87	2.41	1	0	0.68	-100.00	6	0	3.19	-100.00	9	4	7.82	-48.83	4	17	9.66	76.07
24	1992	0.72	0.59	0.86	1.62	1	1	0.72	39.29	14	9	8.21	9.65	35	21	29.94	-29.86	39	68	62.99	7.96
25	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	4	0	2.39	-100.00	5	6	4.24	41.54	24	35	29.92	16.98
26	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	3	0.59	411.69	3	2	2.57	-22.07	12	14	19.38	-27.76
27	1989	0.64	0.54	0.88	-	0	1	0.00	-	4	0	2.16	-100.00	4	2	3.53	-43.29	-	-	-	-
28	1989	0.64	0.54	0.88	-	0	0	0.00	-	2	1	1.08	-7.59	9	8	7.93	0.82	-	-	-	-
29	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	7	3	4.10	-26.90	20	11	17.11	-35.71	38	48	61.37	-21.79
30	1992	0.72	0.59	0.86	1.62	2	0	1.44	-100.00	5	2	2.93	-31.77	9	14	7.70	81.84	26	77	41.99	83.37
31	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	2	1	1.17	-14.72	0	14	0.00	-	19	63	30.69	105.30
32	1992	0.72	0.59	0.86	1.62	1	0	0.72	-100.00	5	6	2.93	104.68	19	30	16.25	84.58	52	97	83.98	15.50
33	1992	0.72	0.59	0.86	1.62	2	0	1.44	-100.00	3	0	1.76	-100.00	3	1	2.57	-61.03	9	16	14.54	10.07
34	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	2	1	1.17	-14.72	10	17	8.55	98.73	31	46	50.07	-8.12
35	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	9	0.86	952.09	14	21	22.61	-7.12
36	1993	0.83	0.60	0.85	1.25	3	0	2.49	-100.00	1	2	0.60	234.53	12	4	10.17	-60.68	34	33	42.39	-22.14
37	1992	0.72	0.59	0.86	1.62	1	0	0.72	-100.00	2	0	1.17	-100.00	18	10	15.40	-35.06	38	52	61.37	-15.27
38	1992	0.72	0.59	0.86	1.62	2	0	1.44	-100.00	5	3	2.93	2.34	20	15	17.11	-12.33	40	52	64.60	-19.51
39	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	4	3	2.39	25.45	7	9	5.93	51.65	42	44	52.36	-15.96
40	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	2	2	1.20	67.26	2	5	1.70	194.87	17	27	21.19	27.40
43	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	2	0	1.06	-100.00	3	4	2.61	53.50	3	30	7.24	314.29
44	1994	0.84	0.62	0.85	1.04	1	0	0.84	-100.00	2	1	1.25	-19.86	5	9	4.25	111.94	31	22	32.22	-31.72
45	1991	0.68	0.53	0.87	2.41	1	0	0.68	-100.00	5	2	2.66	-24.77	23	20	19.98	0.11	47	93	113.45	-18.02
46	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	2	1	1.20	-16.37	5	5	4.24	17.95	9	6	11.22	-46.52
47	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	2	2	1.20	67.26	10	4	8.48	-52.82	30	19	37.40	-49.20
48	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	6	6	3.59	67.26	13	12	11.02	8.87	56	56	69.81	-19.78
49	1993	0.83	0.60	0.85	1.25	0	1	0.00	-	3	4	1.79	123.02	13	12	11.02	8.87	47	49	58.59	-16.37
50	1994	0.84	0.62	0.85	1.04	0	1	0.00	-	3	2	1.87	6.86	1	12	0.85	1312.92	25	21	25.99	-19.19
51	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	5	5	4.25	17.74	10	9	10.39	-13.41
52	1993	0.83	0.60	0.85	1.25	1	2	0.83	141.38	25	16	14.95	7.05	46	34	39.00	-12.82	94	80	117.18	-31.73
53	1993	0.83	0.60	0.85	1.25	1	1	0.83	20.69	14	4	8.37	-52.21	42	25	35.61	-29.79	74	58	92.25	-37.13
54	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	5	1	2.99	-66.55	24	19	20.35	-6.63	81	49	100.98	-51.47
Sum						24	13	18.09	-28.15	226	120	131.18	-8.52	612	565	527.24	7.16	1324	1875	1951.33	-3.91

Table B3. Analysis of crash severity for night time crashes.

						Night Time															
	Implementation	CD Crash Controls				Fatal Injury Crashes				Serious Injury Crashes				Minor Injury Crashes				Non-Injury Crashes			
Site	Date	Fatal	Serious	Minor	Non	Before	After	Exp-Aft	%Change	Before	After	Exp-Aft	%Change	Before	After	Exp-Aft	%Change	Before	After	Exp-Aft	%Change
1	1992	0.72	0.59	0.86	1.62	1	0	0.72	-100.00	2	1	1.17	-14.72	0	3	0.00	-	4	11	6.46	70.27
2	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	0	0.59	-100.00	3	6	2.57	133.80	9	12	14.54	-17.44
3	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	4	2	2.35	-14.72	0	0	0.00	-	3	3	4.85	-38.08
4	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	1	4	0.85	371.79	1	4	1.25	220.86
5	1992	0.72	0.59	0.86	1.62	0	1	0.00	-	3	6	1.76	241.13	19	12	16.25	-26.17	21	44	33.92	29.73
6	1990	0.69	0.52	0.87	4.98	0	0	0.00	-	3	0	1.55	-100.00	5	4	4.34	-7.89	4	12	19.91	-39.74
7	1988	0.65	0.60	0.99	-	0	0	0.00	-	3	0	1.80	-100.00	0	8	0.00	-	-	-	-	-
8	1988	0.65	0.60	0.99	-	0	0	0.00	-	3	1	1.80	-44.38	4	2	3.97	-49.67	-	-	-	-
9	1988	0.65	0.60	0.99	-	0	0	0.00	-	2	0	1.20	-100.00	2	1	1.99	-49.67	-	-	-	-
12	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	0	0	0.00	-	0	2	0.00	-
13	1993	0.83	0.60	0.85	1.25	1	0	0.83	-100.00	0	1	0.00	-	3	5	2.54	96.58	10	14	12.47	12.30
14	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	0	0.59	-100.00	1	1	0.86	16.90	1	3	1.62	85.75
15	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	1	0	0.62	-100.00	2	2	1.70	17.74	11	6	11.43	-47.52
16	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	2	3	1.25	140.43	0	1	0.00	-	10	6	10.39	-42.28
17	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	2	1	1.06	-5.96	5	3	4.34	-30.93	3	21	7.24	190.00
18	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	3	2	1.60	25.38	10	3	8.69	-65.46	4	16	9.66	65.72
19	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	3	2	1.76	13.71	8	3	6.84	-56.16	10	13	16.15	-19.51
20	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	1	0.60	67.26	6	4	5.09	-21.37	16	22	19.95	10.30
21	1989	0.64	0.54	0.88	-	0	0	0.00	-	1	0	0.54	-100.00	3	4	2.64	51.23	-	-	-	-
22	1989	0.64	0.54	0.88	-	0	1	0.00	-	2	0	1.08	-100.00	8	2	7.05	-71.64	-	-	-	-
23	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	2	0	1.06	-100.00	3	2	2.61	-23.25	1	6	2.41	148.58
24	1992	0.72	0.59	0.86	1.62	1	0	0.72	-100.00	6	4	3.52	13.71	14	9	11.98	-24.85	10	24	16.15	48.60
25	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	2	0	1.20	-100.00	2	4	1.70	135.89	4	13	4.99	160.70
26	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	1	0.59	70.56	1	1	0.86	16.90	6	4	9.69	-58.72
27	1989	0.64	0.54	0.88	-	0	1	0.00	-	0	0	0.00	-	1	1	0.88	13.42	-	-	-	-
28	1989	0.64	0.54	0.88	-	0	0	0.00	-	1	0	0.54	-100.00	2	6	1.76	240.27	-	-	-	-
29	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	4	2	2.35	-14.72	5	5	4.28	16.90	6	15	9.69	54.79
30	1992	0.72	0.59	0.86	1.62	2	0	1.44	-100.00	4	1	2.35	-57.36	4	6	3.42	75.35	13	24	21.00	14.31
31	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	0	0.59	-100.00	0	3	0.00	-	4	14	6.46	116.71
32	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	3	0.00	-	6	6	5.13	16.90	8	27	12.92	108.97
33	1992	0.72	0.59	0.86	1.62	2	0	1.44	-100.00	0	0	0.00	-	1	0	0.86	-100.00	4	6	6.46	-7.12
34	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	1	0.59	70.56	2	5	1.71	192.25	11	15	17.77	-15.57
35	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	3	7	4.85	44.47
36	1993	0.83	0.60	0.85	1.25	3	0	2.49	-100.00	0	0	0.00	-	2	1	1.70	-41.03	6	9	7.48	20.32
37	1992	0.72	0.59	0.86	1.62	1	0	0.72	-100.00	1	0	0.59	-100.00	7	4	5.99	-33.20	17	24	27.46	-12.59
38	1992	0.72	0.59	0.86	1.62	1	0	0.72	-100.00	1	2	0.59	241.13	8	9	6.84	31.51	16	20	25.84	-22.60
39	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	1	0.60	67.26	4	3	3.39	-11.54	15	16	18.70	-14.44
40	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	1	0.00	-	1	4	0.85	371.79	5	8	6.23	28.35
43	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	1	8	2.41	231.43
44	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	1	3	0.85	253.23	8	8	8.32	-3.79
45	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	5	1	2.66	-62.38	3	4	2.61	53.50	22	47	53.10	-11.49
46	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	0	0	0.00	-	0	0	0.00	-
47	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	1	0.60	67.26	3	1	2.54	-60.68	10	8	12.47	-35.83
48	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	3	2	1.79	11.51	4	5	3.39	47.43	20	12	24.93	-51.87
49	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	3	3	1.79	67.26	5	3	4.24	-29.23	16	18	19.95	-9.76
50	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	1	1	0.62	60.29	1	4	0.85	370.97	10	8	10.39	-23.03
51	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	1	2	0.85	135.49	4	5	4.16	20.26
52	1993	0.83	0.60	0.85	1.25	0	2	0.00	-	16	7	9.57	-26.82	30	12	25.44	-52.82	47	43	58.59	-26.61
53	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	8	1	4.78	-79.09	15	6	12.72	-52.82	36	21	44.88	-53.21
54	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	2	0	1.20	-100.00	10	10	8.48	17.95	21	13	26.18	-50.34
Sum						12	5	9.06	-44.80	103	52	60.05	-13.40	216	189	185.63	1.82	431	612	633.29	-3.36

Table B4. Analysis of crash severity for day time crashes.

						Day Time															
	Implementation	CD Crash Controls				Fatal Injury Crashes				Serious Injury Crashes				Minor Injury Crashes				Non-Injury Crashes			
Site	Date	Fatal	Serious	Minor	Non	Before	After	Exp-Aft	%Change	Before	After	Exp-Aft	%Change	Before	After	Exp-Aft	%Change	Before	After	Exp-Aft	%Change
1	1992	0.72	0.59	0.86	1.62	1	0	0.72	-100.00	1	3	0.59	411.69	3	6	2.57	133.80	10	30	16.15	85.75
2	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	2	0	1.17	-100.00	14	8	11.98	-33.20	27	39	43.61	-10.56
3	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	5	1	4.28	-76.62	11	8	17.77	-54.97
4	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	2	3	1.70	76.92	11	22	13.71	60.43
5	1992	0.72	0.59	0.86	1.62	1	0	0.72	-100.00	7	2	4.10	-51.27	33	24	28.23	-14.98	60	117	96.90	20.74
6	1990	0.69	0.52	0.87	4.98	0	0	0.00	-	6	2	3.10	-35.49	15	11	13.03	-15.56	5	43	24.89	72.73
7	1988	0.65	0.60	0.99	-	0	0	0.00	-	3	2	1.80	11.24	8	11	7.95	38.40	-	-	-	-
8	1988	0.65	0.60	0.99	-	0	1	0.00	-	2	1	1.20	-16.57	4	3	3.97	-24.51	-	-	-	-
9	1988	0.65	0.60	0.99	-	0	0	0.00	-	3	0	1.80	-100.00	4	4	3.97	0.66	-	-	-	-
12	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	1	2	0.85	135.89	4	3	4.99	-39.84
13	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	1	0.60	67.26	3	17	2.54	568.36	28	19	34.91	-45.57
14	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	0	0.59	-100.00	3	5	2.57	94.83	5	5	8.08	-38.08
15	1994	0.84	0.62	0.85	1.04	2	0	1.68	-100.00	1	0	0.62	-100.00	3	0	2.55	-100.00	10	20	10.39	92.41
16	1994	0.84	0.62	0.85	1.04	0	1	0.00	-	0	1	0.00	-	3	2	2.55	-21.50	13	10	13.51	-25.99
17	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	5	1	2.66	-62.38	12	18	10.42	72.68	17	60	41.03	46.22
18	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	1	2	0.53	276.15	10	11	8.69	26.64	12	43	28.97	48.45
19	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	3	3	1.76	70.56	10	5	8.55	-41.55	23	21	37.15	-43.47
20	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	3	4	1.79	123.02	5	8	4.24	88.71	35	44	43.63	0.84
21	1989	0.64	0.54	0.88	-	0	2	0.00	-	6	2	3.25	-38.39	4	3	3.53	-14.93	-	-	-	-
22	1989	0.64	0.54	0.88	-	1	0	0.64	-100.00	3	1	1.62	-38.39	14	12	12.34	-2.78	-	-	-	-
23	1991	0.68	0.53	0.87	2.41	1	0	0.68	-100.00	4	0	2.13	-100.00	6	2	5.21	-61.63	3	11	7.24	51.91
24	1992	0.72	0.59	0.86	1.62	0	1	0.00	-	8	5	4.69	6.60	21	12	17.96	-33.20	29	44	46.84	-6.06
25	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	2	0	1.20	-100.00	3	2	2.54	-21.37	20	22	24.93	-11.76
26	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	2	0.00	-	2	1	1.71	-41.55	6	10	9.69	3.20
27	1989	0.64	0.54	0.88	-	0	0	0.00	-	4	0	2.16	-100.00	3	1	2.64	-62.19	-	-	-	-
28	1989	0.64	0.54	0.88	-	0	0	0.00	-	1	1	0.54	84.82	7	2	6.17	-67.59	-	-	-	-
29	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	3	1	1.76	-43.15	15	6	12.83	-53.24	32	33	51.68	-36.15
30	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	1	0.59	70.56	5	8	4.28	87.04	13	53	21.00	152.43
31	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	1	0.59	70.56	0	11	0.00	-	15	49	24.23	102.26
32	1992	0.72	0.59	0.86	1.62	1	0	0.72	-100.00	5	3	2.93	2.34	13	24	11.12	115.81	44	70	71.06	-1.50
33	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	3	0	1.76	-100.00	2	1	1.71	-41.55	5	10	8.08	23.83
34	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	0	0.59	-100.00	8	12	6.84	75.35	20	31	32.30	-4.03
35	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	8	0.86	835.19	11	14	17.77	-21.20
36	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	2	0.60	234.53	10	3	8.48	-64.62	28	24	34.91	-31.24
37	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	0	0.59	-100.00	11	6	9.41	-36.24	21	28	33.92	-17.44
38	1992	0.72	0.59	0.86	1.62	1	0	0.72	-100.00	4	1	2.35	-57.36	12	6	10.27	-41.55	24	32	38.76	-17.44
39	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	3	2	1.79	11.51	3	6	2.54	135.89	27	28	33.66	-16.81
40	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	2	1	1.20	-16.37	1	1	0.85	17.95	12	19	14.96	27.01
43	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	2	0	1.06	-100.00	3	3	2.61	15.12	2	22	4.83	355.72
44	1994	0.84	0.62	0.85	1.04	1	0	0.84	-100.00	2	1	1.25	-19.86	4	6	3.40	76.62	23	14	23.91	-41.44
45	1991	0.68	0.53	0.87	2.41	1	0	0.68	-100.00	0	1	0.00	-	20	16	17.37	-7.90	25	46	60.34	-23.77
46	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	1	0.60	67.26	5	5	4.24	17.95	9	6	11.22	-46.52
47	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	1	0.60	67.26	7	3	5.93	-49.45	20	11	24.93	-55.88
48	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	3	4	1.79	123.02	9	7	7.63	-8.26	36	44	44.88	-1.96
49	1993	0.83	0.60	0.85	1.25	0	1	0.00	-	0	1	0.00	-	8	9	6.78	32.69	31	31	38.65	-19.78
50	1994	0.84	0.62	0.85	1.04	0	1	0.00	-	2	1	1.25	-19.86	0	8	0.00	-	15	13	15.59	-16.62
51	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	4	3	3.40	-11.69	6	4	6.24	-35.86
52	1993	0.83	0.60	0.85	1.25	1	0	0.83	-100.00	9	9	5.38	67.26	16	22	13.57	62.18	47	37	58.59	-36.85
53	1993	0.83	0.60	0.85	1.25	1	1	0.83	20.69	6	3	3.59	-16.37	27	19	22.89	-17.00	38	37	47.37	-21.89
54	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	3	1	1.79	-44.25	14	9	11.87	-24.18	60	36	74.80	-51.87
Sum						12	8	9.04	-11.46	123	68	71.13	-4.40	396	376	341.61	10.07	893	1263	1318.04	-4.18

Table B5. Analysis of crash severity for peak period crashes.

						Peak hours															
	Implementation	Crash Controls CD				Fatal Injury Crashes				Serious Injury Crashes				Minor Injury Crashes				Non-Injury Crashes			
Site	Date	Fatal	Serious	Minor	Non	Before	After	Exp-Aft	%Change	Before	After	Exp-Aft	%Change	Before	After	Exp-Aft	%Change	Before	After	Exp-Aft	%Change
1	1992	0.72	0.59	0.86	1.62	1	0	0.72	-100.00	0	2	0.00	-	1	1	0.86	16.90	2	11	3.23	240.54
2	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	0	0.59	-100.00	6	4	5.13	-22.07	14	16	22.61	-29.24
3	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	2	0	1.71	-100.00	1	7	1.62	333.42
4	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	1	0	0.85	-100.00	3	6	3.74	60.43
5	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	2	1	1.17	-14.72	14	11	11.98	-8.15	19	30	30.69	-2.24
6	1990	0.69	0.52	0.87	4.98	0	0	0.00	-	3	0	1.55	-100.00	4	7	3.47	101.49	1	13	4.98	161.11
7	1988	0.65	0.60	0.99	-	0	0	0.00	-	2	1	1.20	-16.57	4	4	3.97	0.66	-	-	-	-
8	1988	0.65	0.60	0.99	-	0	1	0.00	-	1	1	0.60	66.87	4	0	3.97	-100.00	-	-	-	-
9	1988	0.65	0.60	0.99	-	0	0	0.00	-	2	0	1.20	-100.00	3	3	2.98	0.66	-	-	-	-
12	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	0	1	0.00	-	1	2	1.25	60.43
13	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	1	6	0.85	607.68	8	9	9.97	-9.76
14	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	4	0.00	-	3	3	4.85	-38.08
15	1994	0.84	0.62	0.85	1.04	1	0	0.84	-100.00	0	0	0.00	-	1	0	0.85	-100.00	5	10	5.20	92.41
16	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	2	0	1.70	-100.00	6	4	6.24	-35.86
17	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	1	0	0.53	-100.00	6	11	5.21	111.06	8	27	19.31	39.82
18	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	2	0.00	-	6	3	5.21	-42.44	5	18	12.07	49.15
19	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	2	0.00	-	3	0	2.57	-100.00	4	6	6.46	-7.12
20	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	2	0.60	234.53	3	3	2.54	17.95	14	17	17.45	-2.59
21	1989	0.64	0.54	0.88	-	0	1	0.00	-	4	0	2.16	-100.00	3	1	2.64	-62.19	-	-	-	-
22	1989	0.64	0.54	0.88	-	0	0	0.00	-	1	1	0.54	84.82	6	5	5.29	-5.48	-	-	-	-
23	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	1	1	0.87	15.12	2	1	4.83	-79.29
24	1992	0.72	0.59	0.86	1.62	0	1	0.00	-	1	2	0.59	241.13	9	2	7.70	-74.02	7	20	11.31	76.91
25	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	2	0	1.20	-100.00	3	3	2.54	17.95	3	13	3.74	247.60
26	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	1	0.00	-	2	0	1.71	-100.00	2	6	3.23	85.75
27	1989	0.64	0.54	0.88	-	0	0	0.00	-	3	0	1.62	-100.00	2	0	1.76	-100.00	-	-	-	-
28	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	1	1	0.88	13.42	-	-	-	-
29	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	0	0.59	-100.00	7	1	5.99	-83.30	10	10	16.15	-38.08
30	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	1	0.00	-	2	3	1.71	75.35	7	29	11.31	156.51
31	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	3	0.00	-	1	18	1.62	1014.51
32	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	0	0.59	-100.00	4	14	3.42	309.15	9	35	14.54	140.79
33	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	1	0.86	16.90	2	7	3.23	116.71
34	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	2	0	1.17	-100.00	5	6	4.28	40.28	11	11	17.77	-38.08
35	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	2	0.00	-	4	8	6.46	23.83
36	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	2	0.60	234.53	2	2	1.70	17.95	10	10	12.47	-19.78
37	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	0	0.59	-100.00	4	2	3.42	-41.55	6	4	9.69	-58.72
38	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	1	0.59	70.56	4	3	3.42	-12.33	2	10	3.23	209.59
39	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	1	0.60	67.26	2	2	1.70	17.95	12	7	14.96	-53.21
40	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	1	0	0.85	-100.00	6	6	7.48	-19.78
43	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	1	0	0.53	-100.00	1	0	0.87	-100.00	0	8	0.00	-
44	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	1	0.00	-	3	3	2.55	17.74	8	5	8.32	-39.87
45	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	1	0	0.53	-100.00	7	4	6.08	-34.22	9	11	21.72	-49.36
46	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	2	2	1.70	17.95	4	2	4.99	-59.89
47	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	3	0	2.54	-100.00	3	5	3.74	33.69
48	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	3	2	1.79	11.51	2	0	1.70	-100.00	18	19	22.44	-15.33
49	1993	0.83	0.60	0.85	1.25	0	1	0.00	-	0	1	0.00	-	4	6	3.39	76.92	13	16	16.21	-1.27
50	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	1	0	0.62	-100.00	0	1	0.00	-	6	6	6.24	-3.79
51	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	1	1	0.85	17.74	3	3	3.12	-3.79
52	1993	0.83	0.60	0.85	1.25	1	0	0.83	-100.00	1	2	0.60	234.53	4	4	3.39	17.95	13	13	16.21	-19.78
53	1993	0.83	0.60	0.85	1.25	1	0	0.83	-100.00	1	0	0.60	-100.00	8	3	6.78	-55.77	7	8	8.73	-8.32
54	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	9	7	7.63	-8.26	27	15	33.66	-55.44
Sum						4	4	3.21	24.46	46	26	26.52	-1.97	164	141	142.07	-0.75	299	485	437.0014	10.98

Table B6. Analysis of crash severity for off-peak period crashes.

						Off-peak hours															
	Implementation	Crash Controls CD				Fatal Injury Crashes				Serious Injury Crashes				Minor Injury Crashes				Non-Injury Crashes			
Site	Date	Fatal	Serious	Minor	Non	Before	After	Exp-Aft	%Change	Before	After	Exp-Aft	%Change	Before	After	Exp-Aft	%Change	Before	After	Exp-Aft	%Change
1	1992	0.72	0.59	0.86	1.62	1	0	0.72	-100.00	3	2	1.76	13.71	2	8	1.71	367.60	12	30	19.38	54.79
2	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	2	0	1.17	-100.00	11	10	9.41	6.27	22	35	35.53	-1.50
3	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	4	2	2.35	-14.72	3	1	2.57	-61.03	13	4	21.00	-80.95
4	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	2	7	1.70	312.81	9	20	11.22	78.26
5	1992	0.72	0.59	0.86	1.62	1	1	0.72	39.29	8	7	4.69	49.24	38	25	32.51	-23.09	62	131	100.13	30.82
6	1990	0.69	0.52	0.87	4.98	0	0	0.00	-	6	2	3.10	-35.49	16	8	13.90	-42.43	8	42	39.83	5.45
7	1988	0.65	0.60	0.99	-	0	0	0.00	-	4	1	2.40	-58.28	4	15	3.97	277.46	-	-	-	-
8	1988	0.65	0.60	0.99	-	0	0	0.00	-	4	1	2.40	-58.28	4	5	3.97	25.82	-	-	-	-
9	1988	0.65	0.60	0.99	-	0	0	0.00	-	3	0	1.80	-100.00	3	2	2.98	-32.90	-	-	-	-
12	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	1	1	0.85	17.95	3	3	3.74	-19.78
13	1993	0.83	0.60	0.85	1.25	1	0	0.83	-100.00	0	2	0.00	-	5	16	4.24	277.43	30	24	37.40	-35.83
14	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	2	0	1.17	-100.00	4	2	3.42	-41.55	3	5	4.85	3.20
15	1994	0.84	0.62	0.85	1.04	1	0	0.84	-100.00	2	0	1.25	-100.00	4	2	3.40	-41.13	16	16	16.63	-3.79
16	1994	0.84	0.62	0.85	1.04	0	1	0.00	-	2	4	1.25	220.57	1	3	0.85	253.23	17	12	17.67	-32.09
17	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	6	2	3.19	-37.31	11	10	9.55	4.66	12	54	28.97	86.43
18	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	4	2	2.13	-5.96	14	11	12.16	-9.55	11	41	26.55	54.42
19	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	6	3	3.52	-14.72	15	8	12.83	-37.65	29	28	46.84	-40.22
20	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	3	3	1.79	67.26	8	9	6.78	32.69	37	49	46.13	6.23
21	1989	0.64	0.54	0.88	-	0	1	0.00	-	3	2	1.62	23.21	4	6	3.53	70.13	-	-	-	-
22	1989	0.64	0.54	0.88	-	1	1	0.64	56.25	4	0	2.16	-100.00	16	9	14.11	-36.20	-	-	-	-
23	1991	0.68	0.53	0.87	2.41	1	0	0.68	-100.00	6	0	3.19	-100.00	8	3	6.95	-56.83	2	16	4.83	231.43
24	1992	0.72	0.59	0.86	1.62	1	0	0.72	-100.00	13	7	7.62	-8.16	26	19	22.24	-14.57	32	48	51.68	-7.12
25	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	2	0	1.20	-100.00	2	3	1.70	76.92	21	22	26.18	-15.96
26	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	2	0.59	241.13	1	2	0.86	133.80	10	8	16.15	-50.47
27	1989	0.64	0.54	0.88	-	0	1	0.00	-	1	0	0.54	-100.00	2	2	1.76	13.42	-	-	-	-
28	1989	0.64	0.54	0.88	-	0	0	0.00	-	2	1	1.08	-7.59	8	7	7.05	-0.76	-	-	-	-
29	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	6	3	3.52	-14.72	13	10	11.12	-10.08	28	38	45.22	-15.97
30	1992	0.72	0.59	0.86	1.62	2	0	1.44	-100.00	5	1	2.93	-65.89	7	11	5.99	83.70	19	48	30.69	56.42
31	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	2	1	1.17	-14.72	0	11	0.00	-	18	45	29.07	54.79
32	1992	0.72	0.59	0.86	1.62	1	0	0.72	-100.00	4	6	2.35	155.85	15	16	12.83	24.69	43	62	69.45	-10.72
33	1992	0.72	0.59	0.86	1.62	2	0	1.44	-100.00	3	0	1.76	-100.00	2	0	1.71	-100.00	7	9	11.31	-20.39
34	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	1	0.00	-	5	11	4.28	157.18	20	35	32.30	8.35
35	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	7	0.86	718.29	10	13	16.15	-19.51
36	1993	0.83	0.60	0.85	1.25	3	0	2.49	-100.00	0	0	0.00	-	10	2	8.48	-76.41	24	23	29.92	-23.13
37	1992	0.72	0.59	0.86	1.62	1	0	0.72	-100.00	1	0	0.59	-100.00	14	8	11.98	-33.20	32	48	51.68	-7.12
38	1992	0.72	0.59	0.86	1.62	2	0	1.44	-100.00	4	2	2.35	-14.72	16	12	13.69	-12.33	38	42	61.37	-31.57
39	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	3	2	1.79	11.51	5	7	4.24	65.13	30	37	37.40	-1.07
40	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	2	0.60	234.53	1	5	0.85	489.73	11	21	13.71	53.14
43	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	1	0	0.53	-100.00	2	4	1.74	130.25	3	22	7.24	203.81
44	1994	0.84	0.62	0.85	1.04	1	0	0.84	-100.00	2	0	1.25	-100.00	2	6	1.70	253.23	23	17	23.91	-28.89
45	1991	0.68	0.53	0.87	2.41	1	0	0.68	-100.00	4	2	2.13	-5.96	16	16	13.90	15.12	38	82	91.72	-10.60
46	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	2	1	1.20	-16.37	3	3	2.54	17.95	5	4	6.23	-35.83
47	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	2	0.60	234.53	7	4	5.93	-32.60	27	14	33.66	-58.41
48	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	3	4	1.79	123.02	11	12	9.33	28.67	38	37	47.37	-21.89
49	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	3	3	1.79	67.26	9	6	7.63	-21.37	34	33	42.39	-22.14
50	1994	0.84	0.62	0.85	1.04	0	1	0.00	-	2	2	1.25	60.29	1	11	0.85	1195.18	19	15	19.75	-24.05
51	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	4	4	3.40	17.74	7	6	7.28	-17.54
52	1993	0.83	0.60	0.85	1.25	0	2	0.00	-	24	14	14.35	-2.43	42	30	35.61	-15.75	81	67	100.98	-33.65
53	1993	0.83	0.60	0.85	1.25	0	1	0.00	-	13	4	7.77	-48.53	34	22	28.83	-23.68	67	50	83.52	-40.14
54	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	4	1	2.39	-58.18	15	12	12.72	-5.64	54	34	67.32	-49.49
Sum						20	9	14.88	-39.51	180	94	104.65	-10.18	448	424	385.17	10.08	1025	1390	1514.33	-8.21

Table B7. Analysis of crash severity for all crashes for flush median widths greater or equal to 2m.

	Implementation	Crash Controls CD				Fatal Injury Crashes				Serious Injury Crashes				Minor Injury Crashes				Non-Injury Crashes			
Site	Date	Fatal	Serious	Minor	Non	Before	After	Exp -Aft	%Change	Before	After	Exp -Aft	%Change	Before	After	Exp -Aft	%Change	Before	After	Exp -Aft	%Change
4	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	3	7	2.54	175.21	12	26	14.96	73.80
5	1992	0.72	0.59	0.86	1.62	1	1	0.72	39.29	10	8	5.86	36.45	52	36	44.48	-19.07	81	161	130.82	23.07
6	1990	0.69	0.52	0.87	4.98	0	0	0.00	-	9	2	4.65	-56.99	20	15	17.37	-13.65	9	55	44.81	22.74
7	1988	0.65	0.60	0.99	-	0	0	0.00	-	6	2	3.60	-44.38	8	19	7.95	139.06	-	-	-	-
8	1988	0.65	0.60	0.99	-	0	1	0.00	-	5	2	3.00	-33.25	8	5	7.95	-37.09	-	-	-	-
9	1988	0.65	0.60	0.99	-	0	0	0.00	-	5	0	3.00	-100.00	6	5	5.96	-16.12	-	-	-	-
14	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	2	0	1.17	-100.00	4	6	3.42	75.35	6	8	9.69	-17.44
15	1994	0.84	0.62	0.85	1.04	2	0	1.68	-100.00	2	0	1.25	-100.00	5	2	4.25	-52.90	21	26	21.83	19.11
16	1994	0.84	0.62	0.85	1.04	0	1	0.00	-	2	4	1.25	220.57	3	3	2.55	17.74	23	16	23.91	-33.07
17	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	7	2	3.72	-46.26	17	21	14.77	42.21	20	81	48.28	67.79
18	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	4	4	2.13	88.08	20	14	17.37	-19.41	16	59	38.62	52.77
19	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	6	5	3.52	42.14	18	8	15.40	-48.04	33	34	53.30	-36.21
20	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	4	5	2.39	109.08	11	12	9.33	28.67	51	66	63.58	3.81
21	1989	0.64	0.54	0.88	-	0	2	0.00	-	7	2	3.79	-47.19	7	7	6.17	13.42	-	-	-	-
22	1989	0.64	0.54	0.88	-	1	1	0.64	56.25	5	1	2.71	-63.04	22	14	19.40	-27.82	-	-	-	-
23	1991	0.68	0.53	0.87	2.41	1	0	0.68	-100.00	6	0	3.19	-100.00	9	4	7.82	-48.83	4	17	9.66	76.07
24	1992	0.72	0.59	0.86	1.62	1	1	0.72	39.29	14	9	8.21	9.65	35	21	29.94	-29.86	39	68	62.99	7.96
25	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	4	0	2.39	-100.00	5	6	4.24	41.54	24	35	29.92	16.98
26	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	3	0.59	411.69	3	2	2.57	-22.07	12	14	19.38	-27.76
27	1989	0.64	0.54	0.88	-	0	1	0.00	-	4	0	2.16	-100.00	4	2	3.53	-43.29	-	-	-	-
28	1989	0.64	0.54	0.88	-	0	0	0.00	-	2	1	1.08	-7.59	9	8	7.93	0.82	-	-	-	-
29	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	7	3	4.10	-26.90	20	11	17.11	-35.71	38	48	61.37	-21.79
30	1992	0.72	0.59	0.86	1.62	2	0	1.44	-100.00	5	2	2.93	-31.77	9	14	7.70	81.84	26	77	41.99	83.37
31	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	2	1	1.17	-14.72	0	14	0.00	-	19	63	30.69	105.30
32	1992	0.72	0.59	0.86	1.62	1	0	0.72	-100.00	5	6	2.93	104.68	19	30	16.25	84.58	52	97	83.98	15.50
33	1992	0.72	0.59	0.86	1.62	2	0	1.44	-100.00	3	0	1.76	-100.00	3	1	2.57	-61.03	9	16	14.54	10.07
34	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	2	1	1.17	-14.72	10	17	8.55	98.73	31	46	50.07	-8.12
35	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	9	0.86	952.09	14	21	22.61	-7.12
36	1993	0.83	0.60	0.85	1.25	3	0	2.49	-100.00	1	2	0.60	234.53	12	4	10.17	-60.68	34	33	42.39	-22.14
37	1992	0.72	0.59	0.86	1.62	1	0	0.72	-100.00	2	0	1.17	-100.00	18	10	15.40	-35.06	38	52	61.37	-15.27
43	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	2	0	1.06	-100.00	3	4	2.61	53.50	3	30	7.24	314.29
44	1994	0.84	0.62	0.85	1.04	1	0	0.84	-100.00	2	1	1.25	-19.86	5	9	4.25	111.94	31	22	32.22	-31.72
45	1991	0.68	0.53	0.87	2.41	1	0	0.68	-100.00	5	2	2.66	-24.77	23	20	19.98	0.11	47	93	113.45	-18.02
46	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	2	1	1.20	-16.37	5	5	4.24	17.95	9	6	11.22	-46.52
47	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	2	2	1.20	67.26	10	4	8.48	-52.82	30	19	37.40	-49.20
48	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	6	6	3.59	67.26	13	12	11.02	8.87	56	56	69.81	-19.78
49	1993	0.83	0.60	0.85	1.25	0	1	0.00	-	3	4	1.79	123.02	13	12	11.02	8.87	47	49	58.59	-16.37
50	1994	0.84	0.62	0.85	1.04	0	1	0.00	-	3	2	1.87	6.86	1	12	0.85	1312.92	25	21	25.99	-19.19
51	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	5	5	4.25	17.74	10	9	10.39	-13.41
54	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	5	1	2.99	-66.55	24	19	20.35	-6.63	81	49	100.98	-51.47
Sum						17	10	12.74	-21.48	163	84	93.68	-10.34	463	429	400.57	7.10	951	1473	1448.02	1.73

Table B8. Analysis of crash severity for all crashes for flush median widths less than 2m.

	Implementation	Crash Controls CD				Fatal Injury Crashes				Serious Injury Crashes				Minor Injury Crashes				Non-Injury Crashes			
Site	Date	Fatal	Serious	Minor	Non	Before	After	Exp -Aft	%Change	Before	After	Exp -Aft	%Change	Before	After	Exp -Aft	%Change	Before	After	Exp -Aft	%Change
1	1992	0.72	0.59	0.86	1.62	2	0	1.44	-100.00	3	4	1.76	127.42	3	9	2.57	250.70	14	41	22.61	81.33
2	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	3	0	1.76	-100.00	17	14	14.54	-3.73	36	51	58.14	-12.28
3	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	4	2	2.35	-14.72	5	1	4.28	-76.62	14	11	22.61	-51.35
12	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	2	0	1.20	-100.00	1	2	0.85	135.89	4	5	4.99	0.27
13	1993	0.83	0.60	0.85	1.25	1	0	0.83	-100.00	1	2	0.60	234.53	6	22	5.09	332.47	38	33	47.37	-30.34
38	1992	0.72	0.59	0.86	1.62	2	0	1.44	-100.00	5	3	2.93	2.34	20	15	17.11	-12.33	40	52	64.60	-19.51
39	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	4	3	2.39	25.45	7	9	5.93	51.65	42	44	52.36	-15.96
40	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	2	2	1.20	67.26	2	5	1.70	194.87	17	27	21.19	27.40
52	1993	0.83	0.60	0.85	1.25	1	2	0.83	141.38	25	16	14.95	7.05	46	34	39.00	-12.82	94	80	117.18	-31.73
53	1993	0.83	0.60	0.85	1.25	1	1	0.83	20.69	14	4	8.37	-52.21	42	25	35.61	-29.79	74	58	92.25	-37.13
Sum						7	3	5.36	-44.00	63	36	37.49	-3.98	149	136	126.67	7.37	373	402	503.31	-20.13

Table B9. Analysis of crash severity for BF type crashes.

	Implementation	Crash Controls CD				Fatal Injury Crashes				Serious Injury Crashes				Minor Injury Crashes				Non Injury Crashes			
Site	Date	Fatal	Serious	Minor	Non	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change
1	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
2	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
3	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
4	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
5	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
6	1990	0.69	0.52	0.87	4.98	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
7	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
8	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
9	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
12	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
13	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
14	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
15	1994	0.84	0.62	0.85	1.04	1	0	0.84	-100.00	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
16	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	1	0	0.62	-100.00	0	0	0.00	-	2	1	2.08	-51.90
17	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
18	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
19	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
20	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
21	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
22	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
23	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	1	0	0.87	-100.00	0	0	0.00	-
24	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	1	0.59	70.56	0	1	0.00	-	0	0	0.00	-
25	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
26	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
27	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
28	1989	0.64	0.54	0.88	-	0	0	0.00	-	1	0	0.54	-100.00	1	2	0.88	126.85	-	-	-	-
29	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
30	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	0	0.59	-100.00	0	0	0.00	-	1	0	1.62	-100.00
31	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
32	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	0	0.86	-100.00	1	0	1.62	-100.00
33	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
34	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
35	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
36	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
37	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
38	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
39	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
40	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
43	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	0	0	0.00	-
44	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	0	0	0.00	-
45	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
46	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
47	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	1	0	0.85	-100.00	0	1	0.00	-
48	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	0	0	0.00	-	3	2	3.74	-46.52
49	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
50	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	0	0	0.00	-
51	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	1.04	-100.00
52	1993	0.83	0.60	0.85	1.25	1	1	0.83	20.69	4	2	2.39	-16.37	3	2	2.54	-21.37	5	1	6.23	-83.96
53	1993	0.83	0.60	0.85	1.25	1	1	0.83	20.69	3	1	1.79	-44.25	6	2	5.09	-60.68	8	2	9.97	-79.95
54	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
Sum						3	2	2.50	-19.87	12	4	7.12	-43.82	13	10	11.08	-9.78	21	8	26.29	-69.58

Table B10. Analysis of crash severity for CB type crashes.

	Implementation	Crash Controls CD				Fatal Injury Crashes				Serious Injury Crashes				Minor Injury Crashes				Non-Injury Crashes			
Site	Date	Fatal	Serious	Minor	Non	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change
1	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	2	0.00	-
2	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	2	0	1.71	-100.00	1	0	1.62	-100.00
3	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	1	0.00	-	1	0	0.86	-100.00	1	0	1.62	-100.00
4	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
5	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	0	0.86	-100.00	0	8	0.00	-
6	1990	0.69	0.52	0.87	4.98	0	0	0.00	-	1	0	0.52	-100.00	0	0	0.00	-	1	3	4.98	-39.74
7	1988	0.65	0.60	0.99	-	0	0	0.00	-	1	0	0.60	-100.00	0	0	0.00	-	-	-	-	-
8	1988	0.65	0.60	0.99	-	0	0	0.00	-	2	0	1.20	-100.00	0	0	0.00	-	-	-	-	-
9	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
12	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
13	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	1	0	0.85	-100.00	0	1	0.00	-
14	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
15	1994	0.84	0.62	0.85	1.04	1	0	0.84	-100	1	0	0.62	-100.00	0	0	0.00	-	1	1	1.04	-3.79
16	1994	0.84	0.62	0.85	1.04	0	1	0.00	-	0	0	0.00	-	0	1	0.00	-	0	0	0.00	-
17	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	4	0.00	-
18	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	1	1	0.87	15.12	0	2	0.00	-
19	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	1	0.00	-	1	2	0.86	133.80	0	4	0.00	-
20	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	2	1	1.70	-41.03	4	6	4.99	20.32
21	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
22	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
23	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
24	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	1	0.00	-	1	1	0.86	16.90	0	0	0.00	-
25	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	0	0	0.00	-	0	1	0.00	-
26	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
27	1989	0.64	0.54	0.88	-	0	1	0.00	-	0	0	0.00	-	0	1	0.00	-	-	-	-	-
28	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
29	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	1	0.59	70.56	0	1	0.00	-	1	0	1.62	-100.00
30	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	3	0	1.76	-100.00	1	0	0.86	-100.00	2	6	3.23	85.75
31	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	1	1.62	-38.08
32	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	0	0.59	-100.00	2	0	1.71	-100.00	4	6	6.46	-7.12
33	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
34	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	0	1	0.00	-
35	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	2	0.00	-
36	1993	0.83	0.60	0.85	1.25	1	0	0.83	-100	0	0	0.00	-	0	0	0.00	-	0	2	0.00	-
37	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	3	0.00	-
38	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	0	0	0.00	-
39	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	1.25	-100.00
40	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	0	0	0.00	-
43	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
44	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
45	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	2	0	1.74	-100.00	0	5	0.00	-
46	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	1	0	0.85	-100.00	0	0	0.00	-
47	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	2	1	2.49	-59.89
48	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	1	2	1.25	60.43
49	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	0	1	0.00	-	1	7	1.25	461.51
50	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	2	1	2.08	-51.90
51	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	0	0	0.00	-
52	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	2	0.00	-	1	0	0.85	-100.00	4	3	4.99	-39.84
53	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	2	1	1.70	-41.03	3	1	3.74	-73.26
54	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	2	1	1.70	-41.03	2	2	2.49	-19.78
Sum						2	2	1.67	19.96	14	6	8.26	-27.37	21	17	17.94	-5.22	32	77	46.69	64.93

Table B11. Analysis of crash severity for CC type crashes.

	Implementation	Crash Controls CD				Fatal Injury Crashes				Serious Injury Crashes				Minor Injury Crashes				Non Injury Crashes			
Site	Date	Fatal	Serious	Minor	Non	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change
1	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	1.62	-100.00
2	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	0	0	0.00	-
3	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	0	0.86	-100.00	0	0	0.00	-
4	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
5	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	6	0	5.13	-100.00	1	5	1.62	209.59
6	1990	0.69	0.52	0.87	4.98	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	2	0.00	-
7	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	-	-	-	-
8	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
9	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	-	-	-	-
12	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
13	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
14	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
15	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	1.04	-100.00
16	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
17	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
18	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	0	1	0.00	-
19	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	0	0.59	-100.00	1	1	0.86	16.90	2	0	3.23	-100.00
20	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	1	0	0.85	-100.00	0	2	0.00	-
21	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
22	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
23	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
24	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	1	0.86	16.90	2	0	3.23	-100.00
25	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
26	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	0	0	0.00	-
27	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	-	-	-	-
28	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
29	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
30	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	1	0.00	-	0	0	0.00	-	0	2	0.00	-
31	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	2	1.62	23.83
32	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	0	0.86	-100.00	0	1	0.00	-
33	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
34	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	0	0.86	-100.00	1	1	1.62	-38.08
35	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	1.62	-100.00
36	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	1	0	0.85	-100.00	0	0	0.00	-
37	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	0	0.59	-100.00	0	0	0.00	-	0	0	0.00	-
38	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	1	0.00	-	1	0	0.86	-100.00	0	1	0.00	-
39	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
40	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
43	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
44	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
45	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	2.41	-100.00
46	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	0	0	0.00	-	0	0	0.00	-
47	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	2	0	2.49	-100.00
48	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	1	2	1.25	60.43
49	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	3	1	3.74	-73.26
50	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	1.04	-100.00
51	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
52	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	1	0.60	67.26	4	0	3.39	-100.00	1	0	1.25	-100.00
53	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	1	0.60	67.26	0	1	0.00	-	0	1	0.00	-
54	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	2	0	2.49	-100.00
Sum						0	0	0	-	5	4	2.97	34.86	18	10	15.35	-34.86	21	25	30.25	-17.35

Table B12. Analysis of crash severity for DA type crashes.

	Implementation	Crash Controls CD				Fatal Injury Crashes				Serious Injury Crashes				Minor Injury Crashes				Non Injury Crashes			
Site	Date	Fatal	Serious	Minor	Non	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change
1	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
2	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
3	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
4	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
5	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	0	0.86	-100.00	0	0	0.00	-
6	1990	0.69	0.52	0.87	4.98	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
7	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	-	-	-	-
8	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
9	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	1	0	0.99	-100.00	-	-	-	-
12	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
13	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	3	0.00	-
14	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	3	0	2.57	-100.00	5	2	8.08	-75.23
15	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	1	0	0.85	-100.00	2	2	2.08	-3.79
16	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	1	1	0.62	60.29	0	1	0.00	-	5	2	5.20	-61.52
17	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
18	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
19	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
20	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	0	0	0.00	-	0	3	0.00	-
21	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
22	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
23	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	3	0	2.61	-100.00	1	1	2.41	-58.57
24	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	2	0	1.17	-100.00	3	0	2.57	-100.00	4	2	6.46	-69.04
25	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	1	0	0.85	-100.00	1	3	1.25	140.65
26	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	1.62	-100.00
27	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
28	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	6	4	5.29	-24.38	-	-	-	-
29	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	0	0.86	-100.00	0	1	0.00	-
30	1992	0.72	0.59	0.86	1.62	1	0	0.72	-100	1	0	0.59	-100.00	2	0	1.71	-100.00	1	1	1.62	-38.08
31	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
32	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	2	0	1.71	-100.00	5	5	8.08	-38.08
33	1992	0.72	0.59	0.86	1.62	1	0	0.72	-100	0	0	0.00	-	0	0	0.00	-	1	0	1.62	-100.00
34	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	1	0.00	-	1	0	0.86	-100.00	1	1	1.62	-38.08
35	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	1.62	-100.00
36	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	1	1.25	-19.78
37	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	2	1	1.71	-41.55	1	1	1.62	-38.08
38	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
39	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
40	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	1.25	-100.00
43	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
44	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
45	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
46	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
47	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	0	0	0.00	-	3	2	3.74	-46.52
48	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	2	0	1.70	-100.00	5	0	6.23	-100.00
49	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
50	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	2	0	1.25	-100.00	1	3	0.85	253.23	8	4	8.32	-51.90
51	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
52	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	2	2	1.20	67.26	7	6	5.93	1.10	29	10	36.15	-72.34
53	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	8	2	6.78	-70.51	12	4	14.96	-73.26
54	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	2	0	2.49	-100.00
Sum						2	0	1.44	-100	12	4	7.22	-44.58	45	18	38.68	-53.47	90	56	117.62	-52.39

Table B13. Analysis of crash severity for DB type crashes.

	Implementation	Crash Controls CD				Fatal Injury Crashes				Serious Injury Crashes				Minor Injury Crashes				Non Injury Crashes			
Site	Date	Fatal	Serious	Minor	Non	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change
1	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
2	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
3	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
4	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
5	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	0	0.86	-100	0	1	0.00	-
6	1990	0.69	0.52	0.87	4.98	0	0	0.00	-	1	0	0.52	-100	0	1	0.00	-	0	0	0.00	-
7	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
8	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
9	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
12	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	1.25	-100.00
13	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	1.25	-100.00
14	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
15	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	1	0	0.62	-100	0	1	0.00	-	0	1	0.00	-
16	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	2	0.00	-	0	0	0.00	-	4	2	4.16	-51.90
17	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
18	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
19	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	1	1.62	-38.08
20	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100	0	0	0.00	-	1	0	1.25	-100.00
21	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
22	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	1	0	0.88	-100	-	-	-	-
23	1991	0.68	0.53	0.87	2.41	1	0	0.68	-100	1	0	0.53	-100	1	1	0.87	15.12	0	3	0.00	-
24	1992	0.72	0.59	0.86	1.62	1	0	0.72	-100	0	1	0.00	-	7	3	5.99	-49.90	5	7	8.08	-13.32
25	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	1	0	0.85	-100	0	1	0.00	-
26	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
27	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
28	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	1	0.00	-	0	1	0.00	-	-	-	-	-
29	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	0	0.86	-100	0	1	0.00	-
30	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	0	0.86	-100	0	2	0.00	-
31	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
32	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	1	0	1.62	-100.00
33	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	0	0.59	-100	1	0	0.86	-100	0	1	0.00	-
34	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	2	0	3.23	-100.00
35	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
36	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
37	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
38	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	1	1	1.62	-38.08
39	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
40	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
43	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
44	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
45	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
46	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
47	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	1	1	0.85	17.95	2	0	2.49	-100.00
48	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	2	0	1.70	-100.00	2	1	2.49	-59.89
49	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	1.25	-100.00
50	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	1	2	1.04	92.41
51	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	2	0	2.08	-100.00
52	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	6	2	3.59	-44.25	8	2	6.78	-70.51	20	10	24.93	-59.89
53	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	3	0	1.79	-100	1	2	0.85	135.89	8	5	9.97	-49.86
54	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
Sum						2	0	1.39	-100	14	6	8.24	-27.16	26.00	15.00	22.18	-32.38	53.00	44.00	68.31	-35.58

Table B14. Analysis of crash severity for EA type crashes.

	Implementation	Crash Controls CD				Fatal Injury Crashes				Serious Injury Crashes				Minor Injury Crashes				Non Injury Crashes			
Site	Date	Fatal	Serious	Minor	Non	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change
1	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
2	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	0	0.59	-100	0	0	0.00	-	2	0	3.23	-100.00
3	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	1.62	-100.00
4	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	5	0.00	-
5	1992	0.72	0.59	0.86	1.62	0	1	0.00	-	0	1	0.00	-	4	2	3.42	-41.55	5	6	8.08	-25.70
6	1990	0.69	0.52	0.87	4.98	0	0	0.00	-	0	0	0.00	-	2	1	1.74	-42.43	0	3	0.00	-
7	1988	0.65	0.60	0.99	-	0	0	0.00	-	1	0	0.60	-100	0	3	0.00	-	-	-	-	-
8	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	1	0.00	-	1	2	0.99	101.31	-	-	-	-
9	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
12	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100	0	0	0.00	-	1	0	1.25	-100.00
13	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	1	0.00	-	0	2	0.00	-	0	1	0.00	-
14	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
15	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	1	0	0.85	-100.00	2	1	2.08	-51.90
16	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
17	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	8	0.00	-
18	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	1	3	0.87	245.37	5	3	12.07	-75.14
19	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	1	0.00	-	1	0	0.86	-100.00	4	1	6.46	-84.52
20	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	2	2	1.70	17.95	7	7	8.73	-19.78
21	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	1	0	0.88	-100.00	-	-	-	-
22	1989	0.64	0.54	0.88	-	0	0	0.00	-	1	0	0.54	-100	2	0	1.76	-100.00	-	-	-	-
23	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	0	0	0.00	-
24	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	1	0.59	70.56452	1	1	0.86	16.90	5	2	8.08	-75.23
25	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	2	0.00	-	1	2	1.25	60.43
26	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
27	1989	0.64	0.54	0.88	-	0	0	0.00	-	1	0	0.54	-100	1	0	0.88	-100.00	-	-	-	-
28	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
29	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	2	0	3.23	-100.00
30	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	5	7	8.08	-13.32
31	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	2	4	3.23	23.83
32	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	1	0.86	16.90	2	2	3.23	-38.08
33	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	0	0.86	-100.00	1	0	1.62	-100.00
34	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	1	0.86	16.90	5	2	8.08	-75.23
35	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
36	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	1	0.00	-	1	0	0.85	-100.00	5	4	6.23	-35.83
37	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	2	0	1.71	-100.00	3	3	4.85	-38.08
38	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	2	1	1.71	-41.55	1	0	1.62	-100.00
39	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	1	5	1.25	301.08
40	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100	0	0	0.00	-	1	1	1.25	-19.78
43	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
44	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	3	2	3.12	-35.86
45	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	4	4	9.66	-58.57
46	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	2	1	2.49	-59.89
47	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	5	1	6.23	-83.96
48	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	1	0	0.85	-100.00	5	3	6.23	-51.87
49	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	4	3	4.99	-39.84
50	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	2	1	2.08	-51.90
51	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	1.04	-100.00
52	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	2	2	1.70	17.95	2	4	2.49	60.43
53	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	9	2	7.63	-73.79	10	3	12.47	-75.94
54	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	1	0	0.85	-100.00	4	3	4.99	-39.84
Sum						0	1	0	-	7	6	4.05	48.16	38	28	32.66	-14.27	103	95	151.25	-37.19

Table B15. Analysis of crash severity for FD type crashes.

	Implementation	Crash Controls CD				Fatal Injury Crashes				Serious Injury Crashes				Minor Injury Crashes				Non Injury Crashes			
Site	Date	Fatal	Serious	Minor	Non	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change
1	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	3	7	4.85	44.47
2	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	2	4	1.71	133.80	6	12	9.69	23.83
3	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	1	0.86	16.90	7	5	11.31	-55.77
4	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
5	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	2	0.00	-	2	16	3.23	395.34
6	1990	0.69	0.52	0.87	4.98	0	0	0.00	-	0	0	0.00	-	1	1	0.87	15.14	0	5	0.00	-
7	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	1	2	0.99	101.31	-	-	-	-
8	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	2	0	1.99	-100.00	-	-	-	-
9	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	1	0	0.99	-100.00	-	-	-	-
12	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	0	0	0.00	-
13	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	2	0.00	-	1	2	1.25	60.43
14	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	0	0	0.00	-
15	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	4	4	4.16	-3.79
16	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	2	1	2.08	-51.90
17	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	1	0.00	-	0	5	0.00	-	3	16	7.24	120.96
18	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	2	2	1.74	15.12	4	9	9.66	-6.78
19	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	1	1.62	-38.08
20	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	8	1.25	541.73
21	1989	0.64	0.54	0.88	-	0	0	0.00	-	1	0	0.54	-100	0	0	0.00	-	-	-	-	-
22	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	-	-	-	-
23	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	1	0	0.53	-100	0	0	0.00	-	0	1	0.00	-
24	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	0	0.86	-100.00	0	4	0.00	-
25	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100	0	1	0.00	-	2	7	2.49	180.76
26	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	2	4	3.23	23.83
27	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
28	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
29	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	2	0.00	-	8	11	12.92	-14.86
30	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	2	0.00	-	5	6	8.08	-25.70
31	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	2	0.00	-	1	9	1.62	457.25
32	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	4	10	6.46	54.79
33	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	2	1.62	23.83
34	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	2	2	3.23	-38.08
35	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	0	0	0.00	-
36	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	1	1	0.85	17.95	3	2	3.74	-46.52
37	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	2	3	3.23	-7.12
38	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	0	0.86	-100.00	5	0	8.08	-100.00
39	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	7	0	8.73	-100.00
40	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	5	3	6.23	-51.87
43	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
44	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	2	0.00	-	0	5	0.00	-
45	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	1	0	0.87	-100.00	4	6	9.66	-37.86
46	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	2	2	1.70	17.95	3	0	3.74	-100.00
47	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	2	0	1.70	-100.00	0	3	0.00	-
48	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	4	5	4.99	0.27
49	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	4	0.00	-	4	2	4.99	-59.89
50	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	1	2	1.04	92.41
51	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
52	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	3	0.00	-	7	18	8.73	106.27
53	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	2	0.00	-	1	5	1.25	301.08
54	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	0	0	0.00	-
Sum						0	0	0	-	3	1	1.67	-40.14	18	49	15.96	206.93	105.00	198.00	160.34	23.49

Table B16. Analysis of crash severity for GD type crashes.

	Implementation	Crash Controls CD				Fatal Injury Crashes				Serious Injury Crashes				Minor Injury Crashes				Non Injury Crashes			
Site	Date	Fatal	Serious	Minor	Non	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change
1	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
2	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	3	1	2.57	-61.03	3	1	4.85	-79.36
3	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	1.62	-100.00
4	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	1	1.25	-19.78
5	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	7	2	5.99	-66.60	10	9	16.15	-44.27
6	1990	0.69	0.52	0.87	4.98	0	0	0.00	-	1	0	0.52	-100	1	0	0.87	-100.00	2	2	9.96	-79.91
7	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	-	-	-	-
8	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
9	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
12	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100	0	0	0.00	-	2	0	2.49	-100.00
13	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	4	1	4.99	-79.95
14	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
15	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	2	0	2.08	-100.00
16	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	1.04	-100.00
17	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	2	0	4.83	-100.00
18	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	2	0	1.74	-100.00	1	2	2.41	-17.14
19	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	2	0	1.71	-100.00	0	0	0.00	-
20	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	1	0	0.85	-100.00	3	0	3.74	-100.00
21	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	1	0	0.88	-100.00	-	-	-	-
22	1989	0.64	0.54	0.88	-	0	0	0.00	-	1	0	0.54	-100	4	1	3.53	-71.64	-	-	-	-
23	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	1	0	0.53	-100	0	0	0.00	-	0	0	0.00	-
24	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	0	0.86	-100.00	3	1	4.85	-79.36
25	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	1.25	-100.00
26	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	1.62	-100.00
27	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	1	0	0.88	-100.00	-	-	-	-
28	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
29	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	2	0	1.17	-100	7	0	5.99	-100.00	7	0	11.31	-100.00
30	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
31	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	2	3	3.23	-7.12
32	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	2	0	1.71	-100.00	7	1	11.31	-91.15
33	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	1.62	-100.00
34	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	2	1	3.23	-69.04
35	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	3	1	4.85	-79.36
36	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	1	0	0.85	-100.00	0	0	0.00	-
37	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	2	2	3.23	-38.08
38	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	0	0.86	-100.00	2	2	3.23	-38.08
39	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	1	1	0.85	17.95	1	1	1.25	-19.78
40	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	3	0.00	-
43	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
44	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	2	0	2.08	-100.00
45	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	3	1	7.24	-86.19
46	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
47	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	1	0	0.85	-100.00	0	0	0.00	-
48	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	1	0	0.85	-100.00	6	2	7.48	-73.26
49	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	2	0	1.70	-100.00	7	0	8.73	-100.00
50	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	1.04	-100.00
51	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	1.04	-100.00
52	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	1	0	0.85	-100.00	3	0	3.74	-100.00
53	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	2	1	2.49	-59.89
54	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	4	2	4.99	-59.89
Sum						0	0	0	-	6	0	3.36	-100	40.00	8.00	34.35	-76.71	93.00	38.00	145.16	-73.82

Table B17. Analysis of crash severity for HA type crashes.

	Implementation	Crash Controls CD				Fatal Injury Crashes				Serious Injury Crashes				Minor Injury Crashes				Non Injury Crashes			
Site	Date	Fatal	Serious	Minor	Non	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change
1	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	2	0.86	133.80	1	1	1.62	-38.08
2	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	2	1	3.23	-69.04
3	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
4	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
5	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	0	0.86	-100.00	2	5	3.23	54.79
6	1990	0.69	0.52	0.87	4.98	0	0	0.00	-	0	0	0.00	-	1	0	0.87	-100.00	0	1	0.00	-
7	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	-	-	-	-
8	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
9	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
12	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
13	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
14	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
15	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
16	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
17	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	0	0	0.00	-
18	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
19	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
20	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	1	1	0.85	17.95	0	2	0.00	-
21	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
22	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	1	2	0.88	126.85	-	-	-	-
23	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
24	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
25	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
26	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
27	1989	0.64	0.54	0.88	-	0	0	0.00	-	1	0	0.54	-100	0	0	0.00	-	-	-	-	-
28	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
29	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
30	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	0	0.86	-100.00	0	0	0.00	-
31	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
32	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	1	0.00	-	1	2	0.86	133.80	3	1	4.85	-79.36
33	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
34	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
35	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
36	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	1.25	-100.00
37	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	4	1	6.46	-84.52
38	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
39	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	1	0	1.25	-100.00
40	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
43	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
44	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	1.04	-100.00
45	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
46	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
47	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
48	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	1	1	0.85	17.95	0	0	0.00	-
49	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	1	1	0.85	17.95	2	0	2.49	-100.00
50	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
51	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	0	0	0.00	-
52	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
53	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	2	0	1.70	-100.00	0	0	0.00	-
54	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	3	0	1.79	-100	9	10	7.63	31.05	35	22	43.63	-49.58
Sum						0	0	0	-	4	1	2.33	-57.17	20.00	23.00	17.04	34.96	52.00	36.00	69.04	-47.86

Table B18. Analysis of crash severity for JA type crashes.

	Implementation	Crash Controls CD				Fatal Injury Crashes				Serious Injury Crashes				Minor Injury Crashes				Non Injury Crashes			
Site	Date	Fatal	Serious	Minor	Non	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change
1	1992	0.72	0.59	0.86	1.62	1	0	0.72	-100.00	1	0	0.59	-100.00	0	1	0.00	-	2	6	3.23	85.75
2	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	3	0	2.57	-100.00	4	9	6.46	39.31
3	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	1.62	-100.00
4	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	3	4	3.74	6.95
5	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	1	0.00	-	5	5	4.28	16.90	14	32	22.61	41.52
6	1990	0.69	0.52	0.87	4.98	0	0	0.00	-	1	0	0.52	-100.00	2	4	1.74	130.28	3	8	14.94	-46.44
7	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	1	2	0.99	101.31	-	-	-	-
8	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	1	0	0.99	-100.00	-	-	-	-
9	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	-	-	-	-
12	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
13	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	5	0.00	-	9	6	11.22	-46.52
14	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	1	0.86	16.90	0	0	0.00	-
15	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	2	1	1.70	-41.13	2	4	2.08	92.41
16	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	2	1	2.08	-51.90
17	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	2	1	1.74	-42.44	5	13	12.07	7.72
18	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	1	0	0.53	-100.00	2	3	1.74	72.68	0	9	0.00	-
19	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	1	0.59	70.56	2	0	1.71	-100.00	4	6	6.46	-7.12
20	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	2	0.60	234.53	1	2	0.85	135.89	13	18	16.21	11.07
21	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	1	1	0.88	13.42	-	-	-	-
22	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	1	0.00	-	2	0	1.76	-100.00	-	-	-	-
23	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	2	1	4.83	-79.29
24	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	2	2	1.17	70.56	6	1	5.13	-80.52	5	14	8.08	73.37
25	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	2	1	1.70	-41.03	3	0	3.74	-100.00
26	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
27	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	1	0	0.88	-100.00	-	-	-	-
28	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
29	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	0	0.59	-100.00	4	4	3.42	16.90	5	7	8.08	-13.32
30	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	2	1	1.71	-41.55	3	18	4.85	271.50
31	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	3	6	4.85	23.83
32	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	2	4	1.17	241.13	6	11	5.13	114.31	8	35	12.92	170.89
33	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
34	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	2	3	3.23	-7.12
35	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	4	1.62	147.67
36	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	4	1	3.39	-70.51	15	15	18.70	-19.78
37	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	3	0.86	250.70	1	3	1.62	85.75
38	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	2	0.86	133.80	8	9	12.92	-30.34
39	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	0	1	0.00	-	4	6	4.99	20.32
40	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	4	4	4.99	-19.78
43	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
44	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	9	0	9.35	-100.00
45	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	1	0	0.53	-100.00	3	2	2.61	-23.25	4	13	9.66	34.64
46	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	1	0.00	-	0	0	0.00	-	1	0	1.25	-100.00
47	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	2	0.00	-
48	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	1	0.00	-	1	1	0.85	17.95	1	7	1.25	461.51
49	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	0	3	0.00	-
50	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	3	3	3.12	-3.79
51	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	1	1	0.85	17.74	1	3	1.04	188.62
52	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	1	0.60	67.26	3	3	2.54	17.95	0	0	0.00	-
53	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	7	8	8.73	-8.32
54	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	3	0	2.54	-100.00	8	5	9.97	-49.86
Sum						1	0	0.72	-100.00	13.00	14.00	7.48	87.22	63.00	64.00	54.27	17.93	160.00	289.00	242.45	19.20

Table B19. Analysis of crash severity for LB type crashes.

	Implementation	Crash Controls CD				Fatal Injury Crashes				Serious Injury Crashes				Minor Injury Crashes				Non Injury Crashes			
Site	Date	Fatal	Serious	Minor	Non	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change
1	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	1	0.00	-	0	0	0.00	-	1	5	1.62	209.59
2	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	4	0.86	367.60	1	4	1.62	147.67
3	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	0	0.59	-100.00	0	0	0.00	-	0	1	0.00	-
4	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	0	1	0.00	-
5	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	1	0.00	-	2	6	1.71	250.70	10	12	16.15	-25.70
6	1990	0.69	0.52	0.87	4.98	0	0	0.00	-	1	0	0.52	-100.00	1	3	0.87	245.42	0	2	0.00	-
7	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	2	4	1.99	101.31	-	-	-	-
8	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
9	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	3	1	2.98	-66.45	-	-	-	-
12	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
13	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	2	0.00	-	3	3	3.74	-19.78
14	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	0	0.59	-100.00	0	0	0.00	-	0	1	0.00	-
15	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	1	0	0.85	-100.00	0	0	0.00	-
16	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
17	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	1	0	0.53	-100.00	4	3	3.47	-13.66	1	14	2.41	480.01
18	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	1	0	0.53	-100.00	4	1	3.47	-71.22	1	4	2.41	65.72
19	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	1	1.62	-38.08
20	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	2	0.00	-	0	3	0.00	-	1	1	1.25	-19.78
21	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	1	1	0.88	13.42	-	-	-	-
22	1989	0.64	0.54	0.88	-	0	0	0.00	-	1	0	0.54	-100.00	1	2	0.88	126.85	-	-	-	-
23	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	2.41	-100.00
24	1992	0.72	0.59	0.86	1.62	0	1	0.00	-	1	1	0.59	70.56	3	2	2.57	-22.07	5	7	8.08	-13.32
25	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	0	0	0.00	-	2	1	2.49	-59.89
26	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
27	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
28	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	-	-	-	-
29	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	0	0.59	-100.00	0	0	0.00	-	2	4	3.23	23.83
30	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	2	0.86	133.80	2	5	3.23	54.79
31	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	1	8	1.62	395.34
32	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	1	0.59	70.56	1	1	0.86	16.90	1	7	1.62	333.42
33	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	2	1.62	23.83
34	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	2	0.86	133.80	3	0	4.85	-100.00
35	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	3	0.00	-	1	3	1.62	85.75
36	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	0	1	0.00	-
37	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	3	3	4.85	-38.08
38	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	0	0.86	-100.00	5	5	8.08	-38.08
39	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	3	1	2.54	-60.68	8	6	9.97	-39.84
40	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	3	2	3.74	-46.52
43	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	2	2.41	-17.14
44	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	2	1	1.70	-41.13	4	1	4.16	-75.95
45	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	3	1	2.61	-61.63	0	4	0.00	-
46	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	1.25	-100.00
47	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	1	0.00	-	3	0	2.54	-100.00	2	1	2.49	-59.89
48	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	1	0.00	-	1	0	0.85	-100.00	1	1	1.25	-19.78
49	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	4	9	4.99	80.49
50	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	1	0.00	-	0	1	0.00	-	0	2	0.00	-
51	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	1	1	0.85	17.74	1	2	1.04	92.41
52	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	1	0.60	67.26	2	2	1.70	17.95	2	0	2.49	-100.00
53	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	2	0	1.20	-100.00	2	5	1.70	194.87	5	5	6.23	-19.78
54	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	1	2	0.85	135.89	3	3	3.74	-19.78
Sum						0	1	0	-	13	10	7.44	34.34	45.00	61.00	39.28	55.30	81.00	135.00	118.24	14.17

Table B20. Analysis of crash severity for MB type crashes.

	Implementation	Crash Controls CD				Fatal Injury Crashes				Serious Injury Crashes				Minor Injury Crashes				Non Injury Crashes			
Site	Date	Fatal	Serious	Minor	Non	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change
1	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	2	1.62	23.83
2	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
3	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
4	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	1	0	0.85	-100.00	5	0	6.23	-100.00
5	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	1	0.59	70.56	7	1	5.99	-83.30	11	16	17.77	-9.94
6	1990	0.69	0.52	0.87	4.98	0	0	0.00	-	0	0	0.00	-	4	1	3.47	-71.22	2	7	9.96	-29.70
7	1988	0.65	0.60	0.99	-	0	0	0.00	-	1	0	0.60	-100.00	0	0	0.00	-	-	-	-	-
8	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	-	-	-	-
9	1988	0.65	0.60	0.99	-	0	0	0.00	-	3	0	1.80	-100.00	0	0	0.00	-	-	-	-	-
12	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
13	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	1	0.00	-	1	1	0.85	17.95	5	1	6.23	-83.96
14	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
15	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	1.04	-100.00
16	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
17	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	1	0	0.53	-100.00	2	1	1.74	-42.44	4	5	9.66	-48.21
18	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	1	0	0.53	-100.00	2	0	1.74	-100.00	1	4	2.41	65.72
19	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	1	0.00	-	2	2	1.71	16.90	2	4	3.23	23.83
20	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	3	2	3.74	-46.52
21	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
22	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	2	0.00	-	-	-	-	-
23	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	2	0	1.74	-100.00	0	2	0.00	-
24	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	3	0	1.76	-100.00	0	3	0.00	-	4	5	6.46	-22.60
25	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	3	4	3.74	6.95
26	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
27	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
28	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
29	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	0	2	0.00	-
30	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	1	5	1.62	209.59
31	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	3	0.00	-	1	6	1.62	271.50
32	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	2	0.86	133.80	3	6	4.85	23.83
33	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
34	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	4	0.00	-	5	8	8.08	-0.93
35	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	1	0.86	16.90	0	0	0.00	-
36	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	0	1	0.00	-
37	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	4	0	3.42	-100.00	2	5	3.23	54.79
38	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	4	3	3.42	-12.33	11	7	17.77	-60.60
39	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	2	1	1.70	-41.03	6	7	7.48	-6.41
40	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	1	0	0.85	-100.00	0	3	0.00	-
43	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	1	1	0.87	15.12	1	3	2.41	24.29
44	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	7	2	7.28	-72.51
45	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	1	1	0.53	88.08	1	1	0.87	15.12	6	8	14.48	-44.76
46	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	0	2	0.00	-
47	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	1	1	0.85	17.95	4	2	4.99	-59.89
48	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	2	0.00	-	0	1	0.00	-	4	4	4.99	-19.78
49	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	1	0.00	-	1	1	0.85	17.95	4	3	4.99	-39.84
50	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	2	0.00	-	2	2	2.08	-3.79
51	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	2	0	2.08	-100.00
52	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	6	5	5.09	-1.71	4	5	4.99	0.27
53	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	3	1	2.54	-60.68	5	4	6.23	-35.83
54	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	1	0	0.85	-100.00	2	1	2.49	-59.89
Sum						0	0	0	-	12	7	6.94	0.93	48.00	45.00	41.09	9.52	112.00	141.00	173.71	-18.83

Table B21. Analysis of crash severity for NA type crashes.

	Implementation	Crash Controls CD				Fatal Injury Crashes				Serious Injury Crashes				Minor Injury Crashes				Non Injury Crashes			
Site	Date	Fatal	Serious	Minor	Non	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change
1	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	0	0.59	-100.00	1	2	0.86	133.80	0	0	0.00	-
2	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	0	0.86	-100.00	0	0	0.00	-
3	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
4	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	1	1	0.85	17.95	0	0	0.00	-
5	1992	0.72	0.59	0.86	1.62	1	0	0.72	-100.00	4	2	2.35	-14.72	4	2	3.42	-41.55	2	1	3.23	-69.04
6	1990	0.69	0.52	0.87	4.98	0	0	0.00	-	1	1	0.52	93.54	0	1	0.00	-	0	0	0.00	-
7	1988	0.65	0.60	0.99	-	0	0	0.00	-	2	0	1.20	-100.00	0	1	0.00	-	-	-	-	-
8	1988	0.65	0.60	0.99	-	0	1	0.00	-	1	0	0.60	-100.00	0	0	0.00	-	-	-	-	-
9	1988	0.65	0.60	0.99	-	0	0	0.00	-	2	0	1.20	-100.00	0	0	0.00	-	-	-	-	-
12	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
13	1993	0.83	0.60	0.85	1.25	1	0	0.83	-100.00	0	0	0.00	-	2	6	1.70	253.84	1	1	1.25	-19.78
14	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	2	0.00	-	0	0	0.00	-
15	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
16	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	1	0	0.85	-100.00	0	0	0.00	-
17	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	1	0	0.53	-100.00	1	0	0.87	-100.00	0	0	0.00	-
18	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	1	2	0.53	276.15	0	1	0.00	-	0	0	0.00	-
19	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	2	0	1.17	-100.00	1	1	0.86	16.90	0	0	0.00	-
20	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	1	2	0.85	135.89	0	0	0.00	-
21	1989	0.64	0.54	0.88	-	0	1	0.00	-	5	1	2.71	-63.04	0	1	0.00	-	-	-	-	-
22	1989	0.64	0.54	0.88	-	0	1	0.00	-	0	0	0.00	-	4	2	3.53	-43.29	-	-	-	-
23	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
24	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	2	2	1.17	70.56	6	2	5.13	-61.03	0	0	0.00	-
25	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	1	0	0.85	-100.00	0	0	0.00	-
26	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	2	0.00	-	1	1	0.86	16.90	0	0	0.00	-
27	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
28	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
29	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	0	0.86	-100.00	0	0	0.00	-
30	1992	0.72	0.59	0.86	1.62	1	0	0.72	-100.00	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
31	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	1	0.59	70.56	0	1	0.00	-	0	0	0.00	-
32	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	1	3	0.86	250.70	2	0	3.23	-100.00
33	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	0	0.59	-100.00	0	1	0.00	-	0	0	0.00	-
34	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	3	4	2.57	55.87	0	1	0.00	-
35	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	2	0.00	-	0	0	0.00	-
36	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
37	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	0	0.59	-100.00	3	2	2.57	-22.07	1	0	1.62	-100.00
38	1992	0.72	0.59	0.86	1.62	1	0	0.72	-100.00	4	0	2.35	-100.00	7	5	5.99	-16.50	1	2	1.62	23.83
39	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	2	0.60	234.53	0	2	0.00	-	0	0	0.00	-
40	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	1	0.00	-	0	0	0.00	-	0	1	0.00	-
43	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
44	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	1	0	0.62	-100.00	2	1	1.70	-41.13	0	0	0.00	-
45	1991	0.68	0.53	0.87	2.41	1	0	0.68	-100.00	2	0	1.06	-100.00	3	4	2.61	53.50	0	0	0.00	-
46	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	1	1	0.85	17.95	0	0	0.00	-
47	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	1	0.00	-	0	0	0.00	-	0	0	0.00	-
48	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	2	2	1.20	67.26	0	2	0.00	-	0	1	0.00	-
49	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	5	1	4.24	-76.41	0	0	0.00	-
50	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	1	1	0.62	60.29	0	0	0.00	-	0	0	0.00	-
51	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
52	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	0	0	0.00	-	0	1	0.00	-
53	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	2	0.00	-	2	0	1.70	-100.00	0	0	0.00	-
54	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	3	2	2.54	-21.37	0	0	0.00	-
Sum						5	3	3.66	-17.97	38.00	20.00	21.96	-8.94	56.00	56.00	47.92	16.86	7.00	9.00	10.94	-17.71

Table B22. Analysis of crash severity for NB type crashes.

	Implementation	Crash Controls CD				Fatal Injury Crashes				Serious Injury Crashes				Minor Injury Crashes				Non Injury Crashes			
Site	Date	Fatal	Serious	Minor	Non	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change	Before	After	Exp-Aft	% Change
1	1992	0.72	0.59	0.86	1.62	1	0	0.72	-100.00	0	1	0.00	-	0	2	0.00	-	0	0	0.00	-
2	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	0	0.59	-100.00	0	1	0.00	-	0	0	0.00	-
3	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	0	0.59	-100.00	0	0	0.00	-	0	0	0.00	-
4	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	0	1	0.00	-
5	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	2	1	1.17	-14.72	5	6	4.28	40.28	0	0	0.00	-
6	1990	0.69	0.52	0.87	4.98	0	0	0.00	-	1	0	0.52	-100.00	3	2	2.61	-23.24	0	0	0.00	-
7	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	1	0.00	-	2	0	1.99	-100.00	-	-	-	-
8	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
9	1988	0.65	0.60	0.99	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
12	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
13	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	1	0	0.85	-100.00	0	0	0.00	-
14	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	1.62	-100.00
15	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
16	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
17	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	2	1	1.06	-5.96	1	1	0.87	15.12	0	0	0.00	-
18	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	2	0.00	-	1	0	0.87	-100.00	0	0	0.00	-
19	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	0	0.59	-100.00	2	0	1.71	-100.00	0	0	0.00	-
20	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-	0	0	0.00	-
21	1989	0.64	0.54	0.88	-	0	0	0.00	-	1	1	0.54	84.82	2	1	1.76	-43.29	-	-	-	-
22	1989	0.64	0.54	0.88	-	1	0	0.64	-100.00	1	0	0.54	-100.00	0	0	0.00	-	-	-	-	-
23	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	1	0	0.53	-100.00	1	0	0.87	-100.00	0	0	0.00	-
24	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	2	0	1.71	-100.00	0	0	0.00	-
25	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
26	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
27	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
28	1989	0.64	0.54	0.88	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	-	-	-	-
29	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	1	0.00	-	1	0	0.86	-100.00	0	0	0.00	-
30	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	1	0.00	-	0	3	0.00	-	0	0	0.00	-
31	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
32	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	0	0.59	-100.00	0	0	0.00	-	0	0	0.00	-
33	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	0	0.59	-100.00	0	0	0.00	-	0	0	0.00	-
34	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	0	0.59	-100.00	1	0	0.86	-100.00	0	0	0.00	-
35	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
36	1993	0.83	0.60	0.85	1.25	2	0	1.66	-100.00	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
37	1992	0.72	0.59	0.86	1.62	1	0	0.72	-100.00	0	0	0.00	-	0	1	0.00	-	1	0	1.62	-100.00
38	1992	0.72	0.59	0.86	1.62	0	0	0.00	-	1	1	0.59	70.56	0	1	0.00	-	1	2	1.62	23.83
39	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	0	1	0.00	-	0	0	0.00	-
40	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	2	0.00	-	0	0	0.00	-
43	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	1	0	2.41	-100.00
44	1994	0.84	0.62	0.85	1.04	1	0	0.84	-100.00	0	1	0.00	-	0	0	0.00	-	0	0	0.00	-
45	1991	0.68	0.53	0.87	2.41	0	0	0.00	-	0	0	0.00	-	2	3	1.74	72.68	0	1	0.00	-
46	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
47	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
48	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	1	2	0.85	135.89	1	0	1.25	-100.00
49	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	1	0	0.85	-100.00	0	1	0.00	-
50	1994	0.84	0.62	0.85	1.04	0	1	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
51	1994	0.84	0.62	0.85	1.04	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-
52	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	3	0	1.79	-100.00	0	1	0.00	-	0	0	0.00	-
53	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	1	0	0.60	-100.00	1	1	0.85	17.95	1	0	1.25	-100.00
54	1993	0.83	0.60	0.85	1.25	0	0	0.00	-	0	0	0.00	-	0	0	0.00	-	0	1	0.00	-
Sum						6	1	4.57	-78.13	21	11	12.06	-8.77	27	30	23.50	27.66	6	6	9.75	-38.48

Table B23. Summary of crash severity analysis for crash types

Crash Type	Crash Code	Percentage Crash Changes			
		Fatal	Serious	Minor	Non
Lost control on curve	BF	-19.9	-43.8	-9.8	-69.6
Off roadway to left	CB	20.0	-27.4	-5.2	64.9
Off roadway to right	CC	-	34.9	-34.9	-17.3
Lost control turning right	DA	-100.0	-44.6	-53.5	-52.4
Lost control turning left	DB	-100.0	-27.2	-32.4	-35.6
Rear end - parked vehicle	EA	-	48.2	-14.3	-37.2
Rear end - queue	FD	-	-40.1	206.9	23.5
Rear end - near centre line	GD	-	-100.0	-76.7	-73.8
Crossing - right angle	HA	-	-57.2	35.0	-47.9
Right turn right side	JA	-100.0	87.2	17.9	19.2
Making turn	LB	-	34.3	55.3	14.2
U-turn	MB	-	0.9	9.5	-18.8
Pedestrian vs vehicle left side	NA	-18.0	-8.9	16.9	-17.7
Pedestrian vs vehicle right side	NB	-78.1	-8.8	27.7	-38.5

Appendix C Generalised Linear Modelling Analysis Results

Appendix C: Generalised Linear Modelling Analysis Results

Table C1 Analysis of flush medians effect on crash severity

Crash Class	Effect (α)	Proportional Effect (e α)	p-value
Fatal	-0.3234	0.7240	0.35
Serious Injury	-0.07634	0.9265	0.50
Minor Injury	0.0674	1.0697	0.25
Non-Injury	-0.1039	0.9013	0.004

Table C2 Analysis of flush medians effect on night-time and daytime crashes

Crash Class	Period	Effect (α)	Proportional Effect (e α)	p-value
Fatal	Night	-0.4685	0.6260	0.38
	Day	-0.2004	0.8184	0.66
	Difference	-0.2681	0.7648	0.70
Serious Injury	Night	-0.2159	0.8058	0.20
	Day	-0.1298	0.8783	0.39
	Difference	-0.0860	0.9176	0.71
Minor Injury	Night	0.0500	1.0513	0.62
	Day	-0.0038	0.9962	0.96
	Difference	0.0539	1.0553	0.66
Non-Injury	Night	-0.0715	0.9310	0.26
	Day	-0.1222	0.8850	0.006
	Difference	0.0507	1.0520	0.51

Table C3 Analysis of flush medians effect on peak and off-peak crashes

Crash Class	Period	Effect (α)	Proportional Effect (e α)	p-value
Fatal	Peak	0.3457	1.4129	0.63
	Off-peak	-0.4811	0.6181	0.23
	Difference	0.8268	2.2860	0.31
Serious Injury	Peak	-0.0316	0.9689	0.90
	Off-peak	-0.2062	0.8137	0.11
	Difference	0.1746	1.1908	0.53
Minor Injury	Peak	-0.0821	0.9212	0.48
	Off-peak	0.0438	1.0448	0.52
	Difference	-0.1259	0.8817	0.35
Non-Injury	Peak	-0.0541	0.9473	0.47
	Off-peak	-0.1221	0.8851	0.003
	Difference	0.0679	1.0703	0.42

Appendix D Control Data

Appendix D: Control Data

1. Raw Crash Data

1.1 Total Crashes

The data for the control group of sites is given in Table D1. Data for non-injury crashes was not collected before 1989.

Table D1 Control group crash data, all crashes.

Year	Fatal	Serious Injury	Minor Injury	Non-injury
1982	12	98	182	NA
1983	7	97	184	NA
1984	12	132	240	NA
1985	10	111	300	NA
1986	9	122	261	NA
1987	10	97	244	NA
1988	9	98	307	NA
1989	7	81	295	941
1990	5	91	248	1007
1991	8	56	248	933
1992	6	47	223	979
1993	5	60	207	832
1994	8	49	266	962
1995	4	51	278	979
1996	4	53	203	950
1997	7	35	194	930
1998	6	35	179	991
1999	5	35	183	1027

The serious injury data set is larger but there are some difficulties with the log-linear fit in the control group. In the two earliest years (1982-3) of the control group the trend line did not fit very well. Reported crashes were below the trend line. For test sites where the before period included 1982-3, the before proportion would be larger than it should be and the before mean would tend to be under estimated. Thus, any reduction effect present in this group might be masked by comparing the after mean to an under-estimated before mean.

In the control group there is evidence that the reporting regime for minor injury crashes was different (lower) in the early years of the study. This makes the estimation of the relative proportions of the total mean assigned to the before and after periods problematic. However there are a lot of minor injury data and this has made the estimation of any flush median effect easier.

The estimate of the effect is critically dependent on the slope estimate obtained from the control group. This estimate can vary considerably depending on the fitting method and whether the 1982-3 group years were omitted. The estimates chosen had the largest negative values and therefore any reduction observed would be conservative.

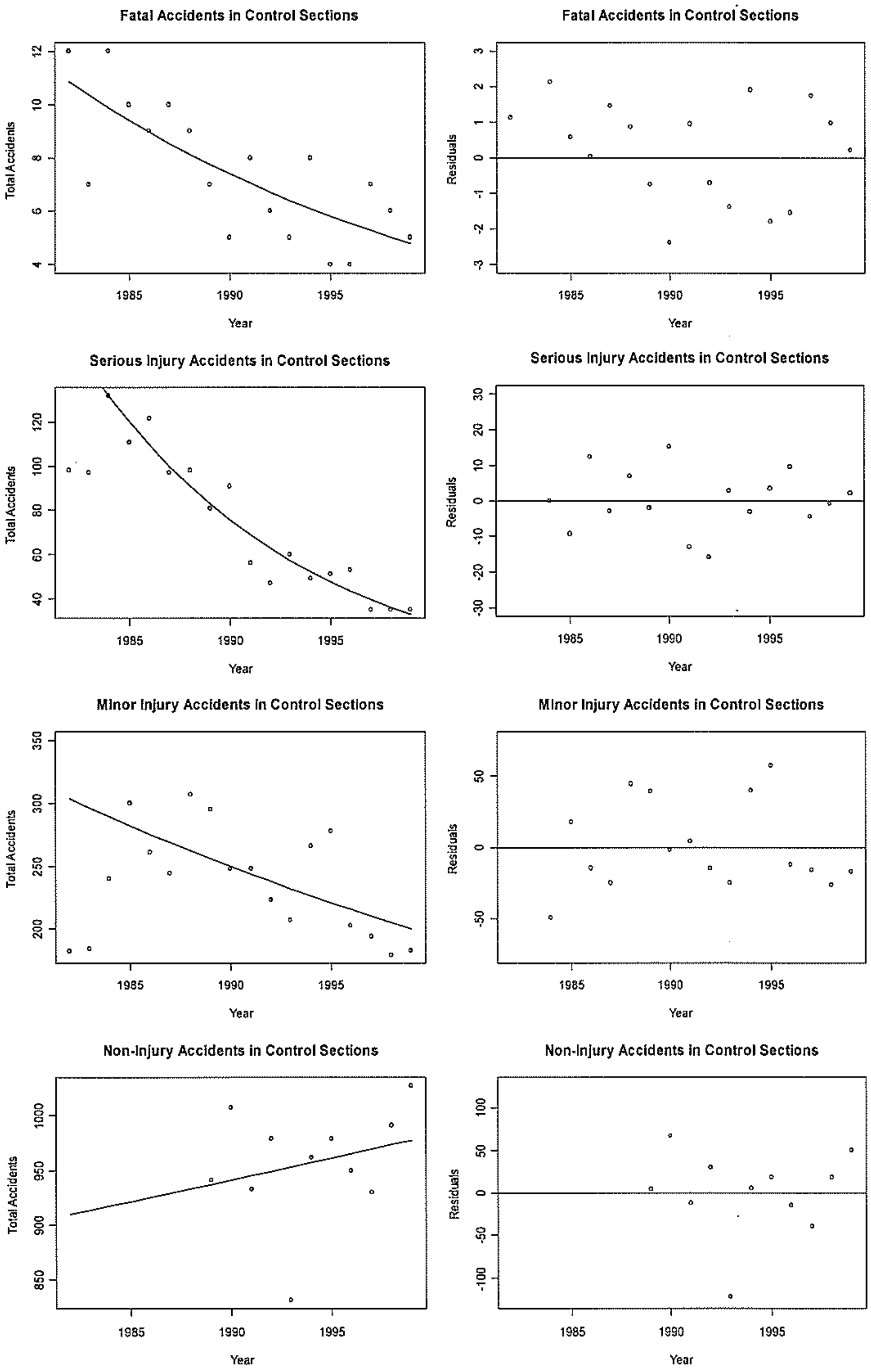


Figure D1 **Plots showing the GLM log linear fitted lines and residuals for the four severity classes.**

1.2 Daytime/Night-time Crashes

Table D2 gives the total numbers of crashes in the control divided between night and day for the four crash types, with the percentages in brackets. It is interesting to note that 58% of fatal crashes occurred at night but less than 40% of all other crash types occurred at night.

Table D2 Control group crash data, night and day crashes

	Fatal		Serious		Minor		Non-injury	
Year	Night	Day	Night	Day	Night	Day	Night	Day
1980	6 (75%)	2 (25%)	41 (41%)	60 (59%)	72 (37%)	122 (63%)		
1981	9 (64%)	5 (36%)	37 (35%)	69 (65%)	65 (37%)	112 (63%)		
1982	6 (50%)	6 (50%)	42 (43%)	56 (57%)	71 (39%)	111 (61%)		
1983	3 (43%)	4 (57%)	39 (40%)	58 (60%)	72 (39%)	112 (61%)		
1984	8 (67%)	4 (33%)	54 (41%)	78 (59%)	93 (39%)	147 (61%)		
1985	7 (70%)	3 (30%)	31 (28%)	80 (72%)	97 (32%)	203 (68%)		
1986	7 (78%)	2 (22%)	53 (43%)	69 (57%)	82 (31%)	179 (69%)		
1987	4 (40%)	6 (60%)	31 (32%)	66 (68%)	79 (32%)	165 (68%)		
1988	7 (78%)	2 (22%)	41 (42%)	57 (58%)	112 (36%)	195 (64%)		
1989	3 (43%)	4 (57%)	33 (41%)	48 (59%)	96 (33%)	199 (67%)	290 (31%)	651 (69%)
1990	4 (80%)	1 (20%)	45 (49%)	46 (51%)	90 (36%)	158 (64%)	304 (30%)	703 (70%)
1991	5 (63%)	3 (38%)	16 (29%)	40 (71%)	81 (33%)	167 (67%)	251 (27%)	682 (73%)
1992	4 (67%)	2 (33%)	20 (43%)	27 (57%)	83 (37%)	140 (63%)	288 (29%)	691 (71%)
1993	1 (20%)	4 (80%)	24 (40%)	36 (60%)	71 (34%)	136 (66%)	233 (28%)	599 (72%)
1994	2 (25%)	6 (75%)	18 (37%)	31 (63%)	65 (24%)	201 (76%)	267 (28%)	695 (72%)
1995	2 (50%)	2 (50%)	16 (31%)	35 (69%)	86 (31%)	192 (69%)	270 (28%)	709 (72%)
1996	3 (75%)	1 (25%)	25 (47%)	28 (53%)	48 (24%)	155 (76%)	276 (29%)	674 (71%)
1997	3 (43%)	4 (57%)	19 (54%)	16 (46%)	57 (29%)	137 (71%)	241 (26%)	689 (74%)
1998	5 (83%)	1 (17%)	13 (37%)	22 (63%)	54 (30%)	125 (70%)	282 (28%)	709 (72%)
1999	2 (40%)	3 (60%)	12 (34%)	23 (66%)	48 (26%)	135 (74%)	301 (29%)	726 (71%)
2000	0 (0%)	1 (100%)	21 (30%)	49 (70%)	92 (30%)	212 (70%)	287 (29%)	709 (71%)
TOTALS	91 (58%)	66 (42%)	631 (39%)	994 (61%)	1614 (33%)	3303 (67%)	3290 (29%)	8237 (71%)

For each crash type (fatal, serious injury, minor injury and non-injury) three different models for the control site data were fitted. In the first model, the time trend coefficient obtained from the non-specific control analysis carried out previously was used. In the second model a common trend parameter was estimated from the specific control data. In the third model, separate time trend parameters for day and night (and for peak and off-peak) were estimated.

Results showed that there was little difference between the fits of the three models. Again there is insufficient data in relation to the inherent variability of the Poisson probability distribution to distinguish between the three. As in the earlier analysis, only the post-1983 data was used for the serious and minor injury analysis.

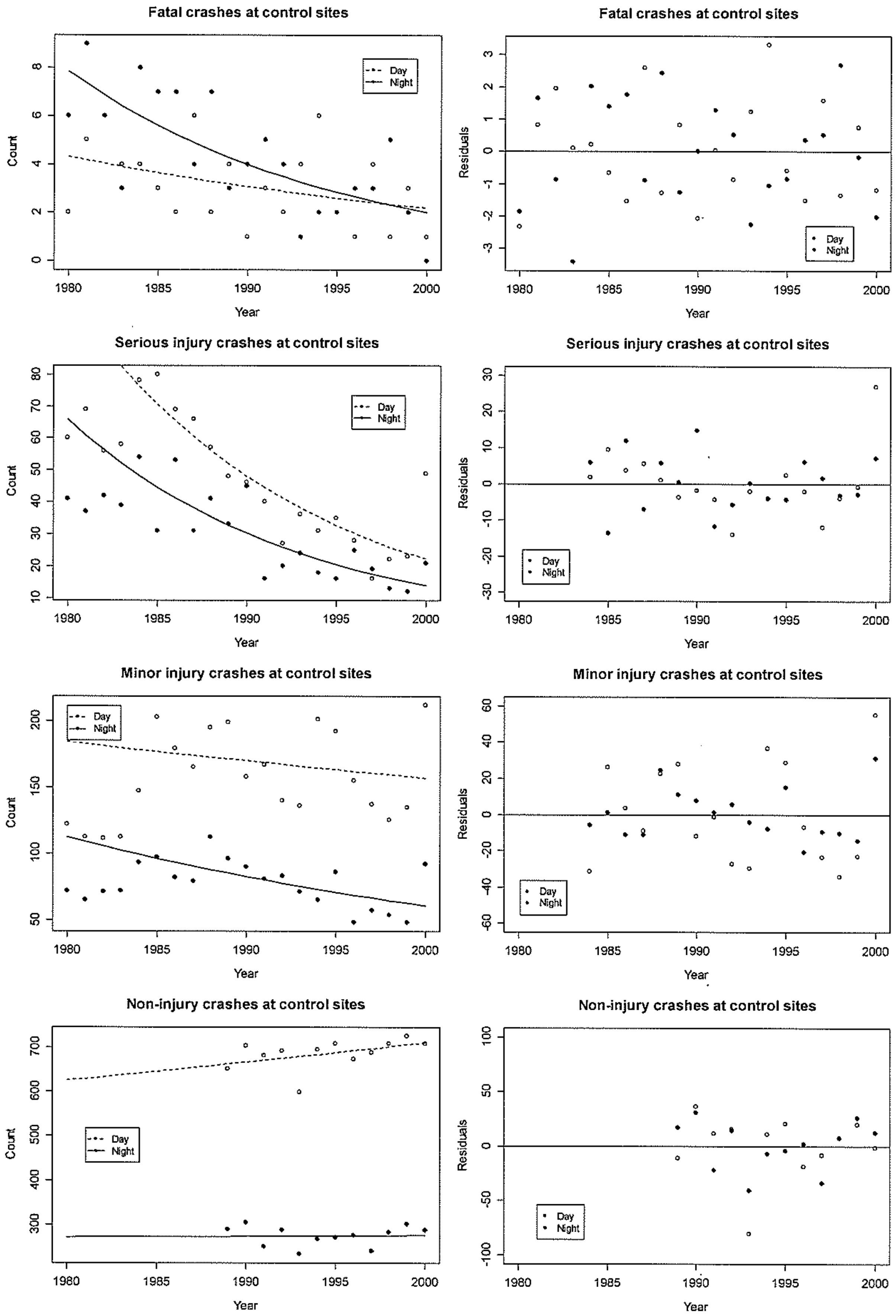


Figure D2 Plots showing the GLM log linear fitted lines and residuals for the night and day crashes for the four severity classes.

1.3 Peak and Off-peak Crashes

Table D3 shows the total numbers of crashes in the control divided between peak and off-peak for the 4 crash types, with the percentages in brackets. Note (unlike the night/day breakdown) that the proportions of fatal crashes in the peak time are much smaller than the proportions of the other type of crashes.

Table D3 Control group crash data, peak and off-peak crashes.

	Fatal		Serious		Minor		Non-injury	
Year	Peak	Off-peak	Peak	Off-peak	Peak	Off-peak	Peak	Off-peak
1980	1 (13%)	7 (88%)	21 (21%)	80 (79%)	44 (23%)	150 (77%)		
1981	0 (0%)	14 (100%)	31 (29%)	75 (71%)	48 (27%)	129 (73%)		
1982	2 (17%)	10 (83%)	22 (22%)	76 (78%)	45 (25%)	137 (75%)		
1983	2 (29%)	5 (71%)	21 (22%)	76 (78%)	45 (24%)	139 (76%)		
1984	1 (8%)	11 (92%)	25 (19%)	107 (81%)	54 (23%)	186 (78%)		
1985	2 (20%)	8 (80%)	39 (35%)	72 (65%)	86 (29%)	214 (71%)		
1986	1 (11%)	8 (89%)	28 (23%)	94 (77%)	82 (31%)	179 (69%)		
1987	1 (10%)	9 (90%)	29 (30%)	68 (70%)	64 (26%)	180 (74%)		
1988	0 (0%)	9 (100%)	17 (17%)	81 (83%)	76 (25%)	231 (75%)		
1989	1 (14%)	6 (86%)	24 (30%)	57 (70%)	76 (26%)	219 (74%)	210 (22%)	731 (78%)
1990	1 (20%)	4 (80%)	16 (18%)	75 (82%)	52 (21%)	196 (79%)	251 (25%)	756 (75%)
1991	0 (0%)	8 (100%)	7 (13%)	49 (88%)	58 (23%)	190 (77%)	215 (23%)	718 (77%)
1992	0 (0%)	6 (100%)	6 (13%)	41 (87%)	52 (23%)	171 (77%)	221 (23%)	758 (77%)
1993	0 (0%)	5 (100%)	15 (25%)	45 (75%)	45 (22%)	162 (78%)	202 (24%)	630 (76%)
1994	0 (0%)	8 (100%)	9 (18%)	40 (82%)	86 (32%)	180 (68%)	242 (25%)	720 (75%)
1995	1 (25%)	3 (75%)	10 (20%)	41 (80%)	70 (25%)	208 (75%)	270 (28%)	709 (72%)
1996	0 (0%)	4 (100%)	9 (17%)	44 (83%)	57 (28%)	146 (72%)	253 (27%)	697 (73%)
1997	1 (14%)	6 (86%)	7 (20%)	28 (80%)	45 (23%)	149 (77%)	258 (28%)	672 (72%)
1998	0 (0%)	6 (100%)	4 (11%)	31 (89%)	46 (26%)	133 (74%)	264 (27%)	727 (73%)
1999	1 (20%)	4 (80%)	14 (40%)	21 (60%)	53 (29%)	130 (71%)	279 (27%)	748 (73%)
2000	1 (100%)	0 (0%)	17 (24%)	53 (76%)	89 (29%)	215 (71%)	263 (26%)	733 (74%)
TOTALS	16 (10%)	141 (90%)	371 (23%)	1254 (77%)	1273 (26%)	3644 (74%)	2928 (25%)	8599 (75%)

The same three forms of the models, as were used in the day/night analysis, were fitted. There were some more obvious differences between the trend slopes obtained in the previous non-specific analysis (model 1) and the estimates obtained for the other two models in the peak off-peak analysis. The differences between the peak and off-peak trend factors in model 3, with the exception of the non-injury crashes, were not significant.

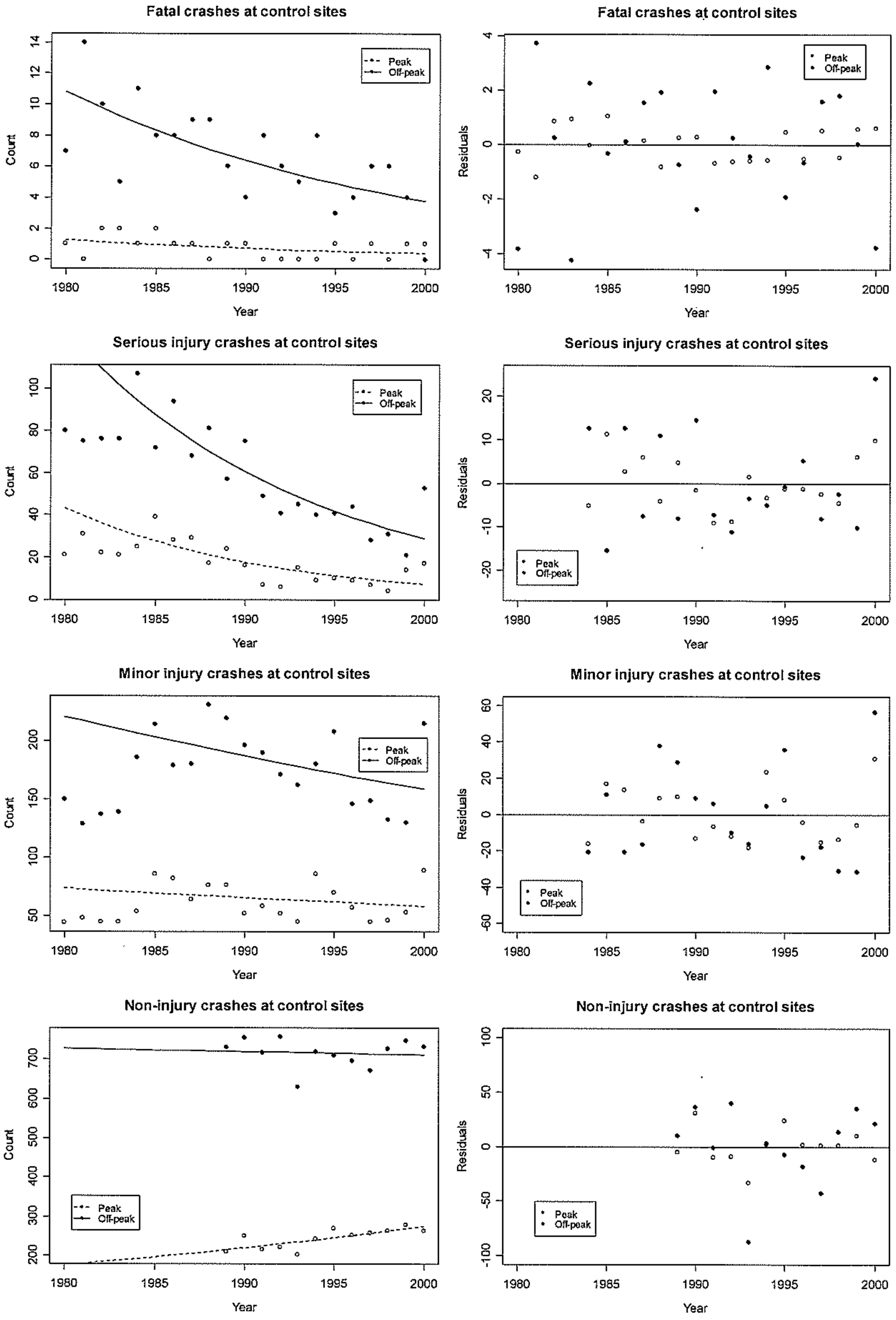


Figure D3 Plots showing the GLM log linear fitted lines and residuals for the peak and off-peak crashes for the four severity classes.

2. Calculation of Control Proportions

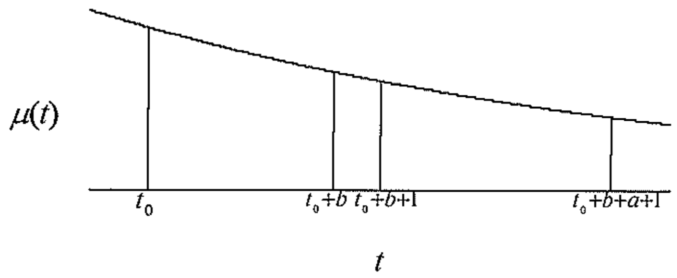
In the log linear model for the control data $\mu(t)$ has the form:

$$\mu(t) = \exp(\beta_0 + \beta_1 t).$$

This can be interpreted as a hazard function (instantaneous mean rate of occurrence of crashes over time) for the combined control group. The mean number of crashes in a time interval (t_1,t_2) can then be expressed as:

$$\int_{t_1}^{t_2} \mu(t)dt = \int_{t_1}^{t_2} \exp(\beta_0 + \beta_1 t)dt = \left[\frac{1}{\beta_1}\exp(\beta_0 + \beta_1 t)\right]_{t_1}^{t_2} = \frac{e^{\beta_0}}{\beta_1}\left(e^{\beta_1 t_2} - e^{\beta_1 t_1}\right).$$

For the situation where we have a before period of length b years starting at time t_0, a 1 year gap (when the flush median is installed) and an after period of a years the total mean number of crashes is given by:



$$\frac{e^{\beta_0}}{\beta_1}\left(e^{\beta_1(t_0+b)} - e^{\beta_1 t_0}\right) + \frac{e^{\beta_0}}{\beta_1}\left(e^{\beta_1(t_0+b+a+1)} - e^{\beta_1(t_0+b+1)}\right)$$

$$= \frac{e^{\beta_0}}{\beta_1}\left(e^{\beta_1(t_0+b)} - e^{\beta_1 t_0} + e^{\beta_1(t_0+b+a+1)} - e^{\beta_1(t_0+b+1)}\right)$$

The proportion of the total mean number of crashes occurring in the before period is then:

$$p_{ib} = \frac{\frac{e^{\beta_0}}{\beta_1}\left(e^{\beta_1(t_0+b)} - e^{\beta_1 t_0}\right)}{\frac{e^{\beta_0}}{\beta_1}\left(e^{\beta_1(t_0+b)} - e^{\beta_1 t_0} + e^{\beta_1(t_0+b+a+1)} - e^{\beta_1(t_0+b+1)}\right)}$$

$$= \frac{e^{\beta_1 b} - 1}{e^{\beta_1 b} - 1 + e^{\beta_1(b+a+1)} - e^{\beta_1(b+1)}} = \frac{1}{1 + e^{\beta_1(b+1)}\dfrac{e^{\beta_1 a} - 1}{e^{\beta_1 b} - 1}}, \qquad (1)$$

which does not depend on the initial time t_0 or on the intercept β_0. It only depends on the length of the before and after periods b, a, and the slope parameter β_1.

For the injury and fatal crash types and for the non-injury crashes from 1994, $a = b$ and the expression for p_{ib} can be further simplified to:

$$p_{ib} = \frac{1}{1 + e^{\beta_1(b+1)}\dfrac{e^{\beta_1 a} - 1}{e^{\beta_1 b} - 1}} = \frac{1}{1 + e^{\beta_1(b+1)}}$$

The proportions of the total mean number of crashes in the before and after periods for the different crash types and severity's are given by expression (1) and appear in Tables D4-D6 below.

Table D4 Proportions of mean numbers of crashes in the before and after periods calculated from the control sites data – all crashes.

Year Flush Median Implemented	Proportions of mean numbers of crashes in before and after periods							
	Fatal		Serious injury		Minor Injury		Non-Injury	
	before	after	before	after	before	after	before	after
1988	0.5719	0.4281	0.6357	0.3643	0.5367	0.4633	0.0000	1.0000
1989	0.5719	0.4281	0.6357	0.3643	0.5367	0.4633	0.0000	1.0000
1990	0.5719	0.4281	0.6357	0.3643	0.5367	0.4633	0.1643	0.8357
1991	0.5719	0.4281	0.6357	0.3643	0.5367	0.4633	0.2818	0.7182
1992	0.5719	0.4281	0.6357	0.3643	0.5367	0.4633	0.3700	0.6300
1993	0.5719	0.4281	0.6357	0.3643	0.5367	0.4633	0.4357	0.5613
1994	0.5719	0.4281	0.6357	0.3643	0.5367	0.4633	0.4936	0.5064

The control sites were used to determine what time trends there are in the day and night-time crash rates. The estimates of the time change factors obtained from these control groups were then used to factor out the time trend for the sites where the flush medians were installed.

The proportions of crashes that would have occurred, if the flush median had no effect, during the pre and post installation periods for the night and day are given in Tables D5 and D6.

Table D5 Before and after installation proportions for night and day injury crashes.

Period	Fatal		Serious Injury		Minor Injury	
	Night	Day	Night	Day	Night	Day
before	0.6004	0.5511	0.6148	0.6137	0.5458	0.5120
after	0.3996	0.4489	0.3852	0.3863	0.4542	0.4880

Table D6 Before and after installation proportions for night and day non-injury crashes for the different installation years.

Period	1990		1991		1992		1993		1994	
	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day
before	0.1663	0.1631	0.2851	0.2798	0.3742	0.3675	0.4435	0.4357	0.4990	0.4903
after	0.8337	0.8369	0.7149	0.7202	0.6258	0.6325	0.5565	0.5643	0.5010	0.5097

It was decided to use a simplified model for the fatal serious and minor injury crash data. Instead of estimating separate λi for day and night for each installation date a single day v night effect was used and the λi were estimated for the combined day and night means. This simplification will have no effect on the estimates or standard errors for the flush median effects because the design is balanced.

The same is not true for non-injury crashes because the before and after proportions are different for different years. In this case the more complex model is used.

The proportions of crashes that would have occurred, if the flush median had no effect, during the pre and post installation periods for the peak and off-peak are given in Tables D7 and D8.

Table D7 Before and after installation proportions for peak and off-peak injury crashes.

Period	Fatal		Serious Injury		Minor Injury	
	Night	Day	Night	Day	Night	Day
before	0.5856	0.5758	0.6316	0.6091	0.5172	0.5247
after	0.4144	0.4213	0.3684	0.3909	0.4828	0.4753

Table D8 Before and after installation proportions for peak and off-peak non-injury crashes for the different installation years.

Period	1990		1991		1992		1993		1994	
	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day
before	0.1547	0.1673	0.2657	0.2867	0.3493	0.3763	0.4146	0.4459	0.4668	0.5017
after	0.8453	0.8327	0.7343	0.7133	0.6507	0.6237	0.5854	0.5541	0.5332	0.4983

As for the day night analysis it was decided to use a simplified model for the fatal serious and minor injury crashes data in the analysis of the peak and off-peak.

Appendix E Regression Analysis

Appendix E: Regression Analysis

Explanatory variables

Table E1Correlation's for explanatory variables

```
              flush date.adj.inj l.sect.l  t.flow  t.dens  x.dens access.dens
flush          1             0.8829  0        0.1567  0       0         0
date.adj.inj   0.8829        1        0.0689  0.1100  0.0462  0.0435    0.0893
l.sect.l       0             0.0689   1      -0.2204 -0.0832  0.1782    0.2079
t.flow         0.1567        0.1100  -0.2204  1       0.0993 -0.1730    0.1054
t.dens         0             0.0462  -0.0832  0.0993  1      -0.1776    0.0462
x.dens         0             0.0435   0.1782 -0.1730 -0.1776  1         0.2392
access.dens    0             0.0893   0.2079  0.1055 -0.0463  0.2392    1
```

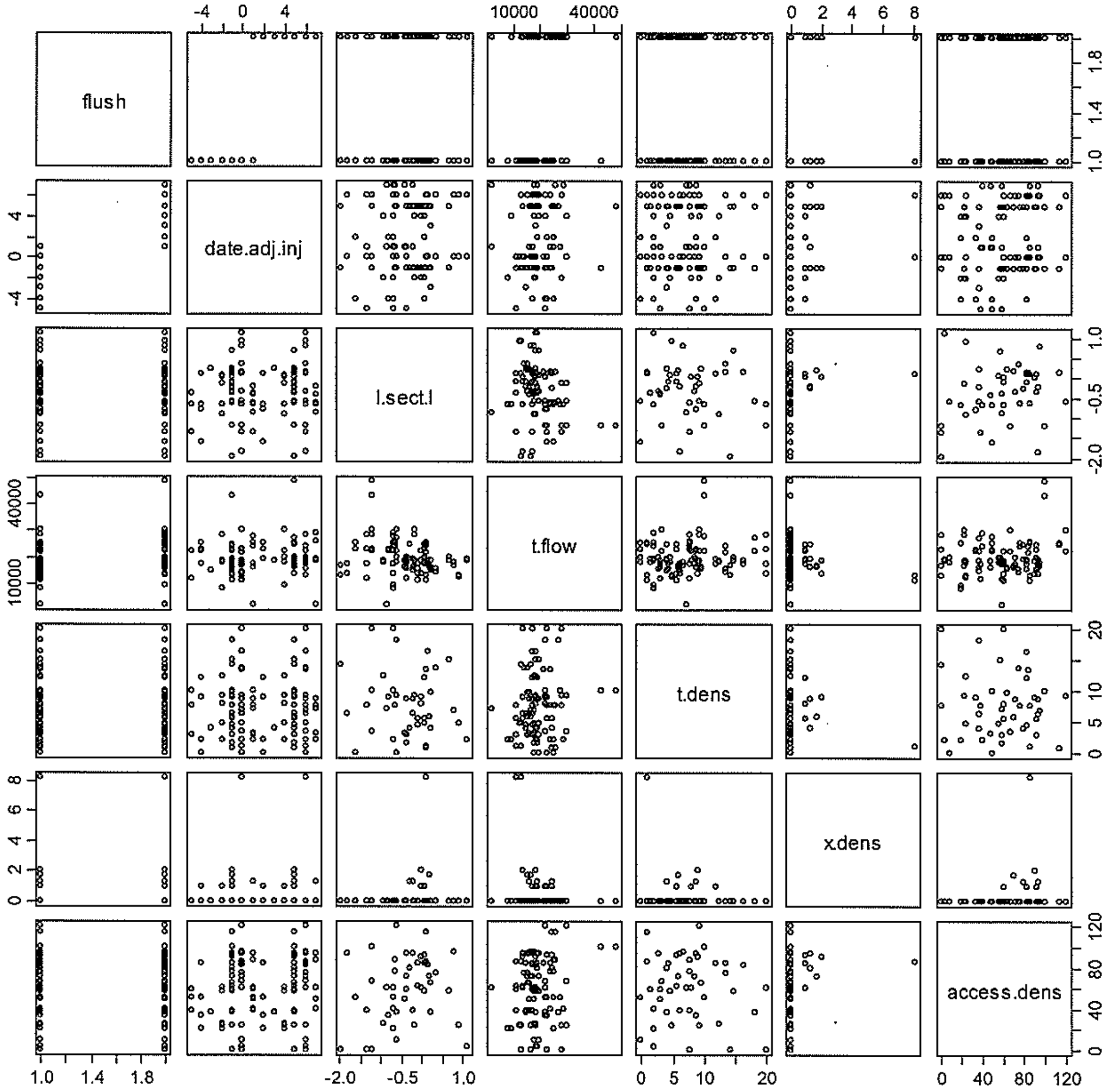


Figure E1.1 Pairs scatter plots of the explanatory variables.

Model Outputs

Fatal Crashes

Full Model Output

```
glm(formula = fat ~ flush + date.adj.inj + l.sect.l + t.flow +
      t.dens + x.dens + access.dens, family = poisson(), data =
      reg.data.df, offset = log(inj.per))
```

Table E2 Fatal crash full model coefficients.

```
               Estimate Std. Error z value Pr(>|z|)
(Intercept)  -2.524e+00  6.955e-01  -3.629 0.000284 ***
flush        -5.702e-01  7.920e-01  -0.720 0.471544
date.adj.inj -1.331e-02  1.186e-01  -0.112 0.910645
l.sect.l      7.855e-01  2.822e-01   2.784 0.005376 **
t.flow        1.908e-05  3.122e-05   0.611 0.541138
t.dens        9.983e-03  3.443e-02   0.290 0.771826
x.dens       -4.795e-02  1.673e-01  -0.287 0.774411
access.dens  -1.160e-03  5.630e-03  -0.206 0.836686
---
    Null deviance: 99.574  on 99  degrees of freedom
Residual deviance: 87.810  on 92  degrees of freedom
```

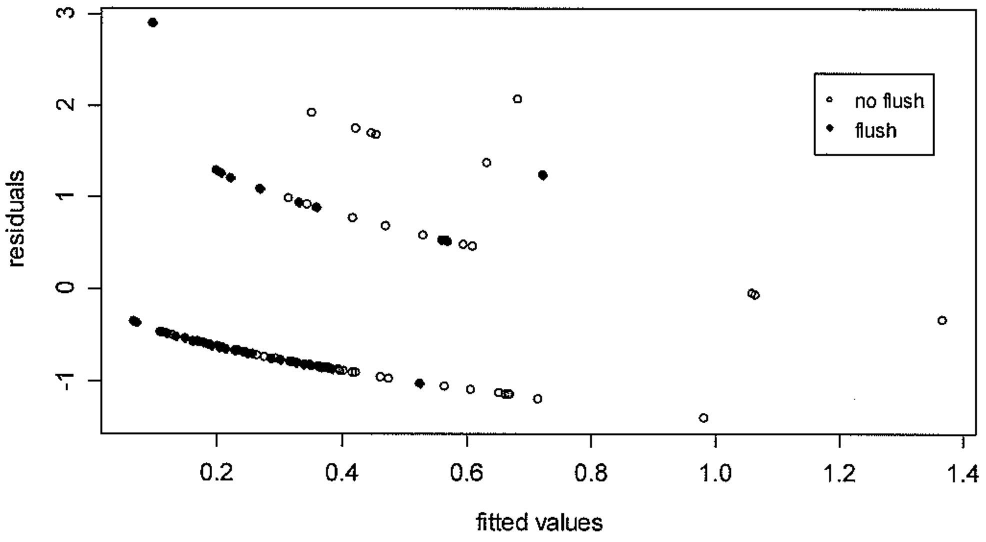


Figure E2.2 Residual plot of fatal crashes against fitted values, full model.

In Table E2 where terms are added sequentially, those with the largest deviance tended to be the most important. However this depended on the order each term was added when there was correlation between the explanatory variables. The reduction in deviance is from a null deviance of 99.57 (model with no covariates) to 87.84. Therefore the model only explains about 1 – 87.810/99.574 = 11.8% of the "variation". This means that the predictive power of the model is somewhat limited.

Because of the potential over-fitting problem a backwards-stepwise analysis was carried out with the mid-point (`date.adj.inj`) and flush (`flush`) variables always present. The model variables that were left were:

`flush, date.adj.inj, l.sect.l`

This model is the best model under the BIC criterion. The order in which each variable is removed from the full model and the corresponding values of the deviance and the BIC are given in the following table.

Table E3 Fatal crash model - BIC analysis outputs.

Variable	df	Deviance	BIC
full model	92	87.810	185.940
`- access.dens`	93	87.853	181.377
`- t.dens`	94	87.923	176.842
`- x.dens`	95	88.099	172.412
`- t.flow`	96	88.558	168.267
`- l.sect.l`	97	96.122	175.831

BIC is reduced until - t.flow is removed after which it starts increasing. This leaves the model with variables `flush`, `date.adj.inj`, `l.sect.l` as the most important predictive variables. Table E4 shows the resulting coefficients.

Table E4 Fatal crash reduced model coefficients.

```
             Estimate Std. Error z value Pr(>|z|)
(Intercept)  -2.19628    0.23475  -9.356  < 2e-16 ***
flush        -0.51149    0.77679  -0.658  0.51024
date.adj.inj -0.01694    0.11606  -0.146  0.88398
l.sect.l      0.72393    0.27004   2.681  0.00734 **
---
    Null deviance: 99.574  on 99  degrees of freedom
Residual deviance: 88.558  on 96  degrees of freedom
```

The change in contribution to deviance as each variable is included sequentially indicates the importance of each of the remaining variables in explaining variation. However, when explanatory variables are correlated the contribution depends on the order of inclusion. Since the correlation is not high there is some indication of importance of various variables in the predictive model. The output from R for this process is given in Table E5.

Table E5 Analysis of deviance.

```
Model: poisson, link: log
Response: fat
Terms added sequentially (first to last)

             Df Deviance Resid. Df Resid. Dev
NULL                            99     99.574
flush         1    3.320        98     96.254
date.adj.inj  1    0.128        97     96.126
l.sect.l      1    7.568        96     88.558
```

Note that the contributions of the 2 additional variables are similar. (Indeed whichever is added second contributes the most, because they are negatively correlated and their coefficients have the same sign).

The mean number of fatal injury crashes using the reduced model is:

exp(log(`period.l`) – 2.19628 – 0.51148*`flush` – 0.07579*log(`sect.l`))

Serious Injury Crashes

Full Model

```
glm(formula = ser ~ flush + date.adj.inj + l.sect.l + t.flow +
t.dens      + x.dens + access.dens, family = poisson(), data =
      reg.data.df,offset = log(inj.per))
```

Table E6 Serious crash full model coefficients.

```
                Estimate Std. Error z value Pr(>|z|)
(Intercept)  -5.411e-01  2.375e-01  -2.278 0.022724 *
flush        -2.763e-01  2.572e-01  -1.074 0.282646
date.adj.inj -7.287e-02  3.856e-02  -1.889 0.058829 .
l.sect.l      9.763e-01  9.511e-02  10.265  < 2e-16 ***
t.flow        4.021e-05  1.052e-05   3.824 0.000131 ***
t.dens        1.675e-02  1.144e-02   1.465 0.142982
x.dens        8.473e-02  4.379e-02   1.935 0.052974 .
access.dens  -6.197e-03  1.834e-03  -3.379 0.000727 ***
---
    Null deviance: 322.00  on 99  degrees of freedom
Residual deviance: 166.61  on 92  degrees of freedom
```

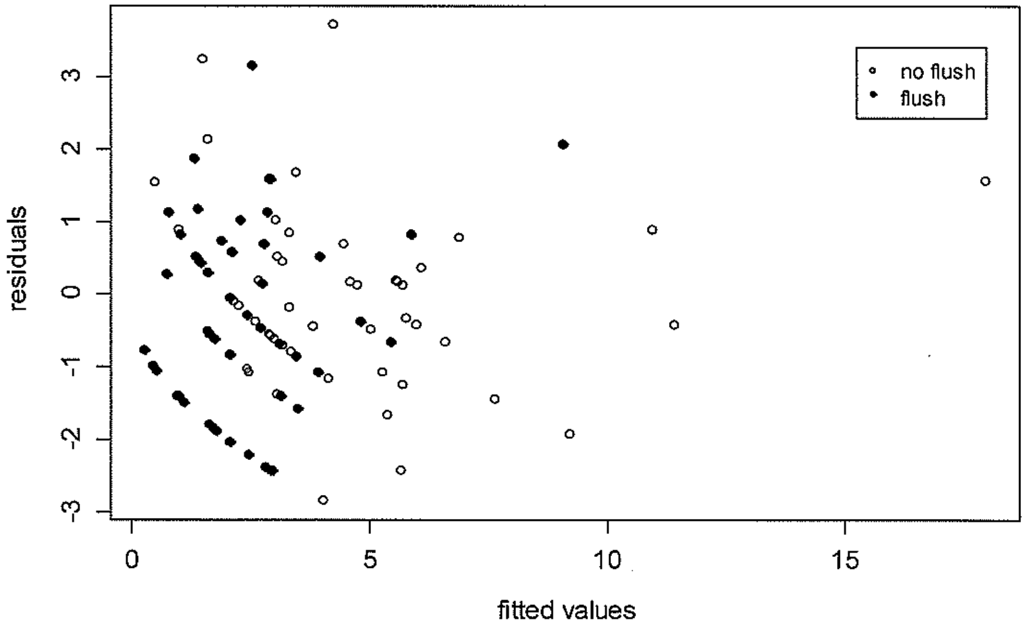


Figure E2.2 Residual plot of fatal crashes against fitted values, full model.

Again a reduced model achieves almost the same explained variation. Applying the BIC criterion (with the requirement that the median effect and the time trend be included) the variables omitted in sequential order are:

Table E7 Serious crash model - BIC analysis outputs.

Variable	df	Deviance	BIC
full model	92	162.62	459.29
- `t.dens`	93	168.72	456.80
- `x.dens`	94	171.14	454.61
- `access.dens`	95	179.32	458.19

Leaving the variables

`flush`, `date.adj.inj`, `l.sect.l`, `t.flow`, and `access.dens`.

The coefficients for this model are:

Table E8 Serious crash reduced model coefficients.

```
               Estimate Std. Error z value Pr(>|z|)
(Intercept)  -3.857e-01  2.212e-01  -1.744 0.081232 .
flush        -3.041e-01  2.556e-01  -1.190 0.234027
date.adj.inj -6.684e-02  3.827e-02  -1.747 0.080701 .
l.sect.l      9.525e-01  9.334e-02  10.205  < 2e-16 ***
t.flow        3.685e-05  1.015e-05   3.629 0.000284 ***
access.dens  -4.960e-03  1.722e-03  -2.881 0.003967 **
---
    Null deviance: 322.00  on 99  degrees of freedom
Residual deviance: 171.14  on 94  degrees of freedom
```

The change in contribution to deviance as each variable is included sequentially indicates the importance of each of the remaining variables in explaining variation. The output from R for adding variables sequentially is given below.

Table E9 Analysis of deviance.

```
Model: poisson, link: log
Response: ser
Terms added sequentially (first to last)

             Df Deviance Resid. Df Resid. Dev
NULL                            99     322.00
flush         1    33.00        98     289.00
date.adj.inj  1     0.01        97     288.99
l.sect.l      1    98.68        96     190.31
t.flow        1    10.99        95     179.32
access.dens   1     8.18        94     171.14
```

Note that log(section length) makes by far the largest contribution and hence is the most important predictive variable.

The mean number of serious injury crashes using the reduced model is

$$\exp(\log(\texttt{period.1}) - 0.3857 - 0.3041{*}\texttt{flush} - 0.06684{*}\texttt{date.adj} + 0.9525{*}\log(\texttt{sect.1}) + 3.685\text{e-}05{*}\texttt{t.flow} - 4.960\text{e-}03{*}\texttt{access.dens})$$

Minor Injury Crashes

Full Model

```
glm(formula = min ~ flush + date.adj.inj + l.sect.l + t.flow +
     t.dens + x.dens + access.dens, family = poisson(), data =
     reg.data.df,
    offset = log(inj.per))
```

Table E10 Minor injury crash full model coefficients

```
                 Estimate Std. Error z value Pr(>|z|)
(Intercept)    3.186e-01  1.346e-01   2.367  0.01794 *
flush          3.820e-01  1.390e-01   2.749  0.00598 **
date.adj.inj -8.717e-02  2.094e-02  -4.163 3.14e-05 ***
l.sect.l       9.576e-01  5.252e-02  18.234  < 2e-16 ***
t.flow         2.927e-05  5.913e-06   4.950 7.42e-07 ***
t.dens         5.391e-02  6.056e-03   8.902  < 2e-16 ***
x.dens         1.780e-01  2.002e-02   8.891  < 2e-16 ***
access.dens  -6.487e-03  1.027e-03  -6.319 2.63e-10 ***
---
    Null deviance: 757.02  on 99  degrees of freedom
Residual deviance: 308.02  on 92  degrees of freedom
```

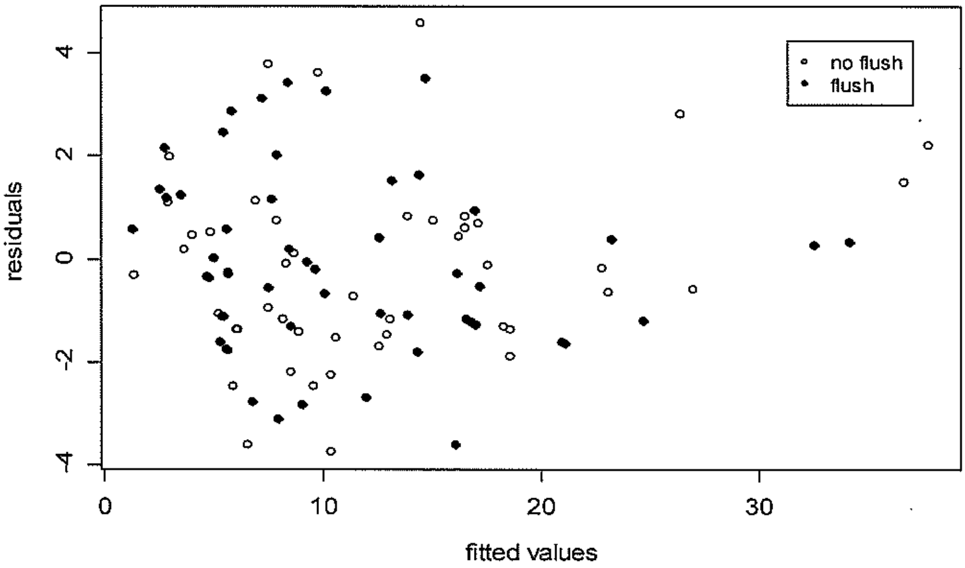


Figure E2.2 Residual plot of minor injury crashes against fitted values, full model.

The residuals have the right appearance, as there appears to be no structure in relation to the fitted values.

Looking for a reduced model that predicts almost as well according to the BIC criterion resulted in the order of removal of variables as given in Table E11.

Table E11 Minor injury crash model - BIC analysis outputs.

Variable	df	Deviance	BIC
full model	92	308.02	739.09
`- t.flow`	96	331.80	758.27

The following Table E12 indicates the importance of the variables to the deviance reduction.

Table E12 Analysis of deviance

```
Model: poisson, link: log
Response: min
Terms added sequentially (first to last)

             Df Deviance Resid. Df Resid. Dev
NULL                            99     757.02
flush         1     1.88        98     755.15
date.adj.inj  1     0.03        97     755.12
l.sect.l      1   306.21        96     448.91
t.flow        1    14.00        95     434.91
t.dens        1    46.27        94     388.64
x.dens        1    41.20        93     347.44
access.dens   1    39.41        92     308.02
```

The change in contribution to the deviance by sequentially adding the additional variables is dominated by log(section length) with the T, crossing and access way densities the next most important.

The mean number of minor injury crashes using the reduced model is:

> exp(log(`period.l`) –0.3186+0.3820*`flush` – 0.08717`date.adj` + 0.9576*log(`sect.l`) + 2.927e-05*`t.flow` + 0.05391*`t.dens` + 0.1780*`x.dens` – 6.487e-03*`access.dens`)

Non-Injury Crashes

Full Model

```
glm(formula = non ~ flush + date.adj.non + l.sect.l + t.flow +
   t.dens + x.dens + access.dens, family = poisson(), data =
   reg.data.df,
    offset = log(non.per))
```

Table E13 Non-injury crash full model coefficients.

```
              Estimate Std. Error z value Pr(>|z|)
(Intercept)    1.532e+00  7.630e-02  20.073  < 2e-16 ***
flush    2.655e-01  7.681e-02   3.457 0.000547 ***
date.adj.non -8.178e-02  1.472e-02  -5.555 2.77e-08 ***
l.sect.l       8.315e-01  3.046e-02  27.298  < 2e-16 ***
t.flow         3.343e-05  3.279e-06  10.197  < 2e-16 ***
t.dens         4.790e-02  3.489e-03  13.727  < 2e-16 ***
x.dens         1.448e-01  1.171e-02  12.359  < 2e-16 ***
access.dens  -3.861e-03  5.850e-04  -6.600 4.11e-11 ***
---
    Null deviance: 1556.93  on 92  degrees of freedom
Residual deviance:  568.26  on 85  degrees of freedom
---
```

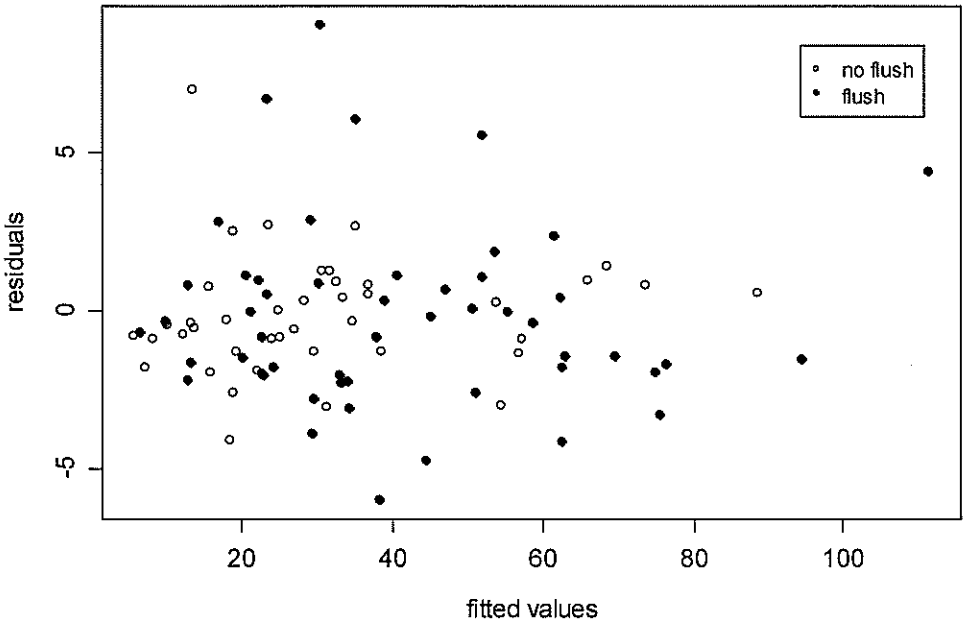


Figure E2.2 Residual plot of non-injury crashes against fitted values, full model.

Looking for a reduced model that predicts almost as well according to the BIC criterion resulted in the order of removal of variables as given in the following table:

Table E14 Non-injury crash model - BIC analysis outputs

Variable	df	Deviance	BIC
full model	85	568.26	1084.84
`- access.dens`	86	611.18	1123.15

All variables contribute to the fit and the stepwise showed that removing the variable explaining the least amount deviance, access density, increases the BIC.

The following table indicates the importance of the variables to the deviance reduction.

Table E15 Analysis of deviance.

```
Model: poisson, link: log
Response: min
Terms added sequentially (first to last)

             Df Deviance Resid. Df Resid. Dev
NULL                            92    1556.93
flush         1     6.29        91    1550.63
date.adj.non  1     3.90        90    1546.74
l.sect.1      1   645.88        89     900.86
t.flow        1    70.78        88     830.07
t.dens        1   122.46        87     707.61
x.dens        1    96.43        86     611.18
access.dens   1    42.92        85     568.26
```

The change in contribution to the deviance by sequentially adding the additional variables is dominated by section length with the T and crossing densities the next most important.

The mean number of non-injury crashes using the reduced model is:

$$\begin{aligned}&\exp(\log(\texttt{period.1}) + 1.532 + 0.2855*\texttt{flush} - 0.08178*\texttt{date.adj}\\ &+ 0.8315*\log(\texttt{sect.1}) + 3.343\text{e-}05*\texttt{t.flow} + 0.04790*\texttt{t.dens}\\ &+ 0.1448*\texttt{x.dens} - 3.861\text{e-}03*\texttt{access.dens})\end{aligned}$$

Appendix F Preliminary Guidelines for Safer Flush Medians

Appendix F: Preliminary Guidelines for Safer Flush Medians

Using these guidelines should ensure greater savings in crash frequency and crash cost when implementing flush medians. Investigation should be made into crash severity, time of day and crash type to provide guidance for implementation of flush medians.

The analysis of 50 Auckland City sites, where flush medians have been implemented, have overall achieved a significant economic benefit in safety. However, the concern still is that crashes increased at several sites.

- Fatal crashes increased at 11 sites;
- Serious injury crashes increased at 16 sites;
- Minor injury crashes increased at 28 sites; and
- Non-injury crashes increased at 18 sites.

Assessment of crashes provides the strongest means of ensuring successful implementation of flush medians. This study has identified several target crash types, and classifications, which have been significantly influenced. Assessment of the numbers and proportions of these crashes should be undertaken at the preliminary assessment stage of flush median implementation in order to identify:

1. Whether a flush median is appropriate at a site; and
2. What should be incorporated in the design to ensure crashes do not increase?

Sites to be studied

Sites for flush median treatment should be assessed taking the following into account:

- Flush medians reduce crash severity. Changes by crash severity are as follows:

- Fatal	-28%
- Serious	-7%
- Minor	+7%
- Non-injury	-10%

Refer to Sections 4.3.1 and 4.4.2 of the main report.

- Flush medians appear to achieve greater savings in night-time crashes compared to daytime crashes. Refer to Sections 4.3.2 and 4.4.3.
- Flush medians appear to result in greater crash savings during the off-peak period. Refer to Sections 4.3.3 and 4.4.4.
- Flush medians appear to have a calming effect on traffic, possibly resulting in slower vehicle speeds and improved driver discipline.
- Flush medians have resulted in significant savings in 'loss of control crashes in bends' and 'pedestrian' crashes.

Table F1 Major types of crash changes that could be expected.

	Crash Type	Severity	% Ch
Straight – Lost Control / Head On	CB Off roadway to left	Fatal	+20
		Serious	-27
		Minor	-5
		Non-inj	+65
	CC Off roadway to right	Fatal	-
		Serious	+35
		Minor	-35
		Non-inj	-17
Bend – Lost Control / Head On	BF Lost control on curve	Fatal	-20
		Serious	-44
		Minor	-10
		Non-inj	-70
	DA Lost control turning right	Fatal	-100
		Serious	-45
		Minor	-53
		Non-inj	-52
	DB Lost control turning left	Fatal	-100
		Serious	-27
		Minor	-32
		Non-inj	-36
Rear End – Obstruction	EA Parked vehicle	Fatal	-
		Serious	+48
		Minor	-14
		Non-inj	-37
	FD Queue	Fatal	-
		Serious	-40
		Minor	+207
		Non-inj	+23
	GD Near centre line	Fatal	-
		Serious	-100
		Minor	-77
		Non-inj	-74
	MB U-turn	Fatal	-
		Serious	+1
		Minor	+10
		Non-inj	-19

	Crash Type	**Severity**	**% Ch**
Crossing / Turning	HA Right angle (70° to 110°)	Fatal	-
		Serious	-57
		Minor	+35
		Non-inj	-48
	JA Right turn right side	Fatal	-100
		Serious	+87
		Minor	+18
		Non-inj	+19
	LB Making turn	Fatal	+100
		Serious	+34
		Minor	+55.3
		Non-inj	+14
Pedestrian vs Vehicle	NA Left side	Fatal	-18
		Serious	-9
		Minor	+17
		Non-inj	-18
	NB Right side	Fatal	-78
		Serious	-9
		Minor	+28
		Non-inj	-39

- ☐ Where the crash rate at a site is lower than the New Zealand average (refer to B/C Manual) caution should be taken in deciding whether a flush median should be installed. A flush median should not be installed unless a study indicates crash savings will be achieved.

- ☐ Investigate the most appropriate median width to install as narrow flush medians (<2m) have been found to have greater savings compared to wider flush medians >2m). Narrow medians may result in increased caution due to driver perception. Refer to Sections 4.3.4 and 4.4.5.

- ☐ Investigate treatment of friction grip at intersections where there are large numbers of LB and JA type crashes as flush medians may encourage more turns. Check visibility is not a problem – strip parking, prune trees, etc., as flushes were shown to increase these types of crashes. This should further increase crash savings. Refer to Section 4.3.5 and 4.4.6.

- ☐ Any pedestrian refuge islands installed should be designed to at least meet the minimum required spacing to access ways as shown in Figures F3 and F4. Night-time visibility of pedestrian refuge islands should also be further increased through implementation of rrpms on the flush median approaches to the islands (shown in Figure F2). Refer to Section 6 of main report.

- ☐ This guideline should be used in association with the LTSA Flush Median and Transit and LTSA Roadmark and Sign Manuals.

- ☐ Where a large number of bend crashes occur, consider advanced bend warning signs and chevrons. This should further increase the safety of flush medians.

- ☐ Where a large number of night-time loss of control crashes occur, consider delineation of bend with rrpms, streetlights, chevron signs, etc.

Figure F1 Pedestrian refuge island with no-overtaking line and rrpms on approaches, at night.

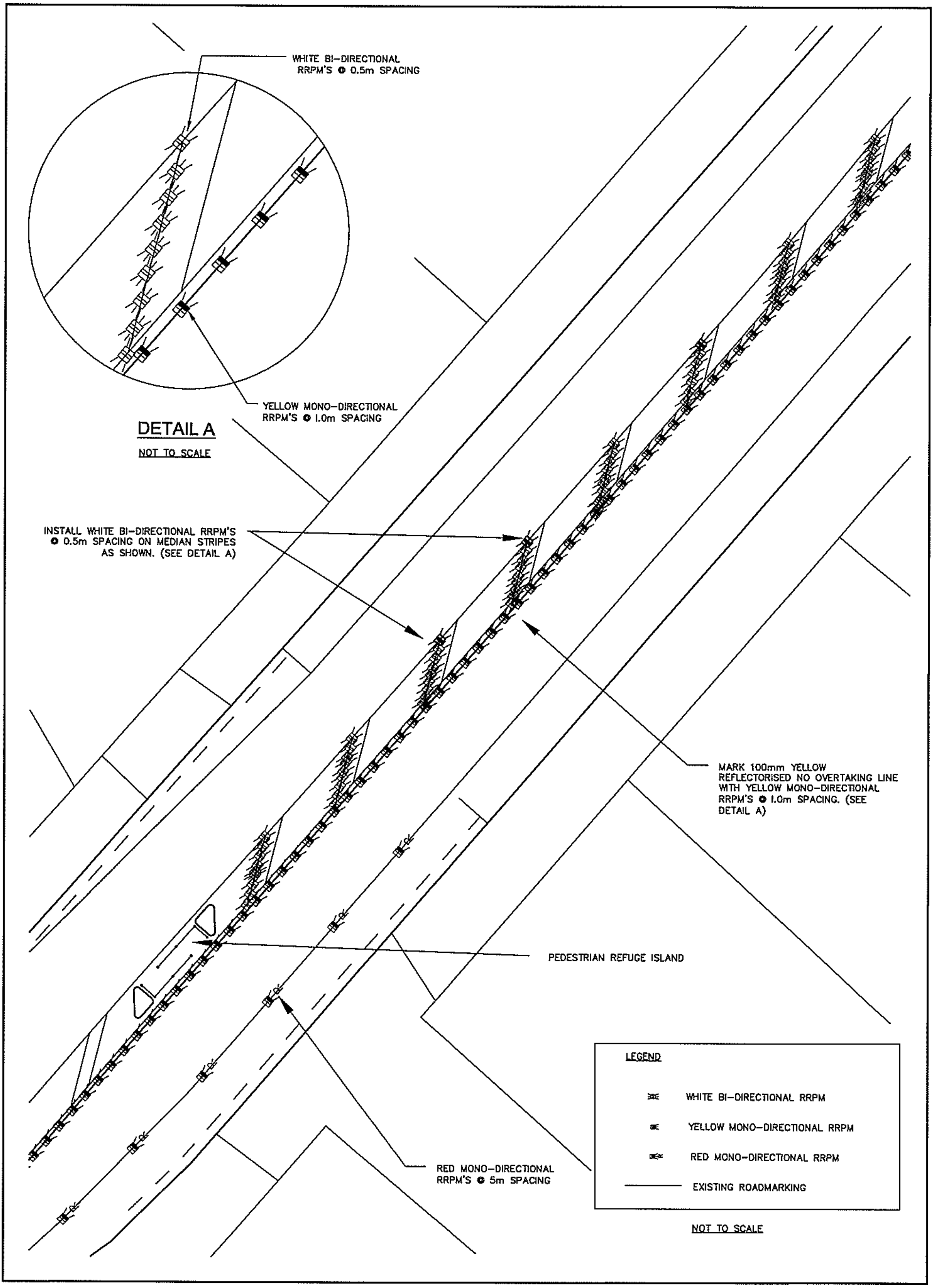


Figure F 2 Example of application of RRPMs and No Overtaking lines on approach to Pedestrian Refuges.

NOTE:

THESE DIMENSIONS ARE ONLY CONSIDERED SUITABLE FOR VEHICLES TRAVELLING AT VERY LOW SPEEDS. IT ENABLES THE VEHICLE TO CLEAR THE THROUGH LANE AND WAIT TO ACCESS ADJACENT RESIDENTIAL PROPERTIES. (1-2 QUEUING SPACES ETC.)

DESIGN CHART MINIMUM DIMENSIONS FOR TYPE 1 REFUGE

x(m)	Cross Section	a(m)	b(m)	c(m)
4	2 Lane	11.0	10.5	10.0
6	2 Lane with Parking	11.0	9.5	9.0
7	4 Lane	10.5	9.5	8.7
9	4 Lane with Parking	8.5	7.8	7.5

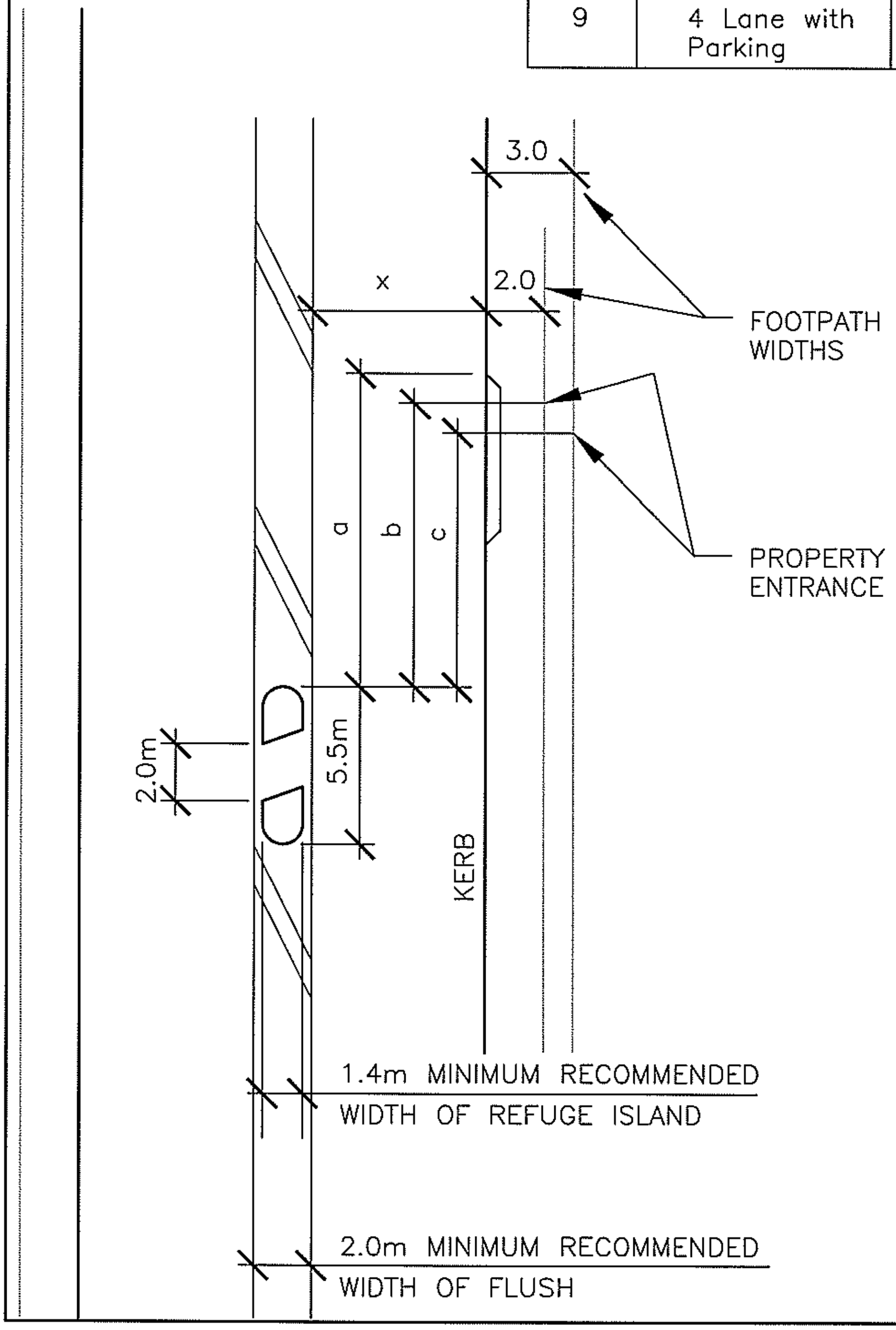
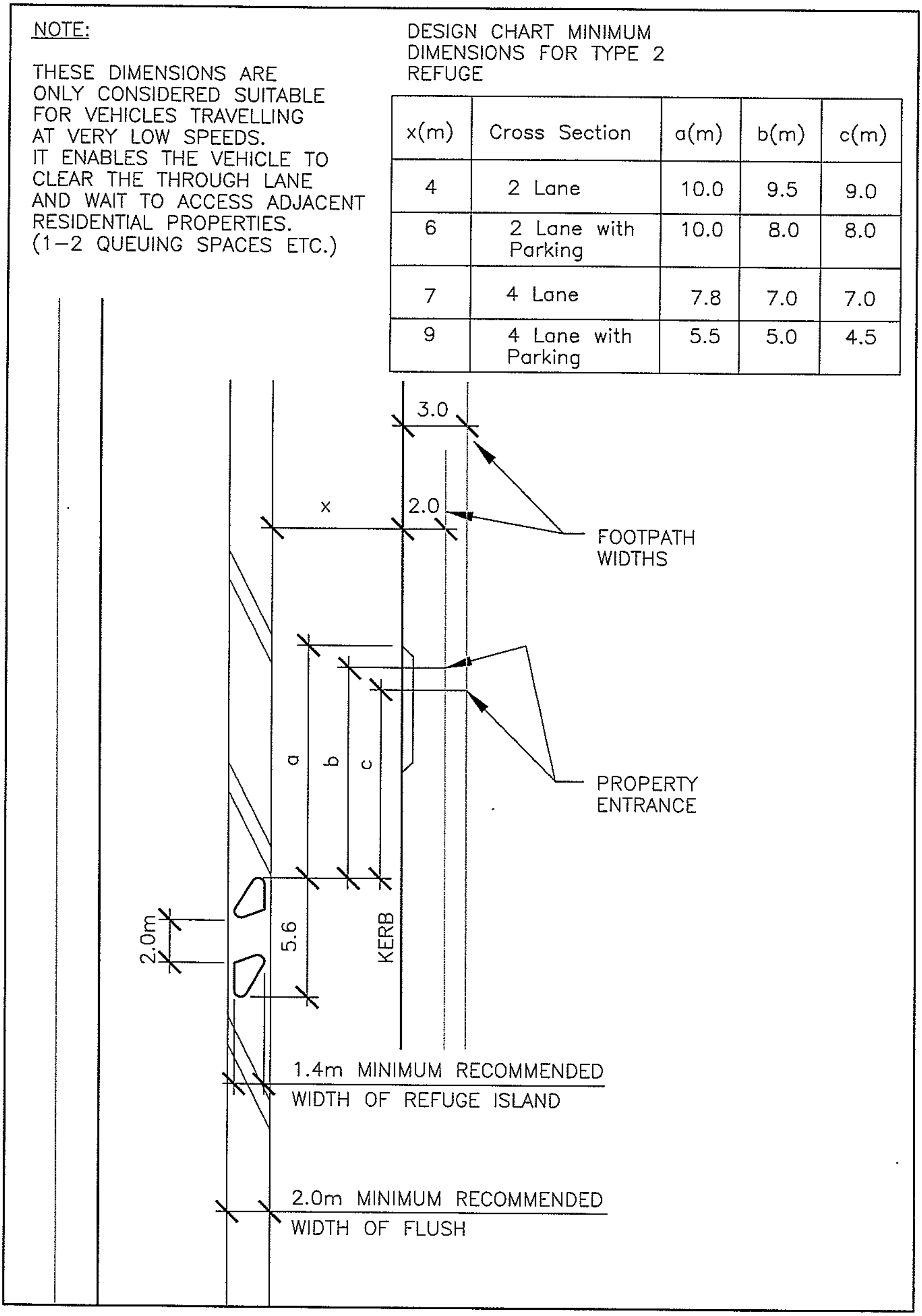


Figure F3 Design detail for pedestrian refuge islands implementation on flush medians - type 1 refuge



NOTE:

THESE DIMENSIONS ARE ONLY CONSIDERED SUITABLE FOR VEHICLES TRAVELLING AT VERY LOW SPEEDS. IT ENABLES THE VEHICLE TO CLEAR THE THROUGH LANE AND WAIT TO ACCESS ADJACENT RESIDENTIAL PROPERTIES. (1–2 QUEUING SPACES ETC.)

DESIGN CHART MINIMUM DIMENSIONS FOR TYPE 2 REFUGE

x(m)	Cross Section	a(m)	b(m)	c(m)
4	2 Lane	10.0	9.5	9.0
6	2 Lane with Parking	10.0	8.0	8.0
7	4 Lane	7.8	7.0	7.0
9	4 Lane with Parking	5.5	5.0	4.5

1.4m MINIMUM RECOMMENDED WIDTH OF REFUGE ISLAND

2.0m MINIMUM RECOMMENDED WIDTH OF FLUSH

Figure F4 Design detail for pedestrian refuge islands implementation on flush medians - type 2 refuge

Appendix G Recommended Further Investigations

Appendix G: Recommended Further Investigations

1. Develop the GLM method of analysis for 'before' and 'after' studies and formalise a guideline for standard studies in New Zealand.
2. Estimate the effect of traffic calming due to the introduction of flush medians through cross sectional analysis. Differences during the night and day and the effect of speed at bends should also be investigated.
3. Identify what type of crashes are less on the narrow flush medians. It is believed that the turning crashes may be less, therefore this should be investigated.
4. Investigate why narrow medians appear to be safer than wide medians?
5. Investigate sites where following implementation of flush medians, crashes increased.
   - Establish why they experienced increases.
   - Identify the type of crash increases.
   - Establish whether changes can be made to the design to ensure positive crash savings.
   - Conclude circumstances where flush medians should not be implemented.
6. Investigate flush medians impact on the capacity of signalised intersections as flush medians in many cases have reduced approaches from two down to one lane.
7. Identify whether turns through queuing areas have increased crashes. Queues from signals are now longer on approaches to intersections, consequently more vehicles are now turning through queues, which could increase crashes.
8. Improve the "Preliminary Guidelines for Safer Flush Medians" including additional findings from further work. This report has shown that there are many areas in flush median design that safety improvements could be achieved. The 'Preliminary Guidelines for Safe Flush Medians' is only very limited, and should be developed further.