Safety Implications of Flush Medians in Auckland City: Further Analyses

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Abbreviations and acronyms

ASD:	Approach Sight Distance
B/C:	Benefit/Cost
CAS:	Crash Analysis System
GIS:	Geographical Information System
LTSA:	Land Transport Safety Association
NAASRA:	National Association of Australian State Road Authorities
NSAAT:	No Stopping At All Times
rrpms:	raised reflectorised pavement markings
SSSD:	Safe Stopping Sight Distance
SISD:	Safe Intersection Sight Distance
TCR:	Traffic Crash Report
TNZRR 233:	Transfund New Zealand Research Report Number 233: *Safety Implications of Flush Medians in Auckland City, New Zealand*

Contents

Executive summary

Introduction

This report details research into the safety implications of installing 50 flush medians in Auckland City, New Zealand. The research was carried out between July 2004 and February 2006. The report answers questions and builds on the research from Transfund New Zealand Research Report 233, (TNZRR 233) and should be read in conjunction with that report. The report aims to provide guidance to help ensure that flush medians are used where they are most likely to produce safety benefits. Additional measures for installation in conjunction with a flush median to improve its safety are also identified.

Site-by-site benefit/cost analysis

To investigate the safety of flush medians on an individual site basis, the benefit/cost (B/C) ratios for the 50 flush median sites investigated in TNZRR 233 were calculated. The previous research indicated that the group of all 50 flush median sites studied resulted in crash cost savings of NZ $35 million and a B/C ratio of 30. Further analysis of each flush median on an individual site basis has indicated that installing a flush median resulted in a negative B/C ratio at 19 of the 50 sites. This confirms that safety is not always improved by installing a flush median. It also highlights the need for specific analysis of a particular site when considering its suitability for a flush median.

Effects caused by variations in flush median widths

The research indicates that no correlation exists between the width of a flush median and the B/C ratio resulting from the flush median installation. The research also concludes that no ‘optimum’ width for safer flush medians is apparent. Hence, flush median width should be determined by specific site characteristics such as the available road width and the desirable width of other traffic lanes, rather than by selecting an ‘optimal’ flush median width.

Previous research in TNZRR 233 on the effect on flush median width indicated that the group of narrow flush medians (width less than 2 m) achieved a higher B/C ratio than the group of wide flush medians (width greater than or equal to 2 m). However, the previous research was affected by a relatively small sample of narrow medians, and an atypical site that achieved very high crash savings within the narrow flush median group significantly increased the B/C ratio for the group of narrow medians.

Crash type investigation

TNZRR 233 analysed changes in different crash types that occurred as a result of installing a flush median. The research identified JA-type (right turning vehicle hit on right side), FD-type (rear end at a queue) and LB-type (right turning vehicle making turn) crashes as the crash types where a significant increase in crashes occurred following the installation of a flush median. To determine why installing flush medians resulted in an increase in JA, FD and LB-type crashes, and to identify measures to minimise these types of crashes, these specific crash types were analysed further.

JA-type crashes

At all sites studied, JA-type crashes increased by 20% following the installation of a flush median. A detailed study of several sites where JA crashes increased significantly following the installation of a flush median suggested that the most likely cause was the reduction in sight distance between drivers turning from side roads that occurred as a result of a flush median being installed.

Further analysis was undertaken on several sites to determine the effect that installing a flush median has on sight distance. This showed that installing a flush median reduced sight distance from side roads by between 18% and 31% at the sites reviewed. It was also noted that the wider the flush median, the greater the reduction in sight distance. Based on this observation, wider flush medians would be expected to increase JA-type crashes by a larger percentage than narrow flush medians. This was confirmed by crash data which indicated that the group of sites where wide flush medians were installed experienced a 37% increase in JA-type crashes compared to a 2% increase at sites where a narrow flush median was installed.

One measure to minimise JA-type crashes is to increase visibility by extending ‘no parking’ zones at intersections and removing any vegetation or other obstructions to visibility. Another measure is to use friction grip, particularly if a large number of wet road crashes occurred before the installation of the flush median. Research also indicated that flush medians installed on four-lane roads are more likely to result in an increase in JA-type crashes than flush medians installed on two-lane roads.

FD-type crashes

At all sites studied, FD-type crashes increased by 39% following the installation of a flush median. The sites that experienced the greatest increase in FD-type crashes following the installation of a flush median were analysed. Despite a thorough review of the traffic crash reports for all FD-type crashes at these sites, no link was identified between the flush median installation and the increase in FD-type crashes.

Because no direct cause between flush medians and the increase in FD-type crashes was identified, it was suggested that these crashes increased as a result of an overall trend of increasing rear end crashes. Over time, as traffic volumes increase, vehicle queues get longer, peak periods extend for longer periods, and more intersections are blocked by queues. All these factors would be likely to lead to a trend of increasing rear end crashes.

To confirm whether or not rear end crashes are increasing, further analysis was undertaken on the overall trend in FD crashes across the Auckland region. This indicated that, unlike the general downward trend for all crashes, FD-type crashes have indeed been increasing. Hence, it is concluded that flush medians are not directly responsible for the increase in FD-type crashes at the sites studied.

LB-type crashes

At all sites, LB-type crashes increased by 26% following the installation of a flush median. Five sites that experienced the greatest increase in LB-type crashes following the installation of a flush median were analysed – all these were four-lane roads. At least 66% of all LB-type crashes at these sites involved vehicles turning right from a flush median into an access way through a traffic queue in the centremost lane. This suggested that queuing was a primary cause of LB-type crashes. If the installation of a flush median is going to reduce or shorten the number of traffic lanes close to intersections where queuing occurs, the median is likely to increase LB crashes indirectly, as more vehicles will have to make turns through queues. Hence, when considering implementing a flush median, it is important to evaluate the likely impact on queue lengths the flush median will have.

Crash prediction methodology

A methodology was formulated to predict crash patterns at proposed flush median sites, and to determine whether a median was viable. This methodology accounts for the number of lanes at a site, as significant differences in crash savings between two-lane and four-lane sites were possible for certain crash types. Consideration was given to separating crash savings for narrow and wide flush medians; however, this was not justifiable, given that this research indicated that flush median width does not significantly affect crash savings. The following table shows the expected percentage changes in crash numbers between crashes expected with no flush median and crashes predicted with a flush median.

# Lanes	**Crash type**						
	GD	BF, DA & DB	CC & CB	NA & NB	FD	JA	LB
	Rear end near centre-line	Loss of control on curve	Loss of control on straight	Pedestrian	Rear end queue	Right turn hit on right side	Right turn making turn
2	-75	-48	+20	-21	+115	+5	+14
4	-75	-38	+7	+31	+8	+37	+40

Table EX1 Percentage changes in crash types expected if a flush median is installed.

Judgement must be exercised when using this table to predict crashes at a particular flush median site. However, the following conclusions can be drawn from the table:

- The number of GD, BF, DA and DB-type crashes is likely to decrease if a flush median is installed.
- The number of JA, LB and FD-type crashes is likely to increase if a flush median is installed.
- The number of pedestrian crashes (NA and NB-type) is likely to increase on four-lane roads and decrease on two-lane roads if a flush median is installed.
- The number of ‘loss of control’ crashes (CC and CB-type) is likely to increase if a flush median is installed.

Preliminary Guidelines for Safer Flush Medians, Version 2.0

The *Preliminary Guidelines for Safer Flush Medians* were updated to include findings from this report. A general process was formed to enable the analysis of flush median implications on a site-by-site basis, including:

- identifying site characteristics important to flush median safety,
- briefly assessing a site's suitability for flush median installation,
- predicting crash patterns in detail using the formulated methodology,
- considering other site characteristics which will alter the predictions, and
- making remedial measures available, as identified in the crash type investigation, either to improve safety further at a site or to make a flush median viable.

Recommendations

Flush medians should continue to be used in New Zealand to improve the safety and operational efficiency of roads. However, site-by-site analysis using the *Preliminary Guidelines for Safer Flush Medians, Version 2.0* should be carried out to assess the suitability of a site before installing a flush median.

This report, along with TNZRR 233, should be distributed to all road controlling authorities. Increased safety and improved crash savings are very likely to result from the guidance given in these reports.

Abstract

Between July 2004 and February 2006, research was continued on the safety implications of flush medians in Auckland, New Zealand. A site-by-site benefit/cost analysis found that 38% of studied sites achieved a negative benefit/cost ratio, proving that separate analysis is required for every proposed flush median site. The width of a flush median was found to have no effect on overall benefit/cost ratios.

Crash types that increased as a result of installing a flush median were investigated. JA, FD and LB-type crashes are the crash types that were shown to increase as a result of installing a flush median.

It was concluded that JA-type crashes increased because installing a flush median reduces visibility. To mitigate the expected increase in crashes that a flush median is likely to cause, visibility from side roads should be improved.

It was concluded that FD and LB-type crashes increased as a result of more congestion, which caused longer queue lengths and longer peak periods. The probable increase in FD and LB-type crashes when a flush median is installed can be minimised by ensuring adequate capacity at all intersections along the route.

A methodology was formed to predict crash patterns at proposed flush median sites. The *Preliminary Guidelines for Safer Flush Medians* were updated to include findings from this research. A general process to follow when implementing flush medians was formed, including the identification of site characteristics, prediction of crashes using the methodology, and remedial measures to improve safety. The use of these guidelines should ensure safety increases and crash savings at all flush median sites.

1. Introduction

1.1 Project context

The research detailed in this report was carried out between July 2004 and February 2006 and relates to the safety implications of flush medians in Auckland City, New Zealand. This report uses and builds upon the material presented in Transfund New Zealand Research Report Number 233 (TNZRR 233) (Segedin et al. 2002). It is intended to be read in conjunction with TNZRR 233, and should not be read in isolation from it.

1.2 Project brief

The research brief for this project was approved by Transfund New Zealand in April 2004. This purpose of the research was to answer questions raised in the TNZRR 233. The research brief was:

- to determine whether all flush median sites previously studied achieved a positive benefit/cost (B/C) ratio, despite some sites experiencing an increase in crash numbers;
- to determine why narrow flush medians appeared to be safer than wide flush medians;
- to identify steps to be taken in the design of new flush medians, including a methodology for predicting crash types at proposed flush median sites, and measures to minimise the types of crashes shown to increase with the installation of flush medians; and
- to update the *Preliminary Guidelines for Safer Flush Medians* to include the answers to these questions.

The research falls within Land Transport New Zealand's key topic area of safety and personal security: 'to promote a high standard of health, safety and personal security through improvements to the land transport environment/architecture' (LTNZ 2007) by:

- identifying factors related to the safety performance of flush medians;
- identifying how specific crash severity classes and types have been affected through flush median implementation; and
- improving the allocation of funds to flush median projects through accurate B/C analysis.

1.3 Relevant documentation and previous research

1.3.1 TNZRR 233

TNZRR 233 was the first major research into flush medians in Auckland, and was carried out between September 2001 and June 2002. The purpose of this research was to assess the safety implications of installing flush medians in Auckland, and to provide guidelines to ensure crash savings while doing so. As a result of this report, preliminary guidelines for safer flush medians were formed and several recommendations for further research were made.

1.3.2 Transfund Project Evaluation Manual

Chapter A6.6.2 in Transfund New Zealand's Project Evaluation Manual (TNZ 2002) states that flush medians in a 50 km/h urban area will reduce overall accident rates by 10–25%. In light of the results from TNZRR 233, this guideline may not be appropriate for sites in Auckland. TNZRR 233 found that at 50 sites in urban Auckland, overall accident rates decreased by only two percent; at 25 of these sites, accident rates actually increased.

1.3.3 Land Transport Safety Authority national flush median study 1995

Basing its findings on a New Zealand-wide study, a Land Transport Safety Authority (LTSA) report in March 1995 titled *Install Flush Median* (LTSA 1995) found that overall, accidents decreased by 19% at flush median sites. Again, this result may not be appropriate to Auckland City.

1.4 Report outline

The main body of this report is divided into five chapters (Chapters 2–6)

- Chapter 2 describes the site-by-site B/C analysis undertaken.
- Chapter 3 investigates the effect of flush median width on overall crash numbers and B/C ratios.
- Chapter 4 investigates the crash types that had been shown, in TNZRR 233, to increase significantly upon flush median installation. It also suggests measures that can be taken to ensure these crash types do not increase.
- Chapter 5 details a methodology for predicting crash patterns at proposed flush median sites. It also explains the reasons for these crash patterns and comments on the practical application of the methodology.
- Chapter 6 outlines additions to the *Preliminary Guidelines for Safer Flush Medians* that have been made as a result of this report and describes situations where flush medians may not be appropriate.

Chapters 7, 8 and 9 list the conclusions, recommendations and further research topics resulting from the study.

2. Site-by-site B/C analysis

2.1 Introduction

TNZRR 233 indicated that 50% of the sites studied experienced an increase in crash frequency in the five years following the implementation of a flush median. The purpose of determining the B/C ratio for each site was to investigate if these sites still had a positive B/C ratio despite an increase in crash numbers.

2.2 Results of previous B/C research

TNZRR 233 used B/C analysis as the means of assessing the effects of installing flush medians at 50 sites in Auckland. This B/C analysis was done for the 50 sites as a whole; wide medians and narrow medians were grouped and analysed separately.

TNZRR 233 identified that 50% of sites experienced an increase in overall crash frequency; however, fatal and serious crashes decreased in frequency. Despite an increase in minor crashes, this resulted in a B/C ratio of 30.2, representing an overall crash cost saving of $35.2 million. For further information on the B/C analysis and descriptions of previous analysis, refer to TNZRR 233.

2.3 Methodology of the B/C analysis

In order to get B/C ratios for each site individually, existing crash data were analysed on a site-by-site basis to determine the cost of crashes at each site based on the number, type and severity of crashes.

B/C ratios for each of the 50 sites were evaluated in accordance with the standard procedure accepted by Transfund New Zealand for B/C analysis. Slight modifications were made to the calculation process to reflect the fact that crash statistics were available for both the before and after periods. B/C ratios were calculated based on crash cost only. Therefore, the benefit of installing a flush median was the savings resulting from the reduction in crashes in the five-year period following installation. This reduction was calculated as the difference between the expected number of crashes with no flush median and the actual number of crashes with a median, for the five-year period following installation.

The costs of flush median installation were the same as those used in TNZRR 233 and were based on the cost of removing the previous road marking and marking the flush median. It should be noted that the costs do not include the ‘physical’ cost of the road required to accommodate the flush medians. At the sites analysed, the flush medians took advantage of an apparent excess in available road space. However, similar B/C ratios would not be expected for a flush median if a road required widening in order to accommodate it, or if it was on a new road which was being constructed wide enough to accommodate the flush median.

2.4 Results of B/C analysis for individual sites

Figure 2.1 shows the B/C ratios for each site studied. A table listing the B/C ratios for each site is included in Appendix B.

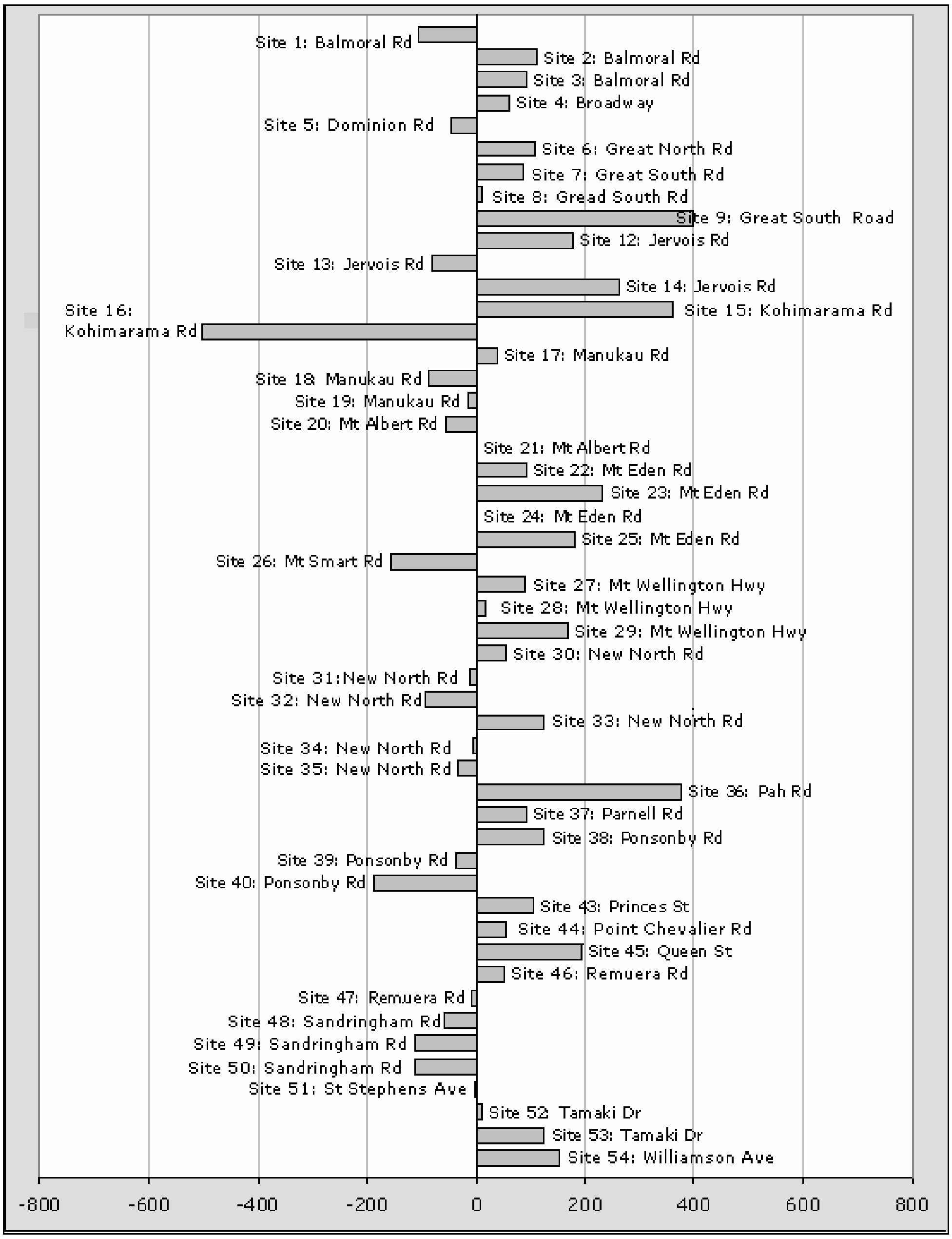

Figure 2.1 B/C ratios of installing flush medians at individual sites.

2.5 Discussion on individual sites' B/C analysis

Nineteen out of the 50 sites studied (38% of sites) had a negative B/C ratio, which indicated that installing a flush median adversely affected safety at these 19 sites. These results indicate that it cannot be assumed that installing a flush median will reduce crashes at a particular site.

Calculating B/C ratios on a site-by-site basis highlighted concerns with using the B/C method for evaluating the success of flush medians. The problem with using a B/C ratio as a performance measure is that it is significantly affected by fatal and serious crashes. This is clearly highlighted by the difference in B/C ratio between the two sites on Kohimarama Road (Sites 15 and 16).Site 15 (Kohimarama Road between Kepa Road and Allum Street) achieved the third highest B/C ratio. Site 16 (Kohimarama Road between Allum Street and St Heliers Bay Road) achieved the most negative B/C ratio. Both sites have similar characteristics, similar traffic volumes and were implemented at the same time. Hence, further analysis was done to attempt to explain the large difference in B/C ratios between the two sites.

Crash data for the two sites for the before, after and 'expect after' period is shown in Table 2.1. This table shows that despite relatively similar total crash savings (4% compared to 14%), the B/C ratios are completely different for both sites. This is because the B/C ratios are significantly affected by the fatal and serious crashes, which have very low occurrences, but decreased for Site 15 and increased for Site 16.

Table 2.1 Crash statistics for Sites 15 and 16.

Crash severity	**Site 15 – Kohimarama Road (Kepa Road and Allum Street)**			**Site 16 – Kohimarama Road (Allum Street to St Heliers Bay Road)**		
	After	Expected after	Percent change	After	Expected after	Percent change
Fatal	0	1.7	-100%	1	0	–
Serious	0	1.3	-100%	4	1.3	+208%
Minor	2	4.3	-53%	3	2.6	+15%
Non-injury	26	21.8	+19%	16	23.9	-33%
TOTAL	**28**	**29.1**	**-4%**	**24**	**27.8**	**-14%**

It is not considered likely that the flush medians are the reason for the fatal and serious crashes increasing at Site 16 and decreasing at Site 15. Hence, the large difference in B/C ratios is related to the random occurrence of fatal and serious crashes. These sites highlight the distortions that can be caused when considering individual sites which have only a relatively small number of crashes. It is therefore concluded that while the B/C ratios are useful overall to assess the success of flush medians, care needs to be taken when considering individual B/C ratios for specific sites.

3. Effects caused by variations in flush median widths

3.1 Introduction

Previous research indicated that narrow flush medians (width <2 m) achieved greater crash savings than wide flush medians (width ≥2 m). The purpose of this phase of research was to identify why narrow flush medians were safer than wide flush medians and to determine if an optimum width to maximise the safety benefits of flush medians existed.

3.2 Results from previous research on flush median widths

In TNZRR 233, flush medians were separated into groups of those narrower than 2 m (10 sites) and those wider than or equal to 2 m (40 sites). These groups were classed as narrow and wide medians respectively. Two metres was chosen as the point of differentiation because this is approximately the width of a 99th percentile car.

The overall B/C for the group of sites where narrow flush medians were installed was 55.8. This is significantly higher than the B/C ratio for the group of sites where wide flush medians were installed, which was 24.0. Additionally, sites with narrow flush medians had a 14% reduction in overall crash numbers, compared to a 2% increase in overall crash numbers for wide flush median sites. Based on these results, it was concluded that narrow medians were safer than wide ones.

TNZRR 233 suggested that the apparent difference in safety between wide and narrow flush medians could be related to driver perception. It was proposed that drivers perceive narrow flush medians as more dangerous to use and therefore exercise greater caution when using them. An optimal width for maximising the safety benefits of a flush median may exist.

3.3 Methodology for flush median width investigation

To investigate the theory that narrow flush medians are safer than wide ones, additional analysis of the crash data was undertaken by a statistician. The analysis was carried out on the B/C ratio of each individual flush median site and its respective width. This differed from the analysis carried out as part of TNZRR 233, where flush medians were split into a group of narrow medians and a group of wide medians, and analysis done for the group of medians.

3.4 Results: effect of flush median width on safety

The statistical analysis found no evidence to support a correlation between B/C ratio and flush median width. Figure 3.1 summarises the relationship between flush median width and B/C ratio. The graph highlights that B/C ratios vary greatly regardless of the flush median widths; however, no trend suggests that narrow medians are safer. It is concluded from the results that no general optimum width for safer flush medians exists. It was also concluded that the width of a flush median has no statistically significant effect on overall crash numbers.

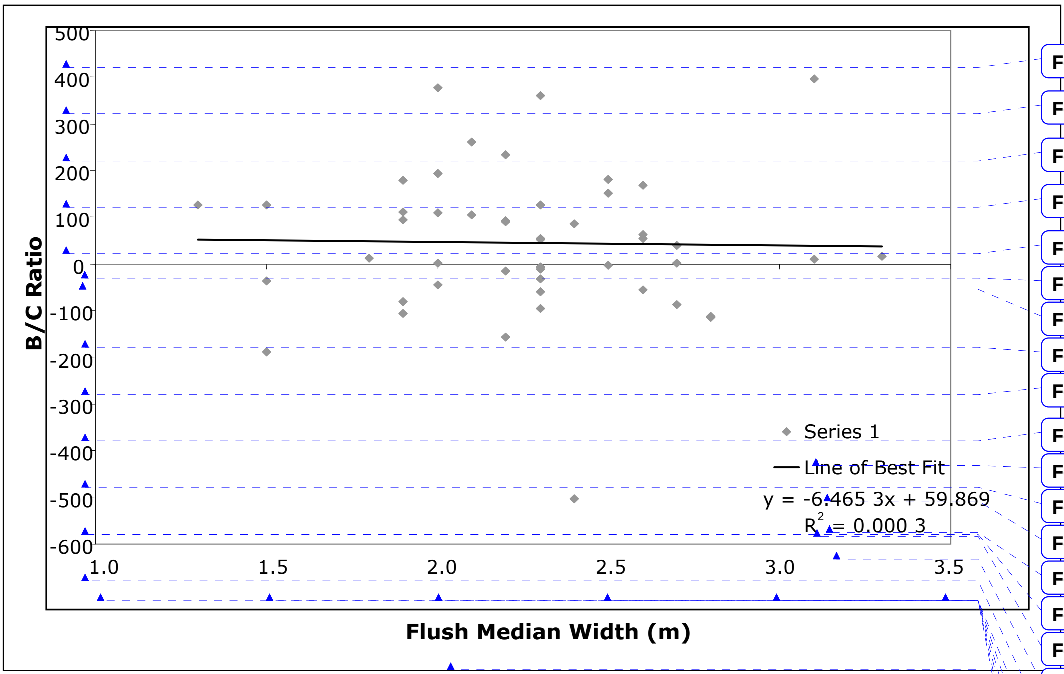

Figure 3.1 **B/C ratio versus flush median width for all sites.**

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Because these results differ from those in TNZRR 233, further analysis was undertaken to determine why the previous research suggested that narrow medians are safer than wide medians.

3.5 Discussion on effects of flush median width on safety

3.5.1 General

Several reasons contributed to the previous analysis which suggested narrow flush medians were safer than wide ones. The first is the low number of fatal crashes that occurred at all sites and the significant effect fatal crashes have on the B/C ratio. The group of wide flush median sites reduced fatal crashes by 26% (13.56 expected after; 10 actual after). The group of narrow flush medians reduced fatal crashes by 44% (5.36 expected after; 3 actual after). The difference in percentage savings of fatal crashes between wide and narrow median significantly affects the respective B/C ratios; however, the sample sizes are not sufficient to draw meaningful conclusions.

The second reason is because the group of narrow medians included only 10 sites, resulting in a sample size that was too small to give statistically significant results. This, combined with the fact that the number of fatal crashes within the narrow flush median sites was particularly low, biased the results for the group of narrow flush medians.

As a result of both these two factors, by chance, fatal crashes at narrow flush median sites decreased by a larger percentage compared to wide flush median sites. Hence, despite only 6 out of 10 narrow median sites experiencing a positive B/C ratio, overall, the group of narrow sites achieved a large positive B/C.

It is also noted that the narrow group of medians only contained 4 sites where the width of the flush median was less than 1.8 m. In practice, flush medians 1.8–1.9 m wide would operate very much like the group of wide medians, despite the cut-off between narrow and wide medians being at this point. This reduced the sample of truly narrow medians, whose widths ranged from 1.3 m to 1.5 m, to only four sites.

Another reason why TNZRR 233 found that narrow medians reduce overall crash numbers while wide medians increase them is because the two narrow median sites on Tamaki Drive (Sites 52 and 53) accounted for a reduction of 73 non-injury crashes, which represents 72% of the total crash reduction. These two sites are not representative of ‘typical’ site conditions because they had very few access ways on one side of the road, and none on the other, for the entire length of the route. Excluding these two sites from the study on the basis that they are not ‘typical’ sites would have meant the decrease in overall crash numbers for narrow medians was only 5%, not 14%.

3.5.2 Possible effects of varying median widths on crash severity

It was proposed that narrower flush medians may reduce the severity of crashes, even though overall crash frequency or B/C ratios did not change. Hence, the frequencies of crashes by severity were examined. Because of a lack of data, fatal and serious crashes were grouped together, as were minor and non-injury crashes. The resulting graph (Figure 3.2) showed a trend of increasing fatal and serious crashes with increasing median width. Fatal and serious crashes appeared to reduce for median widths below about 2.0–2.5 m, and to increase above that. Minor and non-injury crashes appeared to increase slightly, regardless of median width.

However this trend was not statistically significant, because of a lack of data. The data are scattered widely, and a larger sample would be needed to determine if a significant trend actually exists. This is the same problem faced in trying to determine a relationship between B/C ratio and median width.

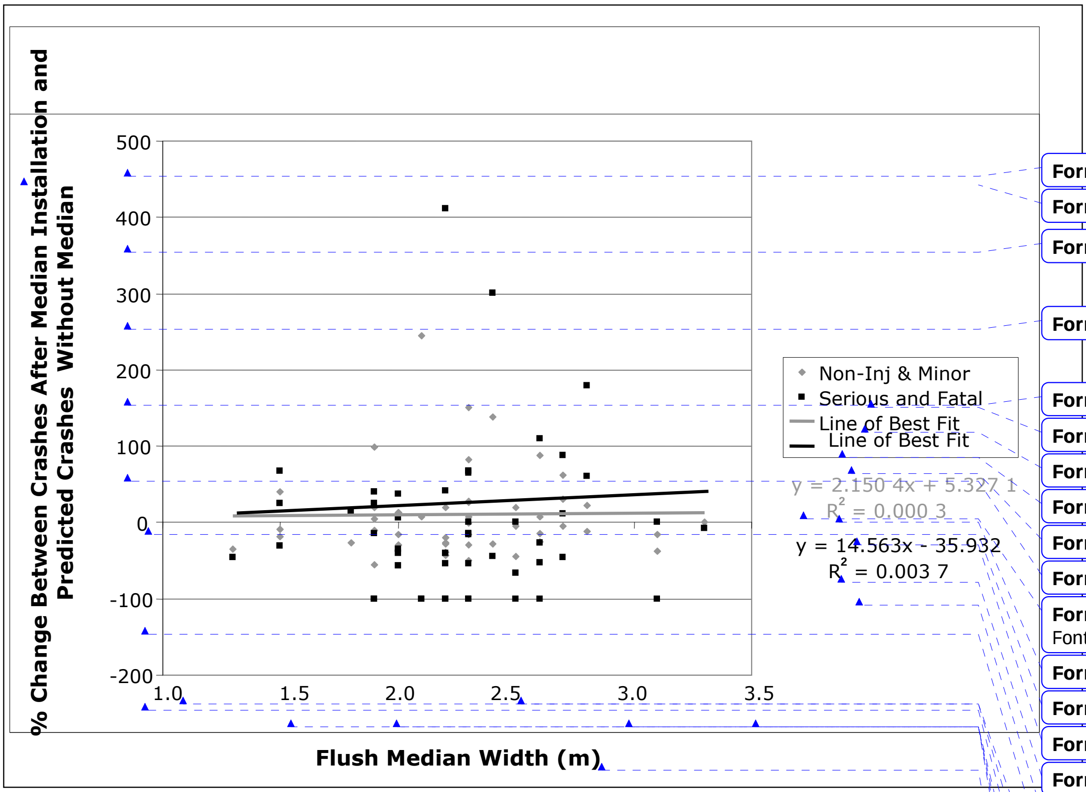

Figure 3.2 Percentage change in crash numbers at the studied sites by severity vs median width.

3.6 Effect of flush median width on sight distances

Increasing the width of a flush median slightly decreases the available sight distance for cars entering from a minor road or driveway when cars are parked adjacent to the road or driveway. This is because flush medians move traffic lanes closer to the kerb and side roads. This relates to the recommended investigation from TNZRR 233 into why turning crashes were lower with narrower medians. That report suggested that increasing the width of flush medians would increase turning crashes –JA-type crashes in particular – but decrease other types, such as 'loss of control' crashes. Crash types that increase as a result of flush median installation are investigated fully in Chapter 4.

Because this research has indicated that the overall B/C ratio has not changed as a result of changing the width of the flush median, this suggests that a trade-off must be made between crash types when deciding flush median width. Changing the width of a flush median may reduce the number of some crash types, but increase the number of other crash types. For example, a narrower median would have slightly longer sight distances, and therefore JA-type crashes may not increase as much. A wider median would provide more room to manoeuvre, and therefore 'loss of control' crashes and centre-line crashes may be reduced more. This means that flush median width must be considered on a site-by-site basis, taking into account factors such as existing crash types and reduction in

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sight distance. This is reinforced by the large site-by-site variation in B/C ratios for flush medians of similar widths.

3.7 Conclusions

The overall B/C ratio for the 50 flush median sites studied was positive. However, no statistical evidence exists to show that the width of a flush median has an effect on the B/C ratio or the frequency of fatal and serious crashes at a given site.

The reason why TNZRR 233 suggested that medians narrower than 2 m wide are apparently safer is because of the low sample number of narrow medians, and the lack of data for serious and fatal crashes at all median sites. The combination of these two factors meant that the B/C ratio for the sample of flush medians narrower than 2 m in width was misleadingly high.

In conclusion, it is considered that no general optimum width for safer flush medians is apparent. The decision on the width of a flush median should therefore be based on other site-specific conditions such as the available carriageway width, the need for on-street parking and the desired lane widths. A trade-off between the frequencies of certain crash types may be necessary with varying median widths. This is investigated in Chapters 4 and 5 of this report.

4. Crash type investigation

4.1 Introduction

Previous research indicated that the frequency of certain crash types increased as a result of installing a flush median. This phase of the research aimed to determine why these types of crashes increased. The research focused on JA (right turning vehicle hit on right side), LB (vehicle turning right) and FD (rear end at queue) type crashes, as these were the crash types shown, in TNZRR 233, to experience the most significant increases.

4.2 Results from previous research

TNZRR 233 showed that most crash types decreased when flush medians were installed. The most significant savings were for 'loss of control on corner' crashes (DA, DB and BF), pedestrian crashes (NA and NB) and 'turning versus the same direction near centre-line' crashes (GD).

It was also highlighted that certain types of crashes increased significantly in frequency with the installation of flush medians. These were 'rear end at queue' crashes (FD), 'right turn right side' turning crashes (JA), and 'right turn against while making turn' crashes (LB). Table 4.1 below shows data from TNZRR 233 comparing crash statistics for these crash types after installation of flush medians to crash statistics expected if no flush median was installed.

Table 4.1 Crash statistics from TNZRR 233 for JA, FD and LB-type crashes after flush median installation, expected and actual.

Crash type	Severity	Actual after crashes	Expected after crashes	Percentage change	$M change
FD	Fatal	0	0	–	0.0
	Serious	1	1.7	-40	-0.6
	Minor	49	16.0	+207	+2.3
	Non-injury	198	160.3	+23	+0.6
	All	**248**	**178**	**+39**	**+2.3**
JA	Fatal	0	0.7	-100	-2.5
	Serious	14	7.5	+87	+6.0
	Minor	64	54.3	+18	+0.6
	Non-injury	289	242.5	+19	+0.6
	All	**367**	**305**	**+20**	**+4.7**
LB	Fatal	1	0	–	+2.3
	Serious	10	7.4	+34	+2.2
	Minor	61	39.3	+55	+1.3
	Non-injury	135	118.2	+14	+0.2
	All	**207**	**164.9**	**+26**	**+6.0**

4.3 Crash type investigation methodology

Research into the likely reasons for the increase in FD, JA and LB-type crashes involved reviewing relevant Traffic Crash Reports (TCRs), and investigating sites with unusually high or low numbers of these type of crashes. Measures to reduce these crash types at proposed and existing flush median sites are also suggested.

4.4 JA-type crashes 'right turn, right side while crossing'

4.4.1 Previous results

JA-type crashes occur when a vehicle turning right out of a minor road into amajor road is hit on its right side by a through-vehicle on the major road. TNZRR 233 concluded that a contributing factor to the increase in JA-type crashes could be the reduction in visibility by moving traffics lanes closer to the kerb with the installation of flush medians. Solutions proposed for existing flush median sites were the use of friction grip to improve the friction of the road surface, and improving visibility by removing obstructions and parking, and pruning trees.

4.4.2 Research description

4.4.2.1 General

To confirm the findings of TNZRR 233, the effects that installing a median had on sight distances were examined in detail. This involved reviewing geometry for several typical situations to assess the effect installing a median had on sight distance. TCRs were also reviewed for a number of sites in an attempt to identify reasons for the increase in crashes.

If on-street parking is close to a minor road intersection, sight distance for a vehicle exiting the minor road is reduced slightly by installing a flush median. This is illustrated in Figure 4.1 below. For a 13 m wide two-lane road with a sight distance of 40 m, installing a 2 m wide median resulted in sight distance being reduced by 17.5%. Installing a 3 m wide median resulted in sight distance being reduced by 22.5%. The effects on sight distance of installing a flush median for other typical situations are included in Appendix D.

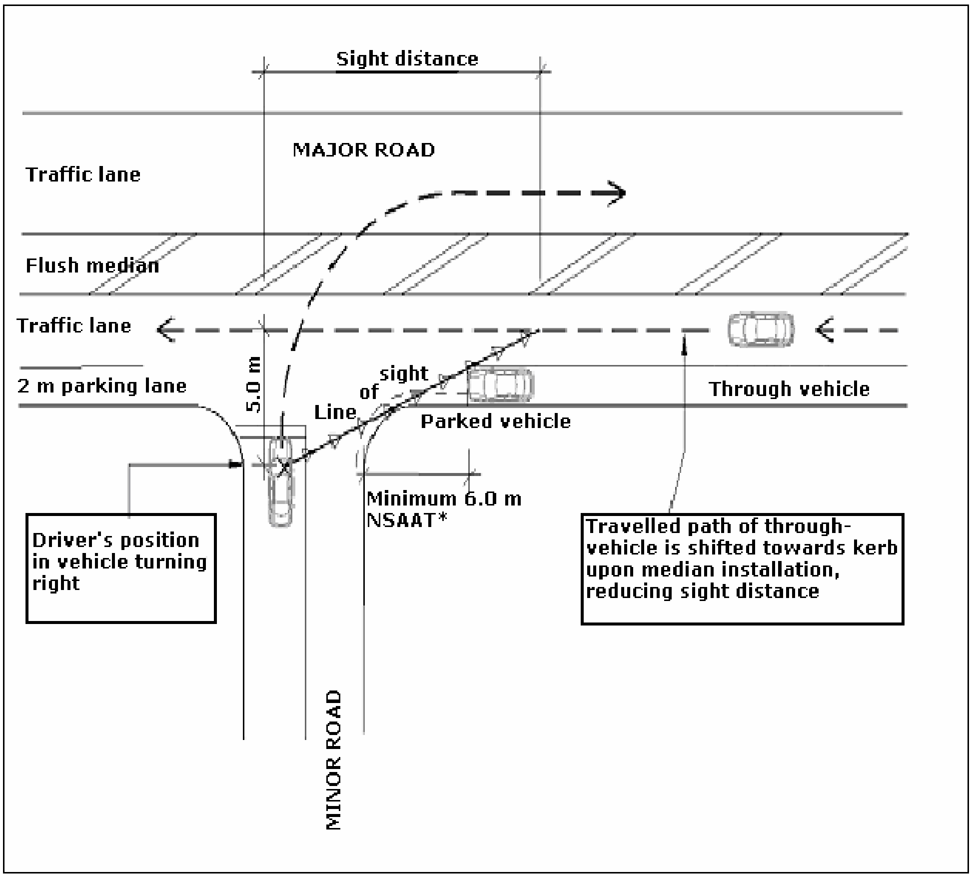

Figure 4.1 Schematic of sight distance calculations, including typical conditions.

*** NSAAT: No Stopping At All Times**

Although the reduced sight distance only occurs when a car is parked close to the minor road, it is often critical, as it could result in sight distance for the driver exiting the minor road dropping below safe stopping sight distance (SSSD). Safe stopping sight distance is considered the absolute minimum sight distance to safely allow a vehicle to turn right from a side road onto a major road, and is equivalent to approach sight distance (ASD).

To further assess the increase in JA-type crashes following flush median installation, the group of two-lane sites and the group of four-lane sites were analysed separately. This indicated that JA-type crashes increased significantly more at four-lane sites when compared to two-lane sites following the installation of a flush median. As such, a review of a number of four-lane sites was undertaken to determine the reasons for the higher increase in crashes.

4.4.2.2 Four-lane roads: case study

Site 30 is at the western end of New North Road and is a straight four-lane road. This site had the greatest increase in JA-type crashes in the five years following flush median installation (5 expected after crashes, 18 actual after crashes). To identify reasons for the poor crash history, traffic crash reports of JA-type crashes at the site were reviewed along with the geometry and sight distances at the site.

The intersection of New North Road and Bollard Road was the main contributing factor for the increases in JA-type crashes. This intersection experienced 4 of the 5 JA-type crashes before flush median installation and 16 of the 18 JA-type crashes after installation. Using aerial photographs and assuming typical conditions, it was concluded that sight distance for traffic turning right from Bollard Road onto New North Road was reduced from approximately 60 m to 50 m as a result of the flush median being installed. This is significant, because at the assumed 85th percentile speed for the site (60 km/h), the SSSD is 55 m.

Further analysis of the 16 TCRs at the Bollard Road intersection indicated that 57% of the JA-type crashes at this intersection were caused by vehicles turning left in the kerbside lane of the major road obscuring through-vehicles in the centre-lane. Figure 4.2 shows a diagram from a TCR involving this type of crash. The driver in Vehicle 1 had their view of Vehicle 2 obscured by a third vehicle (shown in dashed lines), which was slowing down and turning left into Bollard Ave.

Another common cause of JA-type crashes was drivers indicating left to change lanes and being mistakenly interpreted as intending to turn left off the major road.

This is investigated in detail in Chapter 5. Because of this, some solutions are proposed which are applicable to four-lane roads in particular.

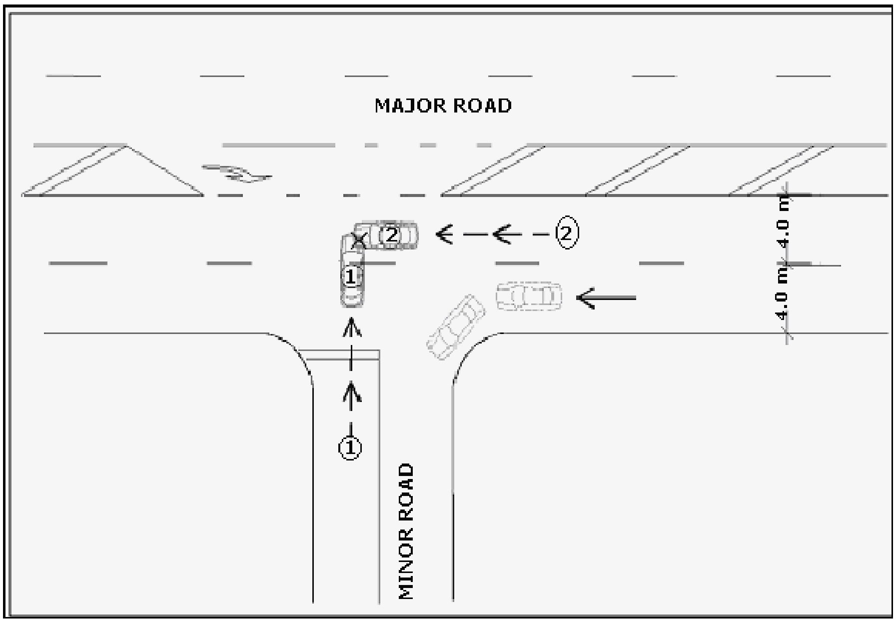

Figure 4.2 A typical four-lane road JA crash (diagram taken from TCR 9535070 (LTSA 2005)).

4.4.3 Results and measures to reduce JA-type crashes

The research has concluded that a significant contributing factor to the increase in JA-type crashes that can occur when a flush median is installed is likely to be the reduction in sight distances from minor roads. Sites where the installation of a median reduces sight distance from above SSSD to below SSSD are more likely to experience an increase in JA-type crashes. If the sight distance beyond safe intersection sight distance (SISD) is ample, a slight reduction in sight distance resulting from median installation would not be expected to have any effect on JA-type crashes.

If a flush median is installed which results in sight distance from a side road being reduced to a level close to or below SSSD, measures should be taken to mitigate the reduced sight distance. This could include removing on-street parking for a short distance, trimming or removing vegetation, or removing other obstructions to visibility.

At four-lane roads, where the increase in JA-type crashes is likely to be more significant than at two-lane sites, further measures to consider include installing friction grip or, in extreme cases, installing a left-turn lane. A left-turn lane would ensure that vehicles turning left on the major road are removed from the line of sight of vehicles turning right out of the minor road. Figure 4.3 shows the effect of a left-turn slip-lane on visibility.

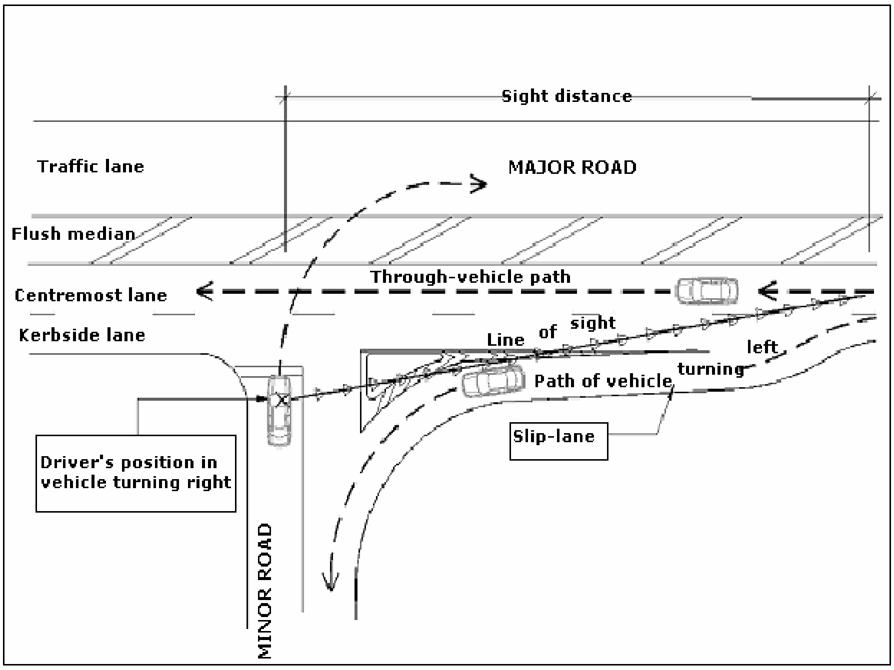

Figure 4.3 The effect of left-turn slip-lanes on visibility for vehicles turning right.

4.5 Type FD 'rear end at queue' crashes

4.5.1 Previous results

FD-type crashes occur when one vehicle crashes into the rear end of another vehicle which is waiting in a traffic queue. Queues do not include vehicles waiting to turn right on a flush median (these are classed as GD-type crashes and have been shown to reduce with the installation of flush medians).

TNZRR 233 proposed that in some cases, installing flush medians reduced the number or lengths of lanes at intersection approaches. This would decrease THE approach capacity and hence increase queue lengths. FD-type crashes at median sites would increase because the longer queues would extend into the median site study area, where previously they were contained to an area close to the intersection.

4.5.2 Research description

Two new theories for the cause of the increase in FD-type crashes were investigated as part of this project. The first was that following the installation of a flush median, effectively, an extra lane was created, so the chance of a driver having their attention distracted by vehicles waiting to turn on the median increased. With no median, these turning vehicles would be in the same lane as other traffic, directly in front of the driver. The second theory was that drivers did not correctly use the median when turning right, meaning that they would wait in the through-lane instead of on the median.

To investigate the two new theories as well as the previously proposed one, the five sites with the worst percentage increase in FD crash frequency after flush median installation were selected. The 44 available FD-type TCRs from these sites following flush median installation were examined.

4.5.3 Results and measures to reduce FD-type crashes

The analysis of the 44 TCRs was inconsequential and no evidence was identified to suggest that flush medians are a contributing factor in FD-type crashes. No FD-type TCR mentioned the median as the cause of, or even as playing a part in, a crash.

The theory that drivers would be distracted by cars on the median and lose concentration on the road directly ahead of them was proved wrong. This was the case in only one of the 43 TCRs. The theory that drivers did not know how to use flush medians was also proved wrong. Even though some crashes occurred because of this reason, they were incorrectly classed. These crashes should have been classed as GD-type crashes, which are still reduced overall.

To research the increase in FD-type crashes further, the overall trend of FD-type crashes in the Auckland region from 1989 to 2004 was investigated. Although previous 'before and after' analysis of the changes in crash numbers had used a control group to determine an 'expected after' number of crashes, this control was based on the overall crash trend. By looking solely at the FD-type crash trend, we sought to determine the reasons for the increase in FD-type crashes.

The results of the review of the FD-type crash trend indicated a significant increase in crashes from 1989 to 2004. This is shown in Figure 4.4. Based on this trend, the increase in FD crashes at the flush median sites appears to be consistent with the overall Auckland trend of FD-type crashes.

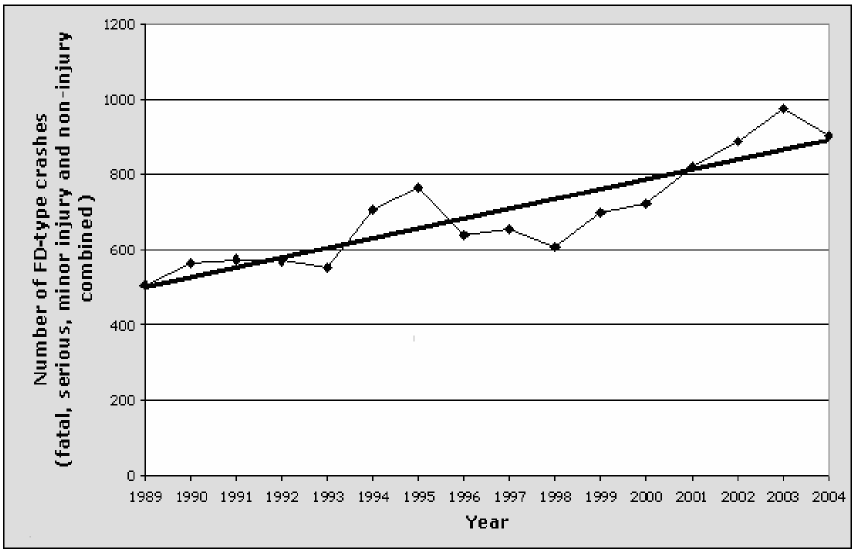

Figure 4.4 **Numbers of FD-type crashes occurring in the Auckland region 1989–2004.**

As the Auckland roading network becomes more congested over time, queues are longer and peak periods (when queues are present) are also longer. Signalised intersections have also increased. All these factors are likely to contribute to the upward trend of FD-type crashes. For these reasons, it is not considered that installing a flush median will have any effect on FD-type crashes. It is likely that as traffic volumes increase, FD-type crashes will increase regardless of whether a flush median is installed or not.

General measures to reduce FD-type crashes include the use of friction grip and improving intersection capacity so the length and frequency of queues forming can be reduced. Although no evidence was found to link flush medians directly to the increase in FD-type crashes, it is important to assess proposed flush median sites to ensure that any extra queuing that results is not excessive, for the whole of the design life.

4.6 Type LB 'right turn against while making turn' crashes

4.6.1 Previous results

LB-type crashes occur when an oncoming vehicle on the major road hits a vehicle turning right from a flush median into a minor road. In TNZRR 233, LB-type crashes were grouped with JA-type crashes as 'turning crashes'. It was proposed that these types of crashes could be collectively reduced by increasing pavement friction and improving visibility, as mentioned in Chapter 4.3.

4.6.2 Research description

To determine if this was a valid conclusion, the five sites with the worst percentage increase in LB-type crash frequency were selected. The 32 available LB-type TCRs for those sites in the five years following median installation were examined.

In theory, the occurrence of LB-type crashes should have reduced following the installation of a flush median. This is because installing a median shifts through-lanes towards the kerb and makes them narrower. Vehicle speeds should be slightly reduced (because of narrower lane widths) and vehicles turning right have a shorter conflict area to cross. Unlike JA-type crashes, shifting the through-lanes towards the kerb has no effect on visibility because both vehicles are on the major road.

The five sites that experienced the greatest increase in LB-type crashes following the installation of a flush median were all four-lane roads. At these sites, crashes appeared to occur randomly at access points and were not confined to specific areas such as intersections. It was found that 83% of LB crashes involved vehicles turning right from a median and colliding with a vehicle on the kerbside through-lane. Sixty-six percent of LB crashes involved vehicles turning right from a median through a traffic queue in the centremost through-lane. This percentage may be higher in reality because information is lacking in some of the TCRs. Furthermore, 59% of LB crashes were caused by a combination of the events mentioned above and also vehicles turning right from a median through a traffic queue in the centremost through-lane and colliding with a vehicle in the kerbside through-lane.

LB-type crashes mostly occurred during periods of heavy flow. Common factors in these crashes included

- trucks and other large vehicles in the centremost through-lane obscuring the view of vehicles in the kerbside through-lane, and
- drivers turning right without checking the kerbside lane when drivers in the centremost through-lane had left a gap for them to turn through.

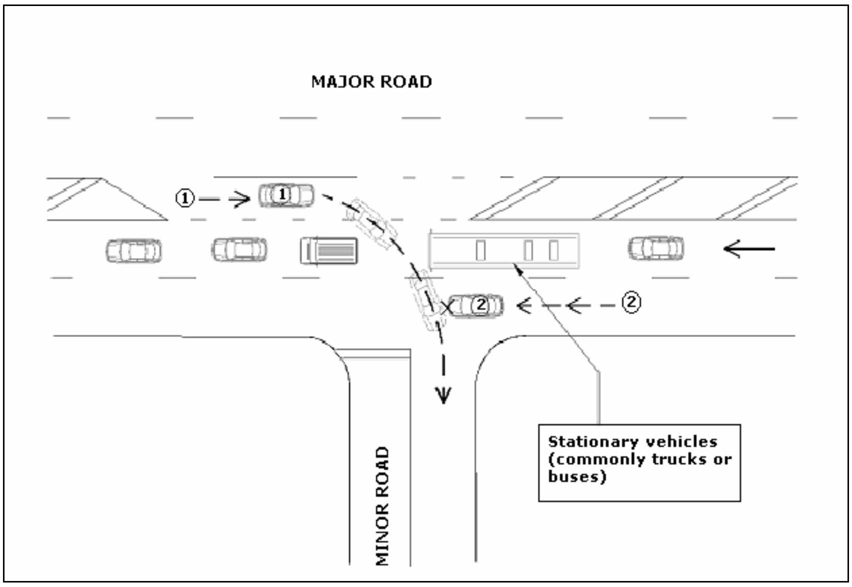

Figure 4.5 A typical four-lane road LB crash (diagram taken from TCR 9541216 (LTSA 2005)).

Figure 4.5 shows a typical LB-type crash on a four-lane road. The driver in Vehicle 1 attempts to turn right from the flush median through a queue of stationary vehicles in the centre-lane. The driver in Vehicle 1 did not see Vehicle 2 in the kerbside lane because his/her visibility was impaired by the queue of vehicles in the centre-lane. This situation could be exacerbated by the increasing use of kerbside bus lanes and transit lanes, as these lanes tend to have significantly lower use than the adjacent lane.

4.6.3 Findings and measures to reduce LB-type crashes

In theory, LB-type crashes should be reduced with the installation of a flush median. In reality, flush medians may lead to longer traffic queues (as described in Chapter 4.4). At the five worst sites, 66% of LB-type crashes involved turning through traffic queues. Hence, the cause of LB-type crashes increasing appears to be similar to the cause of FD crashes increasing – that flush medians are increasing traffic queues. LB and JA-type crashes should not be grouped together as 'turning crashes'. It should be noted that for LB-type crashes, this conclusion is mainly applicable to four-lane roads, because traffic can queue in one lane and flow freely in another. Four-lane roads are where the highest increases in LB crashes can be expected.

A solution for treating existing flush median sites is the use of friction grip. It is the same solution as for reducing FD-type crashes. This solution would be most cost-effective on roads with a high number of predicted LB crashes; for example, four-lane roads with high peak hour flow and a small number of problematic access points or intersections. It would not be cost-effective on roads with many access points, especially if they are spaced out over the route. This would mean friction grip will have to be laid along the entire route because LB crashes are equally likely to occur at any access point. Another solution is to install a raised median to prevent access, but this has other implications that must be considered.

An appropriate solution for proposed flush median sites is to undertake an analysis on the capacity implications of installing a flush median. This is the same solution as for FD-type crashes and, in this case, is particularly appropriate for four-lane major roads. It would need to be ensured that the extra queuing resulting from installing a flush median does not extend past too many access ways, including minor roads and driveways. As queues extend past more access ways, the chances of an LB-type crash occurring at that access way are significantly increased.

4.7 Conclusions on crash types

The cause of increased JA-type crashes with flush median installation is likely to be the corresponding reduction in sight distances along the major road for minor road vehicles. LB-type crashes can increase significantly with flush medians, particularly on four-lane arterial roads with high traffic flows. Flush medians can encourage drivers to turn right; whereas, without a flush median, many drivers may be discouraged from turning right and may adopt an alternative route to approach their access or side road from the other direction, particularly during peak traffic flow.

The cause of increased FD and LB-type crashes with flush median installation is likely to be the extended queuing resulting from decreased capacity. FD and LB-type crashes are similar because theoretically, a flush median should reduce crash numbers, but indirect effects cause crash numbers to increase. Capacity implications are therefore important, as decreased capacity is likely to result in increases of two of the three crash types that increase significantly with flush median installation. The results of this phase of research have been used in assisting preparation of a crash prediction methodology (Chapter 5) and in proposing remedial measures to ensure safer flush medians (Appendix J).

5. Crash pattern prediction methodology

5.1 Research description

This phase of the research aimed to formulate a methodology for predicting crash patterns at new sites where a flush median is proposed. This methodology can be used to assist in assessing whether a flush median is likely to achieve crash savings at a site.

Previous crash prediction methodology (found in Table F1, Appendix F of TNZRR 233) was applicable to overall crash numbers for every crash type and did not account for the number of lanes at a site. This report has shown that the number of lanes at a site is an important factor affecting types of crashes that change significantly with flush median installation. Because statistical evidence did not suggest that the width of a flush median could affect crash savings, no distinction was made for flush median width.

Rather than predicting the changes in every type of crash aggregated (as in TNZRR 233) this research focused on the certain types of crashes that changed significantly with the installation of flush medians. TNZRR 233 found that of all crash types, only 11 showed trends between the numbers of crashes expected with no flush median and the actual number of crashes after installation. These were the 11 crash types investigated. In TNZRR 233, some of these 11 crash types were grouped into similar types that followed the same trend. This grouping has also been used here in order to simplify prediction and to increase the amount of data in a group.

The results, shown in Table 5.1, are expressed as percentage changes between crashes expected without a flush median (before) and crashes expected after installing a flush median (after). Separate percentage changes are given for sites with two or four lanes.

Table 5.1 Expected percentage changes in total crash numbers with the installation of a flush median.

# Lanes	**Crash type**						
	GD	BF, DA & DB	CC & CB	NA & NB	FD	JA	LB
	Rear end near centre-line	Loss of control on curve	Loss of control on straight	Pedestrian	Rear end queue	Right turn hit on right side	Right turn making turn
Two (25 sites)	-75	-48	+20	-21	+115	+5	+14
Four (25 sites)	-75	-38	+7	+31	+8	+37	+40

Notes to Table 5.1:

- A negative percentage represents a predicted decrease in crashes, while a positive percentage represents a predicted increase.
- See Appendix I for full results, including a summary of percentage changes by number of lanes for all median widths.

Some crash types were grouped in the same way as in TNZRR 233 as follows:

- BF, DA and DB-type crashes are all crashes that occur because of loss of control on corners.
- CC and CB-type crashes occur because of loss of control on straight roads.
- NA and NB-type crashes are crashes involving pedestrians.

Crash types within a group all have similar trends and therefore, grouping these crash types is appropriate for the purposes of simplicity and increased sample size.

5.2 Results and points of interest

These results show that it is very important to consider the number of lanes at a site when assessing the suitability of a flush median. It also recognises the results of this research, which suggests that no evidence showing that the width of a flush median affects expected crash savings could be found

The most notable points of interest to be found from the investigation are:

- Pedestrian crashes can be expected to increase by 31% if a flush median is installed on a four-lane road. This result is very important, as previously, pedestrian crashes were assumed to reduce regardless of site conditions. The increase may be caused by pedestrians (especially less mobile pedestrians) not attempting to cross a four-lane road with no median, but being more likely to attempt to cross when a median is present. Installing median islands at regular intervals along the flush median might mitigate this, but the question arises whether it is advisable to leave a gap in the island, which may encourage less mobile people to attempt to cross the road.
- JA and LB-type crashes can be expected to increase at both two-lane and four-lane sites; however, the increase in JA and LB crashes at four-lane sites, of 37% and 40% respectively, is significantly higher than at sites with only two lanes.
- FD-type crashes are expected to increase considerably more at two-lane sites (115%) than at four-lane sites (8%). This may be caused by capacity being affected more under these conditions.
- BF, DA, DB, and GD-type crashes are expected to be reduced for both two and four-lane roads.

5.3 Practical application of results to proposed median sites

In practice, care is needed in applying these results because if a site has unusual characteristics, these results may not apply. Some characteristics of a site may alter the expected changes in crashes. These must be considered, and the expected crashes after flush median installation must be modified accordingly. Characteristics that we have identified are as follows:

- If the sight distance along the major road from any minor road approach is below SISD and close to the SSSD for the road environment, then JA-type crashes can be expected to increase by more than the percentages given in Table 5.1. This means that the sight distances before and after median installation must be calculated and compared to the SSSD. Note that wider medians will reduce sight distances more than narrower ones.
- If the capacity of the road is reduced because a median makes traffic lanes shorter or narrower, then FD and LB-type crashes can be expected to increase by more than the percentages given in Table 5.1. This is mainly applicable at sites near major signalised intersections. In these cases, the decrease in capacity and corresponding increase in queues resulting from median installation must be calculated. Note that with longer queues, FD-type crashes may not increase overall – they may simply move location – but LB-type crashes will definitely increase overall because more access ways will be blocked.
- If a large number of access points (driveways as well as minor roads) lie along a route, then LB-type crashes can be expected to increase by more than the percentages given in Table 5.1. Again, the increases in queues resulting from flush median installation must be calculated. As queues extend past more access points, more LB-type crashes can be expected. Increases will be even greater if the route has four lanes that are not equally used in peak hours.
- If no access points lie along a route, then LB and JA-type crashes will not be expected to increase.

Other characteristics affect the site-by-site application of results in Table 5.1 that we have not identified. Care must be taken and judgement is still required with regard to potential effects on other crash types that could result from median installation.

5.4 Conclusions

It is important to predict the changes in crash types upon flush median installation on a site-by-site basis, accounting for the number of lanes at a site. Table 5.1 provides a guide to the changes in the numbers of crashes for the crash types that were shown in TNZRR 233 to be affected by median installation. This table is based on data from 50 flush median sites around Auckland City. Other site-specific characteristics will affect the changes in crash numbers, so judgement must be used when applying results. Remedial measures are available to prevent increases in certain crash types, which means that if predicted accidents of a certain type are too high, a median can still be installed if such measures are applied. These measures are discussed in Chapter 4 and Appendix J.

6. Updates to the *Preliminary Guidelines for Safer Flush Medians*

6.1 Preliminary notes

The most important and relevant findings of this research have been formatted as guidelines and used to update the *Preliminary Guidelines for the Installation of Safer Flush Medians*, originally found in TNZRR 233. The updated guidelines are found in Appendix J of this report, and include material from this report as well as material from TNZRR 233.

The key point to be taken out of this report is that every site being considered for a flush median should be assessed to determine its safety and effectiveness. This section briefly describes and explains the additions made to the guidelines as a result of the research carried out.

6.2 Additions to guidelines developed from this research

Even though no overall rules can be used to decide whether to install a flush median at a site, a general process can be followed. The process has been developed and used as the basis for the updated guidelines. Refer to the actual guidelines in Appendix J for a comprehensive description of the process.

The first step is to consider whether the flush median is being installed for safety or efficiency or both. It is important that a flush median is not installed without a clear purpose or simply because the Transfund Project Evaluation Manual (TNZ 2002) states that a generalised 10–25% in crash savings can be achieved.

Next, because median installation considerations are site-specific, the characteristics of a particular site must be investigated and recorded. As a result of this research, site characteristics which have proven to be important are:

- the number of lanes,
- the crash history (including crash details by type),
- the volume of traffic and capacities of any intersections along the route,
- the number of access points along the route, and
- sight distances from any access points.

The next step is performing an assessment of a site’s suitability for median installation. This includes looking at more general aspects as mentioned in TNZRR 233, including

- the overall crash rate,
- the severity of crashes, and
- the timing of crashes (peak/off-peak and day/night).

It also includes a more detailed prediction of crash rates after flush median installation. This is performed using the methodology from Chapter 5. At the end of this stage, it should be apparent whether a site is suitable for flush median installation, based on the predicted crashes after it is installed. Some crash types will increase; others will decrease. The overall change in crash rate will depend on the proportion of different crash types before median installation.

Next, other factors need to be considered, as they may have an effect on crashes and the reliability of the crash predictions. Factors that have been identified in this research are:

- sight distances before and after median installation,
- capacity and queues resulting from median installation, and
- the number of access points along the route.

The final step is to consider any appropriate remedial measures that may be taken to improve safety. These remedial measures can be taken to lower crashes further and increase safety, or to make a site viable for median installation when it had been shown to be not viable bcause of predicted crash rates being too high. Remedial measures may be feasible to reduce the following types of crashes:

- JA,
- LB,
- FD,
- pedestrian,
- night-time, and
- 'loss of control' crashes.

Nevertheless, it is important not to limit a safety assessment just to consideration of the available crash data. Relying solely on the 'before' crash data to identify or justify remedial works for a safety improvement can limit the scope for improving safety because of the small datasets that are often available for individual sites. More general experience with other sites and other examples is valuable in identifying potential hazards, so that remedial work can be carried out without the need to establish a crash record at a particular site.

6.3 Reasons why a flush median may not be appropriate

Installing flush medians has been shown to have negative effects on safety at some sites. The following situations are ones in which the safety risk may be unacceptable and flush medians may not be appropriate for safety reasons:

- four-lane roads with a high existing number of pedestrian crashes or a high volume of pedestrian traffic (nevertheless, installing a flush median can provide a useful opportunity to install a refuge island within the median area, offering some improvement in safety for pedestrians crossing at that point);
- four-lane roads with a high existing number of JA and LB-type crashes, especially where speeds in lanes going the same direction are different during peak periods because of queues, lane under-use, or kerbside bus or transit lanes;
- four-lane roads with a high number of access ways;
- sites at which the sight distance from the minor road along the major road is near or at the critical distance (SSSD);
- sites or intersections where lanes must be removed or considerably shortened, resulting in severe capacity implications and much longer queues; and
- sites with a low number of, or existing, GD, BF, DA and DB-type crashes, as these are the types of crashes which can be reduced the most. If a site has a low number of these types of crashes, the B/C ratio for installing a flush median is not likely to be high.

7. Conclusions

7.1 Application

The results of this report apply to Auckland City; they may not apply in other locations. It is important to remember that this report focuses only on the safety implications of flush medians. Other implications such as capacity and efficiency are also important to consider when installing flush medians.

7.2 Site-by-site B/C analysis

TNZRR 233 found that at 50 flush median sites in Auckland City, the overall B/C ratio with respect to safety was 30.2, but this research found that 19 out of the 50 studied sites had a negative B/C ratio. Flush median installation might not have been appropriate at these 19 sites.

7.3 Effects caused by variations in flush median widths

- The width of a flush median (within the range of 1.3 m to 3.1 m) does not appear to have a significant effect on the B/C ratio or crash severity.
- No 'optimum width' for safer flush medians is apparent. TNZRR 233's finding that narrow flush medians have a higher B/C ratio than wide ones was not statistically significant because of a lack of data.
- A trade-off between the numbers of certain crash types is likely when the width of a flush median is changed.

7.4 Crash type investigation

- JA, FD and LB-type crashes tended to increase significantly at sites where flush medians were installed.
- A likely cause of increasing JA-type crashes at sites where a flush median has been installed is a reduction in sight distance caused by traffic lanes being shifted closer to the kerb. A mitigation measure to address this problem is to improve visibility by extending 'no parking' zones, pruning vegetation or removing other obstructions to visibility. On four-lane roads, visibility can be improved by installing left-turn slip-lanes. Another mitigation measure that can be considered is the use of friction grip.
- A probable contributing factor to the increase in FD and LB-type crashes at sites where a flush median has been installed is the reduction in capacity and increase in queues caused by the removal or shortening of lanes. LB-type crashes are particularly bad on four-lane roads with many access ways. A possible mitigation measure to address this problem is the use of friction grip. A better solution is to assess the capacity implications before flush median installation to ensure queues are not long and do not extend past significantly more access ways. To prevent LB-type crashes at access points, a raised median could be installed instead.

- A significant upward trend of FD-type crashes is apparent across the Auckland region. Hence, flush median sites may not actually be experiencing any greater increase in FD-type crashes than other roads.

7.5 Crash pattern prediction methodology

- It is important to predict the expected crashes after flush median installation on a site-by-site basis.
- A methodology was formed for predicting the changes in crashes for the types that change because of flush median installation. This methodology takes the number of lanes at a site into account, which has been shown to affect the changes in crashes at a specific site.
- Other characteristics of a site can influence the changes in crash types, including available sight distances, existing capacity and number of access ways. This means that judgement must be exercised in applying the methodology.
- Remedial measures (see 7.3) should be employed if certain crash types are predicted to be at an unacceptable level.

7.6 Updates to the *Preliminary Guidelines for Safer Flush Medians*

- No single process can be followed when installing flush medians that does not take site-specific conditions into account.
- A general process, which can be used on a site-by-site basis when considering the installation of a flush median, was formed. This process takes the original guidelines from TNZRR 233 into account, as well as new guidelines formed as a result of this report.
- Circumstances where flush medians may not be appropriate were identified.

8. Recommendations

- Flush medians should continue to be used in Auckland and New Zealand as traffic control devices to improve safety and operational efficiency. However, site-by-site analysis is required when assessing the suitability of individual sites for flush median installation.
- It is recommended that the *Preliminary Guidelines for Safer Flush Medians, Version 2.0* be used when assessing the suitability of a site for flush median installation, and when designing flush medians. Generalised figures found in earlier material may be unreliable and should not be used, such as the stated 10–25% accident rate reduction stated in the Transfund Project Evaluation Manual (TNZ 2002).
- This study should be distributed to all controlling authorities along with TNZRR 233, as improved crash savings are most likely to result from the guidance given in these reports.
- Decisions should not be made on the basis of safety alone. This report focuses solely on safety implications of flush medians, but many other implications are apparent. These implications must all be considered, e.g. effects on capacity and operational efficiency, and improved site access.
- Other recommendations made in Chapter 8 of TNZRR 233 are applicable. Please refer to TNZRR 233. Some of these recommendations include:
    - The *Preliminary Guidelines for Safer Flush Medians, Version 2.0* should be developed further.
    - Education on the appropriate use of flush medians and pedestrian refuge islands should be undertaken. Further consideration should be given to the design of such islands to ensure they provide a safe location to cross.
    - Raised reflectorised pavement markers (rrpms) 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 the *Preliminary Guidelines for Safer Flush Medians, Version 2.0* 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.
    - 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 TNZRR 233 should be undertaken, and an observational 'before' and 'after' study guideline be developed. This will encourage consistent economic evaluation of devices through 'before' and 'after' analysis.

9. Possible further investigations

Additional investigations could be undertaken to further improve the safety and benefits of flush median sites. The *Preliminary Guidelines for Safer Flush Medians* is still limited in scope and would benefit from additional findings from further research.

Further investigations should focus on:

- Checking the capacity implications of flush medians caused by lane removal and shortening, especially near intersections. At present, this seems to be the main cause of increasing FD and LB-type crashes. Investigations should focus on:
    - checking whether FD-type crashes are in fact simply moved further back from intersections rather than increasing overall,
    - checking whether the increase in FD-type crashes at flush medians is in fact greater than the overall trend of increasing FD-type crashes across the Auckland region, and
    - checking whether queues are longer on approaches to intersections and whether more access ways are consequently being blocked. This would tend to increase LB-type crashes.
- Checking how the number and density of access points along a flush median route affect safety with respect to LB and JA-type crashes.
- Checking problems relating specifically to four-lane roads. Installing flush medians on four-lane roads appears to have more critical safety problems.

10. References

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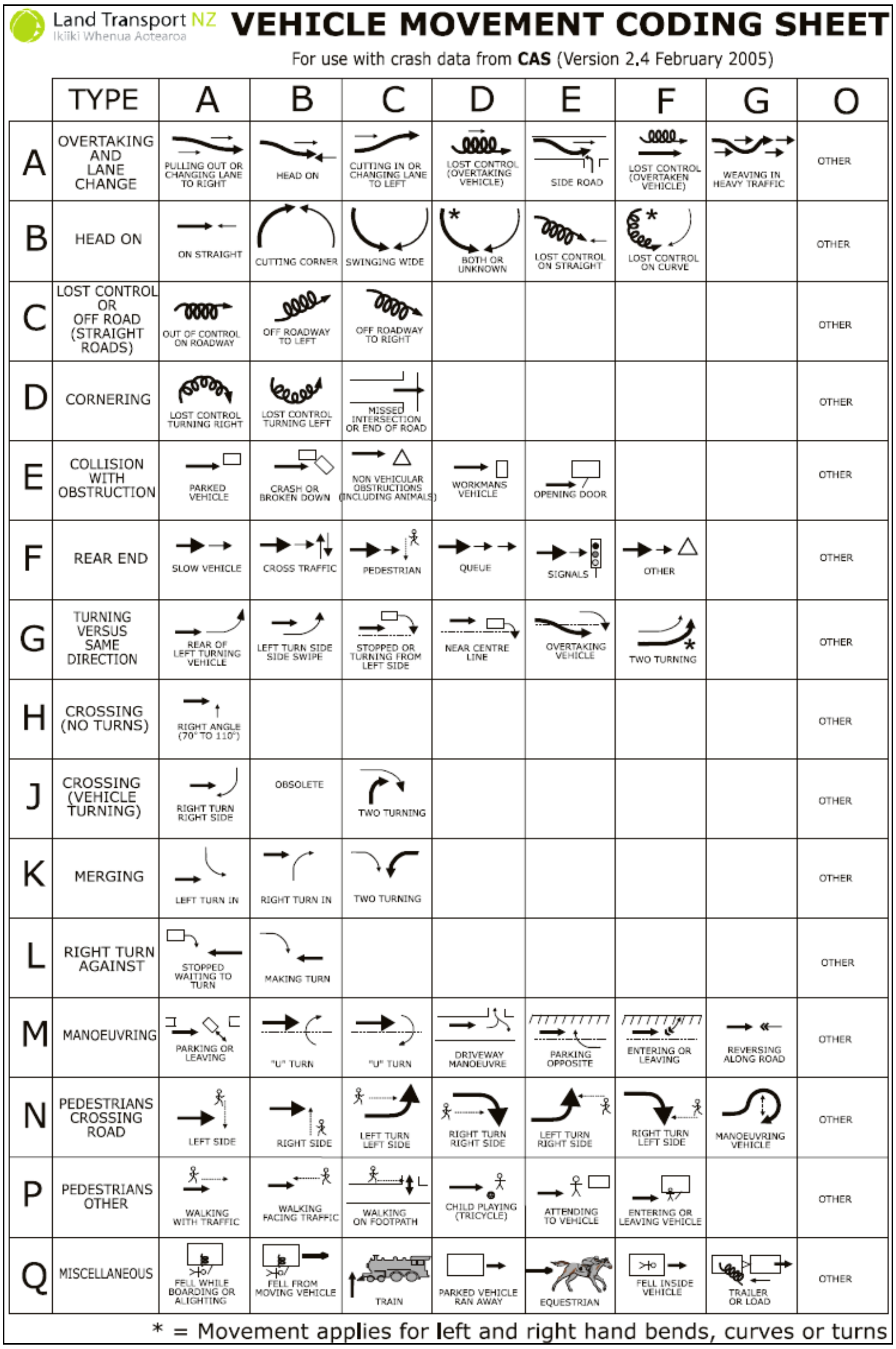
Appendices

Appendix A Vehicle movement coding sheet



Land Transport NZ
Ikiiki Whenua Aotearoa

VEHICLE MOVEMENT CODING SHEET

For use with crash data from **CAS** (Version 2.4 February 2005)

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

* = Movement applies for left and right hand bends, curves or turns

Table A1 **Key to understanding classification and details of crash types (from LTNZ 2005).**

Appendix B B/C ratios for individual sites

Table B1 B/C ratios of installing flush medians at the 50 study sites in Auckland.

Site	B/C Ratio		Site	B/C Ratio
1	-106.1		28	16.4
2	112.5		29	168.2
3	93.8		30	54.5
4	62.6		31	-11.3
5	-45.6		32	-94.6
6	109.9		33	126.2
7	86.6		34	-5.9
8	11.2		35	-32
9	396.8		36	376.8
12	178.3		37	92.9
13	-79.9		38	126.1
14	262.1		39	-37.2
15	360.9		40	-187.6
16	-502.7		43	106.1
17	38.8		44	54.5
18	-85.9		45	193.6
19	-15.5		46	51.9
20	-55.4		47	-7.1
21	1.2		48	-59.4
22	92.8		49	-114.2
23	233.1		50	-112.9
24	2.4		51	-2.2
25	180.7		52	11.7
26	-155.9		53	126.1
27	90.8		54	152.2

Notes to Table B1:

- Sites 10,11, 41 & 42 from the previous study were omitted because conditions had changed significantly at those sites. Refer to TNZRR 233.
- Pale grey fill indicates a negative B/C ratio.

Appendix C Median width investigation data

C1 B/C ratios

For all tables in this chapter, the data were taken from TNZRR 233's research.

Table C1 Costs, savings and site details of the 'narrow' medians used for this study.

Site number	Width (m)	B/C ratio	Lengths	Design life savings	Cost	B/C check
1	1.9	-106	640	$-1,740,616	$16,400	-106.1
2	1.9	112.5	888	$2,519,482	$22,400	112.5
3	1.9	93.8	465	$1,125,332	$12,000	93.8
12	1.9	178.3	240	$1,605,129	$9,000	178.3
13	1.9	-79.9	540	$-1,693,848	$21,200	-79.9
38	1.5	126.1	501	$2,194,867	$17,400	126.1
39	1.5	-37.2	282	$-375,124	$9,600	-37.2
40	1.5	-188	183	$-1,088,115	$5,800	-187.6
52	1.8	11.7	3282	$957,137	$81,500	11.7
53	1.3	126.1	2511	$7,896,458	$62,600	126.1

Table C2 Costs, savings and site details of the 'wide' medians used for this study.

Site number	Width (m)	B/C ratio	Lengths	Design life savings	Cost	B/C check
4	2.6	62.6	240	$338,058	$5,400	62.6
5	2.0	-45.6	1824	$-2,280,780	$50,000	-45.6
6	2.0	109.9	1344	$3,999,310	$36,400	109.9
7	2.4	86.8	447	$1,316,889	$15,200	86.6
8	3.1	11.2	680	$325,931	$29,200	11.2
9	3.1	396.8	258	$3,848,924	$9,700	396.8
14	2.1	262.1	168	$1,415,152	$5,400	262.1
15	2.3	360.9	414	$3,536,864	$9,800	360.9
16	2.4	-503	429	$-4,272,633	$8,500	-502.7
17	2.7	38.8	1164	$1,583,932	$40,800	38.8
18	2.7	-85.9	753	$-2,122,950	$24,700	-85.9
19	2.2	-15.5	1302	$-541,640	$34,900	-15.5
20	2.6	-55.4	1986	$-2,957,736	$53,400	-55.4
21	2.0	1.2	219	$8,773	$7,200	1.2
22	2.2	92.8	1044	$2,179,953	$23,500	92.8
23	2.2	233.1	1053	$5,175,841	$22,200	233.1
24	2.7	2.4	1425	$90,816	$38,600	2.4
25	2.5	180.7	630	$3,161,973	$17,500	180.7
26	2.2	-156	633	$-2,744,146	$17,600	-155.9
27	2.2	90.8	522	$1,715,573	$18,900	90.8
28	3.3	16.4	460	$188,185	$11,500	16.4
29	2.6	168.2	339	$2,489,930	$14,800	168.2
30	2.3	54.5	1095	$1,989,643	$36,500	54.5
31	2.3	-11.3	627	$-216,113	$19,200	-11.3
32	2.3	-94.6	1134	$-3,812,823	$40,300	-94.6
33	2.3	126.2	855	$4,000,567	$31,700	126.2
34	2.3	-5.9	882	$-173,639	$29,600	-5.9
35	2.3	-32	471	$-544,285	$17,000	-32.0
36	2.0	376.8	1128	$10,625,179	$28,200	376.8
37	2.2	92.9	729	$1,989,110	$21,400	92.9
43	2.1	106.1	360	$944,014	$8,900	106.1
44	2.6	54.5	705	$1,210,802	$22,200	54.5
45	2.0	193.6	324	$2,226,831	$11,500	193.6
46	2.3	51.9	258	$503,867	$9,700	51.9
47	2.3	-7.1	540	$-116,414	$16,300	-7.1
48	2.3	-59.4	1182	$-2,089,765	$35,200	-59.4
49	2.8	-114	1029	$-3,472,147	$30,400	-114.2
50	2.8	-113	576	$-1,773,012	$15,700	-112.9
51	2.5	-2.2	414	$-28,473	$12,700	-2.2
54	2.5	152.2	981	$4,002,730	$26,300	152.2

Table C3 Total B/C ratios and costs for all sites.

Medians	Design life savings (benefits)	Costs	B/C
Wide	$31,722,291	$908,000	34.9
Narrow	$1,418,702	$257,900	44.3
Total	**$43,140,993**	**#1,165,900**	**37.0**

C2 Crash data

In the following tables, these abbreviations have been used:

- aft: actual number of crashes after the flush medians were installed
- exp: expected number of crashes with no flush median
- %ch: percentage change between crashes expected with no median and actual crashes after median installation.

The figures have been rounded because of limited space.

Table C4 Predicted and actual crashes at sites with wide flush medians.

Comment [MCF1]: I have rounded all of them to 4 significant figures, using basic rounding, not the Swedish rounding you get in shops.

Site	Width (m)	Non-injury crashes			Minor injury crashes			Severe injury crashes			Fatal injury crashes		
		aft	exp	% ch	aft	exp	% ch	aft	exp	% ch	aft	exp	% ch
4	2.6	26	14.96	73.8	7	2.544	175.2	0	0.598	-100	0	0	0
5	2.0	161	130.8	23.07	36	44.48	-19.07	8	5.863	36.45	1	0.718	39.29
6	2.0	55	44.81	22.74	15	17.37	-13.65	2	4.65	-56.99	0	0	0
7	2.4	–	–	–	19	7.948	139.1	2	3.596	-44.38	0	0	0
8	3.1	–	–	–	5	7.948	-37.09	2	2.996	-33.25	1	0	∞
9	3.1	–	–	–	5	5.961	-16.12	0	2.996	-100	0	0	0
14	2.1	8	9.69	-17.44	6	3.422	75.35	0	1.173	-100	0	0	0
15	2.3	26	21.83	19.11	2	4.247	-52.9	0	1.248	-100	0	1.677	-100
16	2.4	16	23.91	-33.07	3	2.548	17.74	4	1.248	220.6	1	0	∞
17	2.7	81	48.28	67.79	21	14.77	42.21	2	3.722	-46.26	0	0	0
18	2.7	59	38.62	52.77	14	17.37	-19.41	4	2.127	88.08	0	0	0
19	2.2	34	53.3	-36.21	8	15.4	-48.04	5	3.518	42.14	0	0	0
20	2.6	66	63.58	3.809	12	9.326	28.67	5	2.391	109.1	0	0	0
21	2.0	–	–	–	7	6.172	13.42	2	3.788	-47.19	2	0	∞
22	2.2	–	–	–	14	19.4	-27.82	1	2.725	-63.04	1	0.64	56.25
23	2.2	17	9.655	76.07	4	7.818	-48.83	0	3.19	-100	0	0.675	-100
24	2.7	68	62.99	7.958	21	29.94	-229.86	9	8.208	9.649	1	0.718	39.29
25	2.5	35	29.92	16.98	6	4.239	41.54	0	2.391	-100	0	0	0
26	2.2	14	19.38	-27.76	2	2.566	-22.07	3	0.586	411.7	0	0	0
27	2.2	–	–	–	2	3.527	-43.29	0	2.164	-100	1	0	∞
28	3.3	–	–	–	8	7.935	0.820	1	1.082	-7.591	0	0	0
29	2.6	48	61.37	-21.79	11	17.11	-35.71	3	4.104	-26.9	0	0	0
30	2.3	77	41.99	83.37	14	7.699	81.84	2	2.931	-31.77	0	1.436	-100
31	2.3	63	30.69	105.3	14	0	∞	1	1.173	-14.72	0	0	0
32	2.3	97	83.98	15.5	30	16.25	84.58	6	2.931	104.7	0	0.718	-100
33	2.3	16	14.54	10.07	1	2.566	-61.03	0	1.759	-100	0	1.436	-100
34	2.3	46	50.07	-8.123	17	8.554	98.73	1	1.173	-14.72	0	0	0
35	2.3	21	22.61	-7.124	9	0.855	952.1	0	0	0	0	0	0
36	2.0	33	42.39	-22.14	4	10.17	-60.68	2	0.598	234.5	0	2.486	-100
37	2.2	52	61.37	-15.27	10	15.4	-35.06	0	1.173	-100	0	0.718	-100
43	2.1	30	7.241	314.3	4	2.606	53.50	0	1.063	-100	0	0	0
44	2.6	22	32.22	-31.72	9	4.247	111.9	1	1.248	-19.86	0	0.839	-100
45	2.0	93	113.4	-18.02	20	19.98	0.107	2	2.658	-24.77	0	0.675	-100
46	2.3	6	11.22	-46.52	5	4.239	17.95	1	1.196	-16.37	0	0	0
47	2.3	19	37.4	-49.2	4	8.478	-52.82	2	1.196	67.26	0	0	0
48	2.3	56	69.81	-19.78	12	11.02	8.874	6	3.587	67.26	0	0	0
49	2.8	49	58.59	-16.37	12	11.02	8.874	4	1.794	123	1	0	∞
50	2.8	21	25.99	-19.19	12	0.849	1313	2	1.872	6.858	1	0	∞
51	2.5	9	10.39	-13.41	5	4.247	17.74	0	0	0	0	0	0
54	2.5	49	101	-51.47	19	20.35	-6.626	1	2.989	-66.55	0	0	0

Table C5 **Combined crash data for wide medians.**

Site	Width (m)	Non-injury + minor			Severe + fatal		
		aft	exp	% ch	aft	exp	% ch
4	2.6	33	17.50	88.54	0	0.5979	-100
5	2.0	197	175.3	12.38	9	6.581	36.76
6	2.0	70	62.18	12.58	2	4.650	-56.99
7	2.4	19	7.948	139.1	2	3.596	-44.38
8	3.1	5	7.948	-37.09	3	2.996	0.1194
9	3.1	5	5.961	-16.12	0	2.996	-100
14	2.1	14	13.11	6.771	0	1.173	-100
15	2.3	28	26.07	7.385	0	2.925	-100
16	2.4	19	26.45	-28.18	5	1.248	300.7
17	2.7	102	63.04	61.80	2	3.722	-46.26
18	2.7	73	55.99	30.37	4	2.127	88.08
19	2.2	42	68.70	-38.86	5	3.518	42.14
20	2.6	78	72.90	6.989	5	2.391	109.1
21	2.0	7	6.172	13.42	4	3.788	5.611
22	2.2	14	19.40	-27.82	2	3.345	-40.22
23	2.2	21	17.47	20.19	0	3.865	-100
24	2.7	89	92.93	-4.227	10	8.926	12.03
25	2.5	41	34.16	20.03	0	2.391	-100
26	2.2	16	21.95	-27.10	3	0.5863	411.7
27	2.2	2	3.527	-43.29	1	2.164	-53.80
28	3.3	8	7.935	0.8202	1	1.082	-7.591
29	2.6	59	78.48	-24.82	3	4.104	-26.90
30	2.3	91	49.69	83.13	2	4.367	-54.21
31	2.3	77	30.69	150.9	1	1.173	-14.72
32	2.3	127	100.2	26.70	6	3.649	64.41
33	2.3	17	17.10	-0.5958	0	3.195	-100
34	2.3	63	58.62	7.469	1	1.173	-14.72
35	2.3	30	23.47	27.84	0	0	0
36	2.0	37	52.56	-29.60	2	3.084	-35.14
37	2.2	62	76.77	-19.24	0	1.891	-100
43	2.1	34	9.847	245.3	0	1.063	-100
44	2.6	31	36.47	-15.00	1	2.086	-52.07
45	2.0	113	133.4	-15.31	2	3.333	-40.00
46	2.3	11	15.46	-28.84	1	1.196	-16.37
47	2.3	23	45.88	-49.87	2	1.196	67.26
48	2.3	68	80.83	-15.88	6	3.587	67.26
49	2.8	61	69.61	-12.37	5	1.794	178.8
50	2.8	33	26.84	22.97	3	1.872	60.29
51	2.5	14	14.64	-4.377	0	0	0
54	2.5	68	121.3	-43.95	1	2.989	-66.55

Table C6 Predicted and actual crashes at sites with narrow flush medians.

Site	Width (m)	Non-injury crashes			Minor injury crashes			Severe injury crashes			Fatal injury crashes		
		aft	exp	% ch	aft	exp	% ch	aft	exp	% ch	aft	exp	% ch
1	1.9	41	22.61	81.33	9	2.566	250.7	4	1.759	127.4	0	1.436	-100
2	1.9	51	58.14	-12.28	14	14.54	-3.73	0	1.759	-100	0	0	0
3	1.9	11	22.61	-51.35	1	4.277	-76.62	2	2.345	-14.72	0	0	0
12	1.9	5	4.987	0.27	2	0.848	135.9	0	1.196	-100	0	0	0
13	1.9	33	47.37	-30.34	22	5.087	332.5	2	0.598	234.5	0	0.829	-100
38	1.5	52	64.6	-19.51	15	17.11	-12.33	3	2.931	2.339	0	1.436	-100
39	1.5	44	52.36	-15.96	9	5.935	51.65	3	2.931	25.45	0	0	0
40	1.5	27	21.19	27.4	5	1.696	194.9	2	1.196	67.26	0	0	0
52	1.8	80	117.2	-31.73	34	-12.82	-12.82	16	14.95	7.049	2	0.829	141.4
53	1.3	58	92.25	-37.13	25	-29.79	-29.79	4	8.37	-52.21	1	0.829	20.69

Table C7 Combined crash data for narrow medians

Site	Width (m)	Non-injury + minor			Severe + fatal		
		aft	exp	% ch	aft	exp	% ch
1	1.9	50	25.18	98.59	4	3.195	25.20
2	1.9	65	72.68	-10.57	0	1.759	-100
3	1.9	12	26.89	-55.37	2	2.345	-14.72
12	1.9	7	5.834	19.98	0	1.196	-100
13	1.9	55	52.46	4.844	2	1.426	40.21
38	1.5	67	81.71	-18.00	3	4.367	-31.31
39	1.5	53	58.29	-9.081	3	2.391	25.45
40	1.5	32	22.89	39.81	2	1.196	67.26
52	1.8	114	156.2	-27.01	18	15.78	14.10
53	1.3	83	127.7	-35.09	5	9.199	-45.64

Appendix D Sight distance calculations

Table D1 Sight distance changes at two-lane roads after installing flush medians.

Original lane width	Original sight distance (in metres)	Median width	Final lane width	New sight distance as % of original	Reduction in sight distance (%)
4.5	40	2	3.5	82.5	17.5
4.5	40	3	3	77.5	22.5
5	80	2	4	81.3	18.7
5	80	3	3.5	68.8	31.3
4.5	105	2	3.5	87.6	12.4
4.5	105	3	3	81.9	18.1

Notes:

- Results are similar but effects are worse in terms of percentage decrease if the road is wider.
- For wider roads, sight distance is reduced by a greater percentage.
- For shorter original sight distances, the reduction is greater as well.
- Results were taken from diagrams.

Appendix E Point Chevalier Road JA-type crash data

These tables give the data for Site 44 (Point Chevalier Road: Great North to Meola). Sight distances were calculated using GIS (Graphical Information System) maps and typical conditions. All data have been taken from TNZRR 233. To calculate sight distance before flush median installation, the original lane arrangement was estimated based on two equally wide lanes.

- The median was installed in 1994.
- The ASD at 60 km/h is 55 m.
- Only intersections that experienced JA-type crashes are identified.

Table E1 JA-type crashes occurring along Point Chevalier Road from 1989–2004.

Intersection	Total JA-type crash numbers			Sight distance (m)	
	89–94	95–99	00–04	Before 1994	After 1994
Montrose St	0	0	1	55	50
Tui St	4	0	0	?	85*
Smale St	2	0	1	55	45
Walker Rd	4	0	2	60	50
Meola Rd	1	0	3	90	85
All	**11**	**0**	**7**	–	–

* Installing pedestrian crossing changed conditions.

Table E2 CAS details and conditions of JA-type crashes occurring at Point Chevalier Road in 2000–2004 (LTSA 2005).

CAS ID	Intersection	Surface	Light
2204645	Montrose	Wet	Overcast
2033582	Smale	Wet	Dark
2144887	Walker	Wet	Overcast
2334212	Walker	Wet	Overcast
2037945	Meola	Dry	Dark
2131360	Meola	Wet	Overcast
2436001	Meola	Wet	Overcast

Table E3 Road resealing data for Point Chevalier Road.

Section of road	Reseal date	End of design life
Montrose–Walker*	26/12/1993	26/12/2005
Walker–Meola	1/01/1998	1/01/2000

* Section includes Smale and Tui Rd intersections.

Appendix F New North Road JA-type crash data

These tables list the data for JA-type crashes occurring Site 30 (New North Road: Blockhouse Bay to Richardson). Sight distances were calculated using GIS maps and typical conditions. To calculated sight distance before flush median installation, the original lane arrangement was estimated based on two equally wide lanes.

- The data were taken from TNZRR 233.
- The median was installed in 1992.
- New North Road is a major road; Bollard Avenue is a minor road.
- The percentage of JA-type crashes involving a vehicle turning left into Bollard Ave from New North Road was 57%.

Table F1 JA-type crashes occurring on New North Road from 1989–1997.

Intersection	**1989–1992**		**1993–1997**	
	Sight distance (m)	JA-type crashes	Sight distance (m)	JA-type crashes
Bollard Ave	60	4	50	16
All		5		18

Table F2 JA-type crashed occurring 1993–1997 at the intersection of Bollard Avenue and New North Road.

Vehicle manoeuvres attempted	**Number of crashes**
Vehicle turning left into Bollard Ave from New North Road	8
Not involving vehicles turning left into Bollard Ave from New North Rd	6
Cannot tell from TCR because of lack of information	2
Total	**16**

Appendix G FD-type crash data

Table G1 FD-type crashes occurring before and after flush medians were installed, including influence of medians on crashes.

Site	Location	Lanes	FD-type crashes		TCRs examined	TCRs mentioning median as a factor
			Before median	After median		
5	Dominion Rd: Balmoral to Mt Albert	2	2	18	18	0
13	Jervois Rd: Wallace to Curran	4	1	4	4	0
20	Mt Albert Rd: New North to Sandringham	2	1	8	7	0
31	New North Rd: Richardson to Mt Albert	4	1	11	11	0
53	Tamaki Dr: Ronaki to Vale	2	7	21	4	0
All			**16**	**62**	**44**	**0**

Notes:

- Sites were selected on the basis of percentage increase in FD-type crashes.
- Some sites with a high percentage increase may have been omitted because overall numbers of FD-type crashes were extremely low.
- Not all TCRs were available to be examined.
- Data were taken from TNZRR 233.
- TCRs are found in LTNZ 2005.

Appendix H LB-type crash data

Table H1 LB-type crashes occurring before and afer flush medians were installed.

Site	Location	Lanes	LB-type crashes before installation	LB-type crashes after installation				
				Total crashes	TCRs available	Factors		
						MRVKL*	**QCMR	Both
1	Balmoral Rd: Sandringham to Dominon	4	1	6	4	1/3	0/3	0/3
17	Manakau Rd: Alpers to Ranfurly	4	6	17	11	7/8	6/6	5/6
30	New North Rd: Blockhouse Bay to Richardson	4	3	7	4	5/5	5/5	5/5
31	New North Rd: Richardson to Mt Albert	4	1	9	8	3/3	¼	¼
32	New North Rd: Mt Albert to St Lukes	4	3	9	5	8/10	7/11	6/11
All		**4**	**14**	**48**	**32**	**24/29 (83%)**	**19/29 (66%)**	**17/29 (59%)**

Notes:

- *MRVKL: Major Road Vehicle in Kerbside Lane
- **QCMR: Queueing in Centre-lane of Major Road
- Some TCRs were not available in the CAS database (LTSA 2005).
- For LB crashes after median installaion, some TCRs did not have the required information and were left out of calculations. For example, 1/3 means that one occurrence was found in the three TCRs which had the required information.
- Sites were selected on the basis of percentage increase in LB-type crashes.
- Some sites with a high percentage increase may have been omitted because overall numbers of LB-type crashes were very low.
- Data were taken from TNZRR 233.

Appendix I Crash prediction methodology data

For all tables in this chapter, the following should be noted:

- Values have been rounded because of space limitations, so displayed values in columns may not equal the given total value.
- JA-type crashes will increase more if sight distances are near critical.
- LB-type crashes will increase more if the site contains many access points.
- FD and LB-type crashes will increase more if capacity is reduced.
- Other crash types show no obvious trends.
- Remedial measures can be taken if crash numbers are too high.
- Width affects the balance of crash types, not overall numbers.
- A positive percentage indicates a reduction in crashes; a negative percentage indicates an increase in crashes (shown by pale grey fill).
- The following abbreviations apply:
  - exp: expected crashes without median,
  - act: actual crashes after median installation.

Table I1 Predicted and actual crashes at two-lane roads with narrow medians (≤2 m).

Comment [MCF2]: I have rounded figures in these tables to two sig. fig. because of space (as you mentioned in the notes).

Crash type		**BF**		**CB**		**CC**		**DA**		**DB**		**NA**		**NB**		**GD**		**FD**		**JA**			
		exp	act	exp	act	exp	act	exp	act	exp	act	exp	act	exp	act	exp	act	exp	act	exp	act	exp	act
Site	**Width (m)**																						
5	2	–	–	0.9	8	6.8	5	0.9	–	0.9	5	9.7	5	5.5	7	22	11	3.2	18	27	38	18	19
36	2	_	–	0.8	2	0.9	–	1.3	1	–	–	–	–	1.7	–	0.9	–	4.6	3	22	16	–	2
52	1.8	12	6	5.8	5	5.2	1	43	18	35	1	0.6	1	1.8	1	4.6	–	8.7	21	3.1	4	4.8	3
53	1.3	18	6	5.4	2	0.6	3	22	6	13	2	1.7	2	2.7	1	2.5	1	1.3	7	8.7	9	9.1	10
Total		**30**	**12**	**13**	**17**	**13**	**9**	**67**	**25**	**49**	**8**	**12**	**8**		**12**	**30**	**12**	**18**	**49**	**61**	**67**	**32**	**34**
% change		**60**		**-31**		**33**		**62.8**		**55**		**32**		**22**		**60**		**-175**		**-10**		**-7**	

Table 12 Summary predicted and actual crashes at two-lane roads with narrow medians (≤2 m).

Crash type		NA & NB		CB & CC		BF/DA/DB	
Site	**Width (m)**	exp	act	exp	act	exp	act
5	2	15	12	7.6	13	1.7	1
36	2	1.7	0	1.7	2	1.3	1
52	1.8	2.4	2	11	6	91	38
53	1.3	4.4	3	6	5	52	19
Total		**24**	**17**	**26**	**26**	**146**	**59**
% change		**28**		**1.6**		**59**	

Table I3 Predicted and actual crashes at two-lane roads with wide medians (>2 m).

Crash type		BF		CB		CC		DA		DB		NA		NB		GD		FD		JA		LB	
		exp	act	exp	act	exp	act	exp	act	exp	act	exp	act	exp	act	exp	act	exp	act	exp	act	exp	act
Site	**Width (m)**																						
4	2.6	–	–	–	–	–	–	–	–	–	1	0.9	1	–	2	1.3	1	–	1	3.7	5	–	2
15	2.3	0.8	–	2.5	1	1	–	2.9	2	0.6	2	–	–	–	–	2.1	–	4.2	4	3.8	5	0.9	–
16	2.4	2.7	1	–	2	–	1	5.8	4	4.2	4	0.9	–	–	–	1	–	2.1	2	2.1	1	–	–
19	2.2	–	–	0.9	7	4.7	1	–	–	1.6	1	2	1	2.3	–	1.7	–	1.6	1	8.8	7	1.6	1
20	2.6	–	–	7.3	7	0.9	2	0.6	3	1.9	–	0.9	2	–	1	4.6	–	1.3	8	18	22	1.3	6
22	2.2	–	–	–	–	–	–	–	–	0.9	–	3.5	3	1.2	–	4.1	1	–	1	1.8	1	1.4	2
23	2.2	0.9	–	–	–	–	1	5	1	2.1	4	–	–	1.4	–	0.5	–	0.5	1	4.8	2	2.4	–
24	2.7	0.6	2	0.9	2	4.1	1	10	2	15	11	6.3	4	1.7	–	5.7	1	0.9	4	14	17	11	11
25	2.5	–	–	0.6	1	–	1	2.7	3	0.9	1	0.9	–	–	–	1.3	–	3.1	8	5.4	1	2.5	1
26	2.2	–	–	–	1	–	1	1.6	–	–	–	0.9	3	–	–	1.6	–	3.2	4	–	1	–	1
28	3.3	1.4	2	–	–	–	–	5.3	4	–	2	–	–	–	–	–	–	–	–	–	–	–	1
34	2.3	–	–	–	2	2.5	1	2.5	2	3.2	–	2.6	5	1.5	–	3.2	1	3.2	2	3.2	3	5.7	2
35	2.3	–	–	–	2	1.6	–	1.6	–	–	–	–	2	–	–	4.9	1	–	1	1.6	4	1.6	6
37	2.2	–	–	–	3	0.6	–	3.3	2	–	–	4.8	2	2.3	1	3.2	2	3.2	3	2.5	6	4.9	4
43	2.1	–	1	–	–	-	–	–	1	–	–	–	–	2.4	–	–	–	–	–	–	1	2.4	2
44	2.6	–	1	–	1	–	1	–	1	–	1	2.3	1	0.8	1	2.1	–	–	7	9.4	–	3.2	2
48	2.3	4.3	2	1.3	3	1.3	3	8.5	–	4.2	–	1.2	5	2.1	2	8.3	2	5.0	5	2.1	9	3.3	2
49	2.8	–	–	1.9	8	3.7	1	–	1	1.3	1	4.2	1	1.5	1	10	–	5.0	6	–	4	5.7	10
50	2.8	–	1	2.1	2	1	–	10	7	1	7	0.6	1	–	1	1	–	1.0	3	3.1	3	0.6	4
51	2.5	1	–	–	1	–	–	–	1	2.1	1	–	–	–	1	1	–	–	1	1.9	4	0	3
54	2.5	–	–	4.2	3	2.5	–	2.5	–	–	–	3.1	2	–	–	5	2	–	1	13	5	3.1	5
Total		**12**	**10**	**22**	**46**	**24**	**14**	**63**	**34**	**39**	**31**	**35**	**33**	**17**	**10**	**63**	**11**	**34**	**63**	**99**	**101**	**52**	**65**
% change		**15**		**-114**		**41**		**46.1**		**20**		**5.7**		**42**		**83**		**-84**		**-2.3**		**18**	

Table I4 Summary predicted and actual crashes at two-lane roads with wide medians (>2 m).

Crash type		**NA & NB**		**CB & CC**		**BF/DA/DB**	
		exp	act	exp	act	exp	act
Site	**Width (m)**						
4	2.6	0.9	3	0	0	0	1
15	2.3	0	0	3.5	1	4.4	4
16	2.4	0.9	0	0	3	13	9
19	2.2	4.3	1	5.5	8	1.6	1
20	2.6	0.9	3	8.1	9	2.5	3
22	2.2	4.7	3	0	0	0.9	0
23	2.2	1.4	0	0	1	8	5
24	2.7	8	4	5	3	26	15
25	2.5	0.9	0	0.6	2	3.6	4
26	2.2	0.9	3	0	2	1.6	0
28	3.3	0	0	0	0	6.7	8
34	2.3	4	5	2.5	3	5.7	2
35	2.3	0	2	1.6	2	1.6	0
37	2.2	7.1	3	0.6	3	3.3	2
43	2.1	2.4	0	0	0	0	2
44	2.6	3.2	2	0	2	0	3
48	2.3	3.3	7	2.5	6	17	3
49	2.8	5.7	2	5.6	9	1.3	1
50	2.8	0.6	2	3.1	2	11	11
51	2.5	0	1	0	1	3.1	1
54	2.5	3.1	2	6.7	3	2.5	0
Total		**52**	**43**	**45**	**60**	**113**	**75**
% change		**18**		**-32**		**34**	

Table I5 Predicted and actual crashes at four-lane roads with narrow medians (≤2 m).

Crash type		**BF**		**CB**		**CC**		**DA**		**DB**		**NA**		**NB**		**GD**		**FD**		**JA**		**LB**	
		exp	act	exp	act	exp	act	exp	act	exp	act	exp	act	exp	act	exp	act	exp	act	exp	act	exp	act
Site	**Width (m)**																						
1	1.9	–	–	–	2	1.6	–	–	–	–	–	1.5	2	0.7	3	–	–	4.9	7	4.5	7	1.6	6
2	1.9	–	-	3.3	–	–	1	–	1	–	1	0.9	–	0.6	1	7.4	2	11	16	9.0	9	2.5	8
3	1.9	–	–	2.5	1	0.9	–	–	–	–	–	–	–	0.6	–	1.6	–	12	6	1.6	–	0.6	1
6	2	–	–	5.5	3	–	2	–	1	0.5	1	0.5	2	3.1	2	11	2	0.9	6	17	12	1.4	5
12	1.9	–	–	–	–	–	–	–	–	1.3	–	–	–	–	–	3.1	–	–	1	–	1	–	1
13	1.9	–	–	0.9	1	–	–	–	3	1.3	–	3.8	7	0.9	–	5	2	1.3	4	11	11	3.7	5
21	2	–	–	–	–	–	–	–	–	–	–	2.7	3	2.3	2	0.9	–	0.5	–	0.9	1	0.9	1
38	1.5	–	–	–	1	0.9	2	–	–	1.6	2	11	7	2.2	4	4.1	22	8.9	–	14	11	8.9	5
39	1.5	–	–	1.3	–	–	–	–	–	–	–	0.6	4	0.6	1	3.1	2	8.7	–	5.6	7	13	7
40	1.5	–	–	−0	1	–	–	1.3	–	–	–	–	2	–	2	–	3	6.2	4	5.0	4	3.7	3
45	2	–	–	1.7	5	2.4	–	–	–	–	–	4.4	4	1.7	4	7.2	2	11	6	13	15	2.6	5
Total		**0**	**0**	**15**	**14**	**5.8**	**5**	**1.3**	**5**	**4.6**	**4**	**25**	**31**	**13**	**19**	**44**	**15**	**66**	**50**	**82**	**78**	**39**	**47**
% change		**0**		**7.59**		**13**		**-300**		**14**		**-24**		**-49**		**66**		**23.7**		**4.47**		**-2**	

Comment [MCF3]: I know it makes a statistical difference, but in real life, how is having 5 crashes an improvement on having 5.8? How does someone have 0.8 of a crash ("That was close – I think that was 0.8 of a crash!")?

Table I6 Summary predicted and actual crashes at four-lane roads with narrow medians (≤2 m).

Crash type		**NA & NB**		**CB & CC**		**BF/DA/DB**	
		exp	act	exp	act	exp	act
Site	**Width (m)**						
1	1.9	2.2	5	1.6	2	0	0
2	1.9	1.5	1	3.3	1	0	2
3	1.9	0.6	0	3.3	1	0	0
6	2	3.7	4	5.5	5	0.5	2
12	1.9	0	0	0	0	1.3	0
13	1.9	4.6	7	0.9	1	1.3	3
21	2	5	5	0	0	0	0
38	1.5	13	11	0.9	3	1.6	2
39	1.5	1.2	5	1.3	0	0	0
40	1.5	0	4	0	1	1.3	0
45	2	6.1	8	4.2	5	0	0
Total		**38**	**50**	**21**	**19**	**5.9**	**9**
% change		**-33**		**9.1**		**-53**	

Table I7 Predicted and actual crashes at two-lane roads with wide medians (>2 m).

Crash type		**BF**		**CB**		**CC**		**DA**		**DB**		**NA**		**NB**		**GD**		**FD**		**JA**		**LB**	
Site	**Width (m)**	exp	act	exp	act	exp	act	exp	act	exp	act	exp	act	exp	act	exp	act	exp	act	exp	act	exp	act
7	2.4	–	–	0.6	–	–	1	–	1	–	–	1.2	1	2	1	–	1	1.0	2	1.0	2	2	4
8	3.1	–	–	1.2	–	–	–	–	–	–	–	0.6	1	–	–	–	–	2.0	–	1.0	–	–	–
9	3.1	–	–	–	–	–	1	1.0	–	–	–	1.2	–	–	–	–	–	1.0	-	–	1	3	1
14	2.1	–	1	–	–	–	–	11	2	–	–	–	2	1.6	–	–	1	–	1	0.9	1	0.6	1
17	2.7	–	–	–	4	–	–	–	1	–	1	1.4	–	1.9	2	4.8	–	7.2	22	14	14	6.4	17
18	2.7	–	–	0.9	3	–	2	–	–	–	1	0.5	3	0.9	2	4.2	2	11	11	2.3	12	6.4	5
27	2.2	–	–	–	2	–	1	–	–	–	–	–	–	–	–	0.9	–	–	–	0.9	–	–	–
29	2.6	–	–	2.2	2	–	–	0.9	1	0.9	1	0.9	–	–	1	18	–	13	13	12	11	3.8	4
30	2.3	2.2	–	5.9	6	–	3	4.6	1	0.9	2	0.7	1	–	4	–	–	8.1	8	6.6	19	4.1	7
31	2.3	–	–	1.6	1	1.6	2	–	1	–	–	0.6	2	–	–	3.2	3	1.6	11	4.9	7	1.6	9
32	2.3	2.5	–	8.8	6	0.9	1	9.8	5	1.6	1	4.1	3	0.6	–	13	1	6.5	11	19	50	3.1	9
33	2.3	–	–	–	–	–	–	2.3	–	1.5	1	0.6	1	0.6	–	1.6	–	1.6	2	–	1	1.6	2
46	2.3	–	–	1.5	–	0.6	–	–	–	–	–	0.9	1	–	–	–	–	5.4	2	1.3	1	1.3	–
47	2.3	0.9	1	2.5	1	2.5	–	4.3	2	3.3	1	–	1	–	–	0.9	–	1.7	3	–	2	5	2
Total		**5.5**	**2**	**25.1**	**25**	**5.6**	**11**	**34**	**14**	**8.1**	**8**	**13**	**16**	**7.6**	**10**	**47**	**8**	**61**	**86**	**64**	**121**	**39**	**61**
% change		**64**		**0.2**		**-97**		**58.3**		**1.6**		**-27**		**-32**		**83**		**-42**		**-90**		**-57**	

Table I8 Summary predicted and actual crashes at four-lane roads with wide medians (>2 m).

Crash type		**NA & NB**		**CB & CC**		**BF/DA/DB**	
		exp	act	exp	act	exp	act
Site	**Width (m)**						
7	2.4	3.2	2	0.6	1	0	1
8	3.1	0.6	1	1.2	0	0	0
9	3.1	1.2	0	0	1	1	0
14	2.1	1.6	2	0	0	11	3
17	2.7	3.3	2	0	4	0	2
18	2.7	1.4	5	0.9	5	0	1
27	2.2	0	0	0	3	0	0
29	2.6	0.9	1	2.2	2	1.7	2
30	2.3	0.7	5	5.9	9	7.7	3
31	2.3 2.3	0.6	2	3.2	3	0	1
32	2.3	4.7	3	9.6	7	14	6
33	2.3	1.2	1	0	0	3.8	1
46	2.3	0.9	1	2.1	0	0	0
47		0	1	5	1	8.5	4
Total		**20**	**26**	**31**	**36**	**47**	**24**
% change		**-29**		**-18**		**49**	

Table I9 Summary data for all crash types (predicted and actual) and lane numbers .

Crash type	Total		% change
	exp	act	
All two-lane roads (25 sites)			
BF	41	22	47
CB	34.5	63	-83
CC	37	23	38
DA	130	59	54.7
DB	87	53	39
NA	47	41	13
NB	29	19	34
GD	93	23	75
FD	52.1	112	-115
JA	160	168	-5.3
LB	87	99	-14
NA & NB	76	60	21
CB & CC	72	86	-20
BF/DA/DB	259	134	48
All four-lane roads (25 sites)			
BF	5.5	2	64
CB	40.2	39	2.99
CC	11	16	-41
DA	34.9	19	45.5
DB	13	12	6
NA	38	47	-25
NB	20	29	-43
GD	91	23	75
FD	126	136	-8
JA	145	199	-37
LB	77	108	-40
NA & NB	58	76	-31
CB & CC	52	55	-6.8
BF/DA/DB	53	33	38
All roads with narrow medians (≤2 m) (15 sites)			
BF	30	12	60
CB	28.1	31	-10
CC	19	14	27
DA	68.4	30	56.1
DB	53	26	51
NA	37	39	-5.5
NB	24	28	-15
GD	74	27	63
FD	83.3	99	-19
JA	143	145	-1.8
LB	70	81	-15
NA & NB	61	67	-9.3
CB & CC	47	45	4.9
BF/DA/DB	151	68	55
All roads with wide medians (>2 m) (35 sites)			
BF	17	12	31
CB	46.5	71	-53
CC	29	25	15
DA	96.7	48	50.3
DB	47	39	17
NA	48	49	-2.9
NB	25	20	19
GD	110	19	83
FD	94.8	149	-57
JA	163	222	-37
LB	94	126	-34
NA & NB	72	69	4.7
CB & CC	76	96	-26
BF/DA/DB	161	99	38

Note: boxes highlighted in grey were used for the final summary table (Table I16).

Table I15 (continued) Summary data for all crash types (predicted and actual) and lane numbers.

Crash type	**Total**		**% change**
	exp	act	
All roads (50 sites)			
BF	47	24	49
CB	74.4	102	-37
CC	49	39	20
DA	165	78	52.7
DB	100	65	35
NA	85	88	-4
NB	49	48	2.2
GD	184	46	75
FD	178	248	-39
JA	305	367	-20
LB	164	207	-26
NA & NB	134	136	-1.7
CB & CC	123	141	-14
BF/DA/DB	312	167	47

Note: boxes highlighted in grey were used for the final summary table (Table I16)

Table I6 Percentage change in total crashes before and after installing flush medians.

Number of lanes and median width	**Crash type**						
	GD	**Loss of control on straight road (CB & CC)**	**Loss of control on corners (BF, DA & DB)**	**Pedestrian (NA & NB)**	**FD**	**JA**	**LB**
2 lanes, ≤2 m	60	1.55	59	28	-175	-10	-7
2 lanes, >2 m	83	-32	34	18	-84	-2.3	-18
4 lanes, ≤2 m	66	9.09	-53	-33	23.7	4.5	-22
4 lanes, >2 m	83	-18	49	-29	-42	-90	-57
2 lanes	75	-20	48	21	-115	-5.3	-14
4 lanes	75	-6.8	38	-31	-8	-37	-40
≤2 m	63	4.88	55	-9.3	-19	-1.8	-15
>2 m	83	-26	38	7.4	-57	-37	-34
All	**75**	**-14**	**47**	**-1.7**	**-39**	**-20**	**-26**

Comment [MCF4]: I've changed this for you.

Appendix J Preliminary Guidelines for Safer Flush Medians, Version 2.0

This appendix contains a copy of the *Preliminary Guidelines for Safer Flush Medians, Version 2.0.* It is designed to stand alone, and therefore contains references, including one to the main body of the report.

Preliminary Guidelines for Safer Flush Medians, Version 2.0

J1 Introduction

This guideline should be used in association with the LTSA Flush Median Manual (LTSA 1995) and the Transit and LTSA Roadmark and Sign Manual (LTNZ/Transit 2007). It should also be used in association with Transfund New Zealand Research Report (TNZRR) 233 (Segedin et al. 2002) and Land Transport New Zealand Research Report (LTNZRR) 312 (Cleaver et al. 2007).

The following is a guide to improving the safety of flush medians. It is important for readers to use their own judgement, as decisions should not be made on the basis of safety alone. Other important factors such as road operation and efficiency must be considered. Nevertheless, using these guidelines should ensure greater reductions in crash frequency and cost when implementing flush medians. The most important things to consider with regard to safety are:

- whether a flush median is appropriate at a site and, if so, of what width; and
- what remedial measures should be incorporated in the design to minimise crashes.

In TNZRR 233, despite an overall positive benefit/cost (B/C) ratio of 30.2, 19 out of 50 sites were found to have a negative B/C ratio. Flush medians are a way to treat problem sites, but they should not be installed without careful consideration. A full site-specific analysis should be undertaken to maximise the B/C ratio. The 10–25% crash savings as currently stated in the Transfund Project Evaluation Manual (TNZ 2002) do not give reliable answers for specific sites.

J2 Investigation into site characteristics

Firstly, several important characteristics of a site need to be identified prior to assessing the suitability of that site for flush median installation. These are:

- the number of lanes along the route,
- crash history at the site in the previous five years, including crash types,
- volumes of traffic along the route and the classification of the road,
- sight distances along the major road from all intersecting minor roads,
- the number of access points along the route, including roads and driveways,
- any other features of the site deemed to be relevant.

J3 General effects of flush medians on crashes

Next, proposed sites for flush median treatment should be briefly assessed taking the following general effects into account (as a result of TNZRR 233):

- In general, flush medians reduce crash severity. Overall changes by crash severity for the 50 studied sites were as follows (note that the width of a median has no general effect on crash severity):

-	fatal	-28%
-	serious	-7%
-	minor	+7%
-	non-injury	-10%.

- Flush medians appear to achieve greater savings in night-time crashes compared to daytime crashes. They also appear to result in greater crash savings during the off-peak period.

These results mean that if a site has a high number of fatal or serious injury crashes, or a high number of night-time and off-peak crashes, it is more likely to be suitable for flush median installation.

J4 Detailed crash prediction methodology

J4.1 Initial predictions

Next, changes in individual crash types at a site should be predicted in detail with the following table, using a site's crash history and number of lanes. The effects of installing both narrow and wide medians should be predicted. It can then be decided which width is most appropriate, or if a median should not even be installed. Note that if certain crash types are predicted to be too high, remedial measures to reduce them can be taken.
Of all crash types, only the 11 in the table below have been shown to have significant trends from before to after flush median installation. These 11 crash types must be picked out of a site's crash history. We can then predict the numbers of these types of crashes after flush median installation. Other crash types can be assumed not to change.

Table J1 Expected percentage changes in crashes upon installation of flush medians.

# Lanes	Crash type						
	GD	**BF, DA & DB**	**CC & CB**	**NA & NB**	**FD**	**JA**	**LB**
	Rear end near centre-line	Loss of control on curve	Loss of control on straight	Pedestrian	Rear end queue	Right turn hit on right side	Right turn making turn
2	-75	-48	+20	-21	+115	+5	+14
4	-75	-38	+7	+31	+8	+37	+40

Notes to Table J1:

- A negative percentage represents a decrease in crashes; a positive percentage represents an increase.
- Some crash types were grouped because they are similar and have similar trends: BF, DA and DB-type crashes all occur because of loss of control on corners; CC and CB-type crashes occur because of loss of control on straight roads; and NA and NB-type crashes involve pedestrians.

J4.2 Important implications of results presented in Table J1

- Pedestrian crashes are likely to increase by about 31% if a flush median is installed on a four-lane road, unless other remedial measures are applied. This result is important, as previously pedestrian crashes were assumed to reduce regardless of site conditions.
- At sites with four lanes, JA and LB-type crashes can be expected to increase by a considerably larger amount than at sites with only two lanes.
- BF, DA and DB, and GD-type crashes are expected to be reduced regardless of the number of lanes.

J5 Factors affecting the accuracy of crash predictions

Although this methodology considers the number of lanes at a site and the width of the proposed median, many other factors influence the number of crashes. Some of these have been identified as described below:

J5.1 Sight distance

If the sight distance along the major road for vehicles entering at any minor roads is close to critical, then a flush median is likely to reduce sight distance below critical. JA-type crashes can then be expected to increase by a greater amount than that given in Table J1. Because of this, sight distances before and after median installation must be calculated. The critical minimum sight distance is generally the safe stopping sight distance (SSSD), which is also equivalent to approach sight distance (ASD). A higher standard is the AUSTROADS safe intersection sight distance (SISD).

J5.2 Capacity and queuing

If the median removes sections of lanes or makes them narrower, then the capacity of the route will be reduced and queues at intersections will increase. If a severe effect on capacity occurs and very long queues result, then LB and FD-type crashes can be expected to increase by a greater amount than that given in Table J1, particularly on four-lane roads. Because of this, the capacity and corresponding queue lengths before and after median installation should be calculated.

J5.3 Access points

If many access points lie along a route, then JA and LB crashes can be expected to increase by a greater amount than that given in the table. If extended queues block many access points, then LB-type crashes can be expected to increase even further.

J6 Remedial measures available to reduce crashes

J6.1 General

Remedial measures are available to reduce certain types of crashes at flush median sites. The uses of these measures are either to:

- lower certain types of crashes further, increasing the B/C ratio more, or
- make a flush median a viable option at a site that has previously been deemed unsuitable because certain crash types were predicted to be too high.

J6.2 JA-type crashes

Improving visibility for drivers entering the major road and therefore increasing available sight distance is one way to help reduce JA-type crashes. This can be done by extending 'no parking' zones further beyond intersections, pruning vegetation, other regular maintenance and removing obstructions. At four-lane roads, visibility can be improved by separating vehicles turning left from through-traffic on the major road. One way of doing this is by installing left-turn slip-lanes. Decreasing the required stopping distance by improving road surface friction is another way to help reduce JA-type crashes. This can be done using friction grip or by re-surfacing.

J6.3 LB-type crashes

Decreasing the required stopping distance through the use of friction grip is a method to help reduce LB-type crashes as well. This method may not be viable if many access points meet the major road, as friction grip would need to be installed along the whole route. Alternatively, a raised median could be installed to prevent vehicles turning right.

J6.4 FD-type crashes

Again, decreasing the required stopping distance using friction grip will help reduce FD-type crashes. It should be noted that the use of friction grip does not treat the actual cause of the problem in any of these cases.

J6.5 Pedestrian crashes (NA and NB-type crashes)

This is particularly relevant at four-lane sites, where pedestrian crashes are likely to increase. One possible measure to minimise pedestrian crashes is to install pedestrian refuge islands. Please refer to Chapter 6 of TNZRR 233, where pedestrian islands are discussed in detail.

Any pedestrian refuge islands installed should be designed to at least meet the minimum required spacing to access ways as shown in Figures J4 and J5 and Tables J2 and J3.

Night-time visibility of pedestrian refuge islands should also be further increased through implementation of raised reflectorised pavement markings (rrpms) on the flush median approaches to the islands (for example, as shown in Figure J3).

J6.6 Night-time and 'loss of control' type crashes

Where a large number of night-time or loss of control crashes occur, consider delineating bends with rrpms, streetlights, chevron signs, etc.

J6.7 'Loss of control on corner' crashes (BF, DA and DB-type crashes)

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

J7 Photos, tables and figures

Figure J1: **Night view of a pedestrian refuge island with standard markings.**

Figure J2: Night view of a pedestrian refuge island with a 'no overtaking' line and rrpms on approaches.

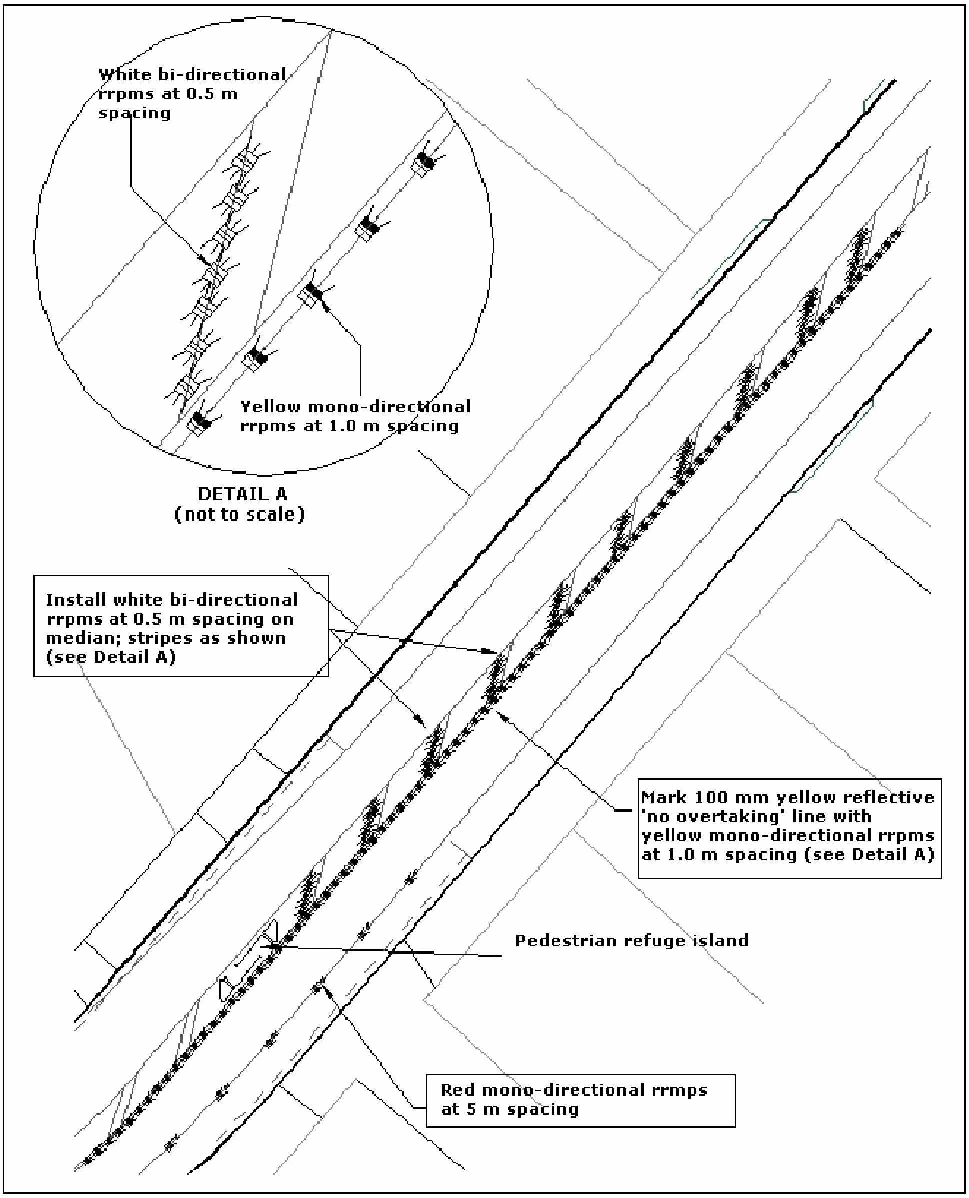


Figure J3 Example of how of rrpms and 'no overtaking' lines on approach to pedestrian refuges should be applied.

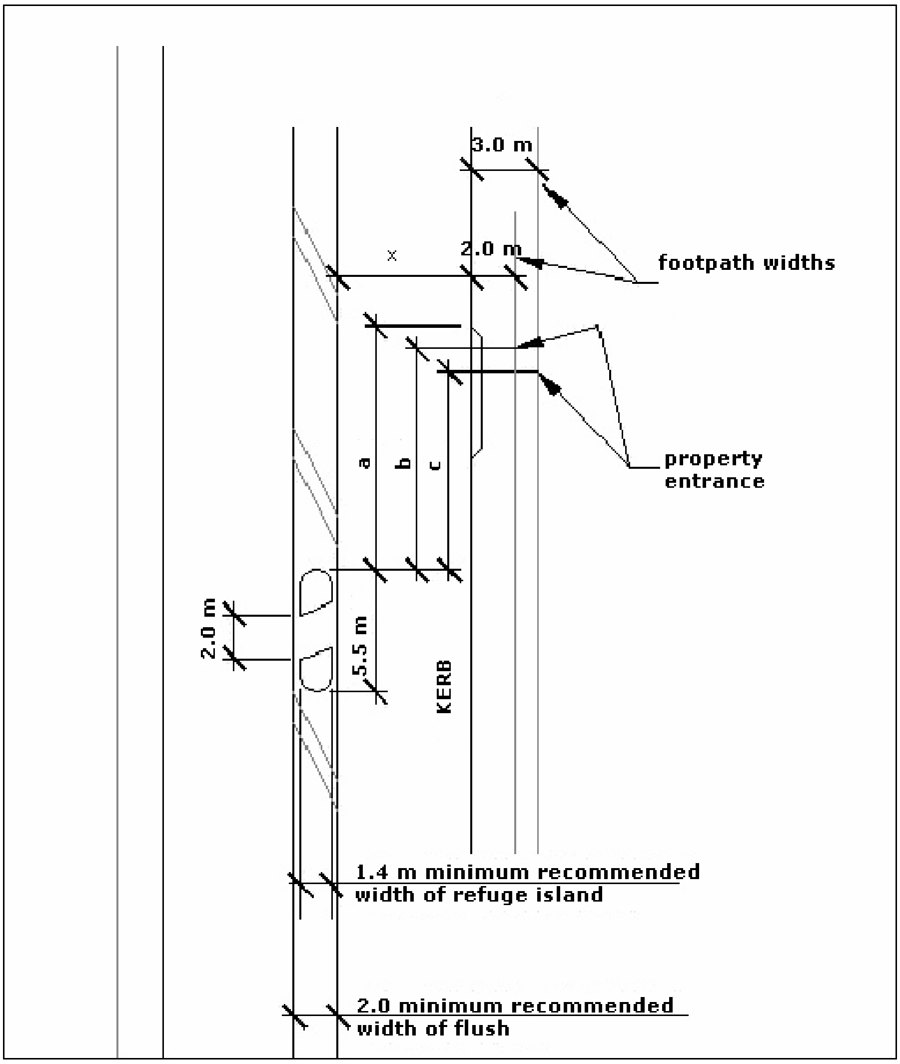


Figure J4: Design detail for implementing pedestrian refuge islands on flush medians – Type 1 refuge.

Notes to Figure J4:
These dimensions are only considered suitable for vehicles travelling at very low speeds. They enable the vehicle to clear the through-lane and wait to access adjacent residential properties (1–2 queuing spaces).

Table J2 Design chart for minimum dimensions for Type 1 refuge (as used in Figure J4).

x (m)	Cross section	a (m)	b (m)	c (m)
4	two-lane	11.0	10.5	10.0
6	two-lane with parking	11.0	9.5	9.0
7	four-lane	10.5	9.5	8.7
9	four-lane with parking	8.5	7.8	7.5

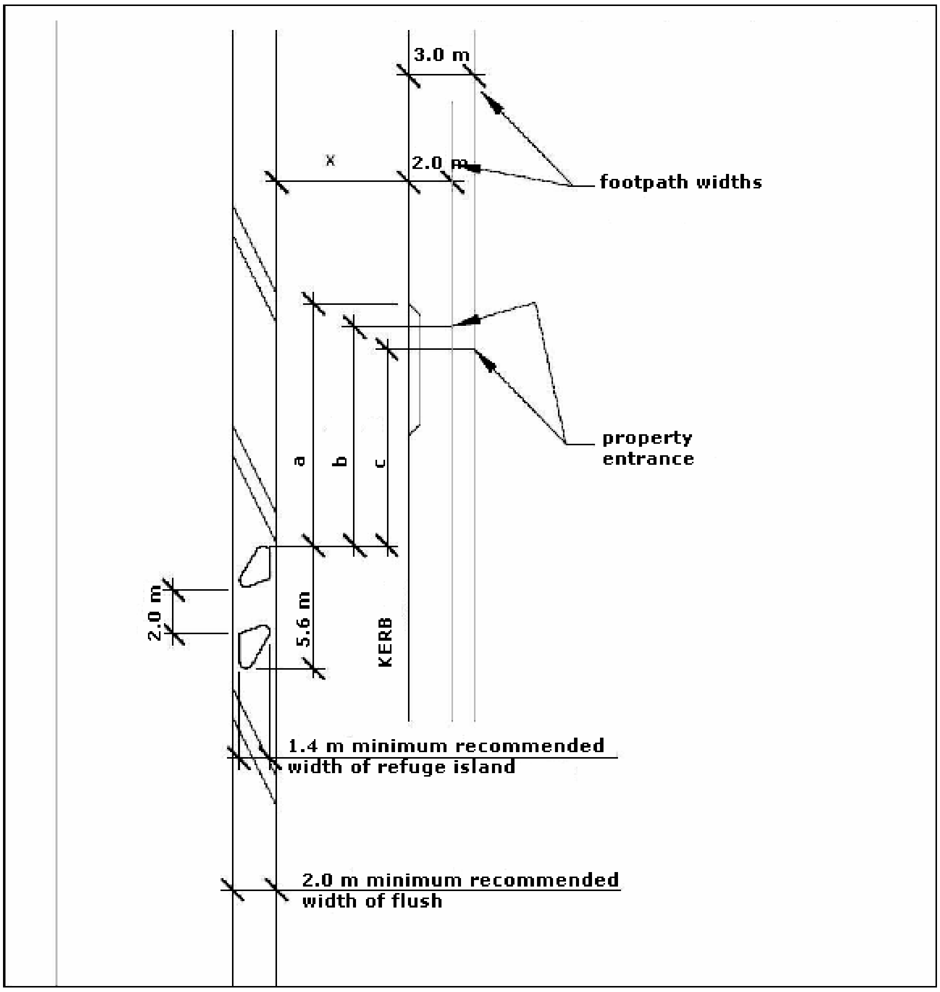


Figure J5: Design detail for implementing pedestrian refuge islands on flush medians – Type 2 refuge.

Notes to Figure J5:
These dimensions are only considered suitable for vehicles travelling at very low speeds. They enable the vehicle to clear the through-lane and wait to access adjacent residential properties (1–2 queuing spaces, etc.).

Table J3 Design chart minimum dimensions for Type 2 refuge (as shown in Table J5).

x (m)	Cross section	a (m)	b (m)	c (m)
4	two-lane	10.0	9.5	9.0
6	two-lane with parking	10.0	8.0	8.0
7	four-lane	7.8	7.0	7.0
9	four-lane with parking	5.5	5.0	4.5

J8 References

Cleaver, S., Jurisich, I., Dunn, R. 2007. Safety implications of flush medians in Auckland City: further analyses. *Land Transport New Zealand Research Report 312.* Wellington: Landt Transport New Zealand. 86 pp.

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