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Evaluating the use of rural-urban gateway treatments in New Zealand

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Abstract

Speed has been widely identified as a leading factor in crash occurrence and severity. On rural networks, a key problem is speeding where vehicles transition from a high speed to low speed environment. Research has identified rural-urban gateway/threshold treatments as a speed reducing measure in transition zones. Gateways include the use of signs, road markings and lane narrowing to lower vehicle speeds and improve road safety. Although gateways have been used extensively, e.g. UK and New Zealand, there has been no comprehensive evaluation on their effectiveness in Australia or New Zealand. The main objective of this research was to assess the changes in crash frequency and severity attributable to the implementation of gateways over time. The study involved a before and after comparison of crashes at treatment sites after gateways were installed compared to the general trend at similar sites across New Zealand over the same period. The study was designed as a non-equivalent quasi-experiment using 102 treated and 62 control sites. The results showed that gateways, particularly pinch point gateways, were effective in lowering crashes at rural urban transition zones in the New Zealand context.

Keywords

Crash modification factors, gateway effectiveness, gateway evaluation, New Zealand gateways.

Introduction and background

Speed has been identified as a leading factor in crash occurrence and severity, including on rural roads [1]. Although speed management techniques for urban roads are well documented, less has been done for rural roads. To this end, Austroads commissioned research to identify effective speed management measures for rural roads including the management of speed at transition zones. Transition zones refer to road sections where vehicles move from high speed to low speed environments. Rural-urban gateway/threshold treatments were identified as a possible speed management measure at the transition zones.

Gateways are defined as a combination of traditional and non-traditional traffic calming measures designed to slow traffic entering low speed environments [2-3]. Treatments include the use of lighting, murals, signage, wall and fence structures, lane narrowings, surface markings, median treatments and vegetation to mark road sections where the speed environment changes or alert road users of changing road and traffic conditions (Figure 1). The type of treatment used depends on general guidelines, installation costs and availability of funds, road geometry, underlying concerns and, in some instances, public opinion. Although gateways have been used extensively, e.g. UK and New Zealand, there has been no evaluation on their effectiveness in Australia or New Zealand.

The broader aims of the research involved evaluating the effectiveness of gateways in lowering crashes and speeds as well as determining the economic viability of the treatment. This paper focuses on the effectiveness of gateways in lowering crashes.

Method

Gateway effectiveness was evaluated through a controlled retrospective before and after analysis of crash data at treatment sites across New Zealand. Given that other major road safety campaigns and treatments were underway during the gateway implementation period, a comparison of crashes before and after gateway installations alone would not have accurately reflected the full effect of the treatment on safety outcomes. Consequently, the analysis was set up as a non-equivalent control group quasi experimental design as the sites were not randomly assigned to either treatment or control group and the probability of a site belonging to either group was not equal.

The analysis involved 102 treatment sites and 62 control sites across New Zealand's road network. The treatment sites included sites where gateways were implemented while the control sites were selected from comparable sites across New Zealand. The process involved matching town/township population sizes to those in the treatment group and ensuring that the selected sites had no existing gateways in place. Limiting the population size allowed for comparable road use estimates at both control and treatment sites, reducing the selection threat inherent in this type of experimental design.

Installation dates and gateway features in the control group were assigned using proportionate stratification. The number of control sites allocated to an installation year was proportionate to the number of treatment sites installed per year. Once the distribution of installation dates within the control group was determined, the dates were randomly allocated to the control sites. Using the same approach, it was possible to determine the distribution of gateway types within the control group. Gateway types and features were

Figure 1. Gateway treatment [4]

then randomly assigned to the control sites. This was done in order to reduce bias and systematic errors as well as provide a more consistent comparison basis.

Crash data

Crash data for the before and after periods was extracted from the New Zealand Crash Analysis System (CAS). The analysis periods covered five years both before and after the gateways were installed. This period took into consideration seasonal variations and was long enough to capture the habituation effect. The before period consisted of five full years of data for all locations while the after period ranged from one to five years of data, depending on the installation year. To counter these differences, the analysis was undertaken using crashes per year as the dependent variable rather than the number of crashes per site.

Earlier research on the effectiveness of gateways found significant speed reductions around the gateways dissipated about 250m downstream from the treatment [5]. With this in mind, the study covered road segments 100m in advance of the gateways, and through the full extent of the township for which the sign applied.

As the majority of treatment sites in this study, with the exception of three, were not selected on the basis of crash history but excessive speed, regression to the mean was not expected to be a significant problem.

To measure the effectiveness of gateway treatments, crash modification factors (CMFs) were developed. CMFs are estimates of changes in crashes due to the implementation of the treatment. They are derived from changes in crashes at treatment sites relative to expected crashes. Expected crashes are a function of the trend at control sites. They represent crashes that would have been observed had the treatment not been present.

Statistical analysis

The aim of the statistical analysis was to determine whether gateways significantly impacted crash frequency and severity and whether the scale and significance of the effect differed by gateway type and feature.

A log-linear model (primarily, a Poisson regression model with unequal time periods) would have been the preferred test for this type of exercise as it would allow the examination of conditional and interaction effects. However, data screening negated the use of a log-linear model due to insufficient expected crash counts in some of the cross tabulation cells from which the log-linear model is evaluated. Statistical testing was therefore undertaken using chi-square tests in SPSS (IBM Statistical Package for Social Sciences 21).

The p-value produced by this test and reported in the results represents the probability of the observed difference between crashes and expected crashes occurring in the absence of any treatment effect. Given the multiple levels of significance tests undertaken, the data was adjusted for type I error. Type I error involves accepting the null hypothesis when it is false. The significance tests in this study were adjusted for type I error using the Bonferroni correction indicated in Equation 1.

α=Target *p value/n*[1]

where

n^1 = Number of significance tests undertaken

α = New alpha level

Analysis stratification

The data analysis was carried out in the following stages:

1. All sites where gateways were installed. This was an overall measure of gateway effects on crash frequency and severity. This stage included crashes at all sites, regardless of direction of travel and an additional analysis for relevant/affected direction of travel.
2. Sites where pinch point and sign only gateways were installed. All gateways were categorised into one of two broad groups; pinch point and sign only gateways. This level of evaluation measured the general impacts by gateway type.
3. Individual gateway type or configuration. This stage measured the impact of gateway features, e.g. a combination of flush median and solid island or hatched edges and flush median, on crash frequency and severity (see Figure 2).
4. Supplementary analysis. This level measured the magnitude of changes in crash frequency and severity by road type (arterial, collector, local and state highway), crash cause factors (vehicle movements) and rural urban transition speeds.

Results

The evaluation of before and after crashes at treatment and control sites showed an overall crash modification factor (CMF) of 0.74. This indicates a 26% reduction in crashes as a result of gateway implementation across New Zealand. The crash reduction was statistically significant at α = 0.0167 significance level ($p = 0.002$)[2]. The results discussed in this report are for both directions of study and so provide a conservative measure of the expected effect.

[1] n = k(k-1)/2 where k is the level of significance tests

[2] p values in this section are Bonferroni corrected. The Bonferroni correction is a multiple-comparison correction used when testing several dependent and/or independent variables simultaneously.

A comparison of crash severity before and after gateway implementation is outlined in Table 1. The results show reductions in serious and minor injury crashes of 32% and 27% respectively (CMFs of 0.68 and 0.73). The results also show an increase in fatal crashes of 79%. The results indicate an increase in the relative risk of fatal crashes and reductions for all other crash types with serious injury crashes having the lowest risk levels. The changes were statistically significant for minor and serious injury crashes but not for fatal crashes. In keeping with the Safe System approach, an analysis of the combined changes in fatal and serious crashes was also undertaken. There was a 23% statistically significant reduction in these severe outcome crashes.

Table 1. Crash frequency and severity analysis

Severity	Control		Treatment		CMF
	Before	After	Before	After	
Fatal and serious	26	24	25	18	**0.77**
Fatal	4	2	3	3	1.79[a]
Serious	22	21	22	14	**0.68**
Minor	64	66	66	50	**0.73**
Overall	90	90	91	67	**0.74**

Bold indicates result was statistically significant at $\alpha = 0.008$ significance level

[a] Net increase in crashes

Analysing the crashes by gateway type (pinch point and sign only gateways) showed an increase of 3% in crashes at sign only gateways and a 35% reduction at pinch point gateways (CMFs of 1.03 and 0.65 respectively). The changes were statistically significant for pinch points but not for sign only gateways as outlined in Table 2. The results also show the impact of gateways on crash severity by gateway type. There were non statistically significant increases in all injury crash types at sign only gateway sites as well as fatal crashes at pinch point gateways. On the other hand, the crash reductions at pinch point gateways were 51% and 33% for serious and minor injury crashes respectively.

Table 3 shows overall reductions in crashes for the different gateway features. The lowest risk levels were observed at coloured surface gateways (CMF of 0.20). However, these sites also had the least number of crashes.

Secondary objectives of this analysis included determining whether gateway effectiveness varied by road type and the rural-urban transition speed as well as differences by road type.

Figure 3 shows the expected and observed crashes for selected transition zones. There were statistically significant crash reductions of 17% and 29% for the 100-80 km/h zone 100-70 km/h respectively. On the other hand, non statistically significant increases of 1% and 68% in crashes were observed for 100-50 km/h and 70-50 km/h transition zones respectively.

Figure 2. Gateway classifications for analysis (Source: New Zealand Transport Agency)

Table 2. Crash frequency and severity by gateway type

Gateway type	Severity	Control		Treatment		CMF
		Before	After	Before	After	
Sign only	Fatal	1.2	1.0	0.4	0.5	1.35
	Serious	8.2	5.2	4.0	4.2	1.66
	Minor	28.2	27.6	13.4	11.9	0.91
	Fatal and serious	9.4	6.2	4.4	4.7	1.16
	Total	37.6	33.8	17.8	16.6	1.03
Pinch point	Fatal	2.4	1.4	2.2	2.7	2.06
	Serious	14.2	16.1	18.4	10.2	**0.49**
	Minor	36.0	38.3	52.8	37.8	**0.67**
	Fatal and serious	16.6	17.5	20.6	12.9	**0.59**
	Total	52.6	55.8	73.4	50.6	**0.65**

Bold indicates result was statistically significant at α = 0.005 significance level

Table 3. Crash frequencies by gateway features

Gateway	Control		Treatment		CMF
	Before	After	Before	After	
Flush median	12.2	11.2	15.2	5.8	0.42
Solid island	1.2	1.4	8.6	7.9	0.78
Coloured surface	0.4	2.0	1.4	1.4	0.20
Flush median and solid island	4.8	4.8	10.0	6.2	**0.62**
Flush median and hatched edges	6.8	5.7	21.6	12.9	**0.72**
Solid island and hatched edges	5.0	5.8	7.4	9.8	1.14

Bold indicates result was statistically significant at α = 0.005 significance level

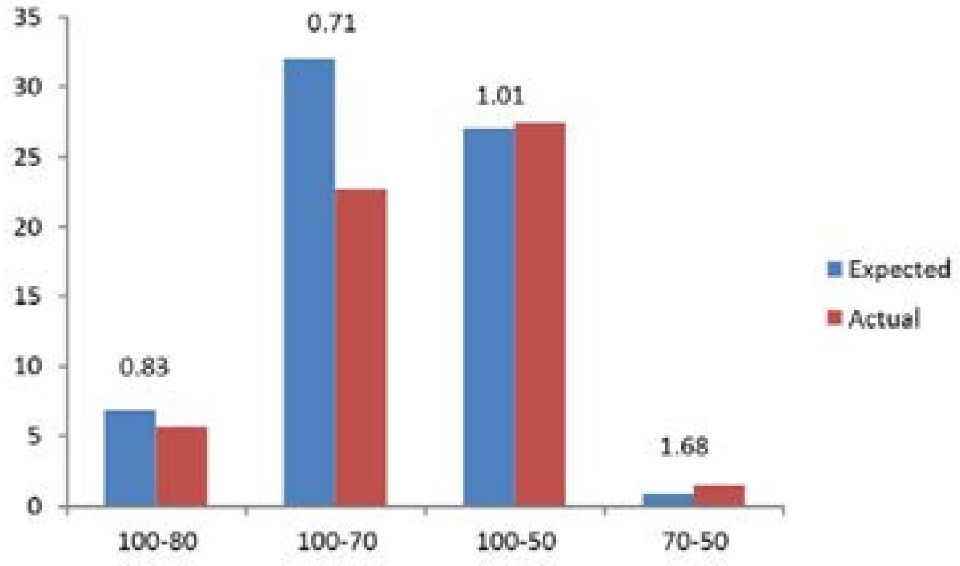

Figure 3. Crash frequency by transition zones

Table 4 shows changes in crashes for the different rural urban speed zones by gateway type. The results indicate increases of 218% and 59% at the 100-80 km/h and 70-50 km/h with pinch point gateways respectively. At the same time, there were overall increases for the sign only gateway transitions except for the 100-80 km/h transition.
A comparison of crash changes at the 100-70 km/h transitions for both pinch point and sign only gateways showed significantly higher reductions at pinch point gateways.

Further analysis of before and after crashes by selected vehicle movements was undertaken. The main interests from this sub analysis were pedestrian and speed related movements. The results for the specified movements are outlined in Table 5. There were non statistically significant increases in head on crashes at pinch point gateways and pedestrian related crashes at sign only gateways. The highest crash reductions were in head-on crashes at sign only gateways and pedestrian related crashes at pinch point gateway sites, both of which were statistically significant.

Analysing crashes by road classifications and gateway types illustrated increases of 2% and 108% on state highways and arterial and collector roads with sign only gateways and 113% on arterial and collector roads with pinch point gateways respectively. The crash reduction was highest on arterial roads and state highways with pinch points (CMFs of 0.32 and 0.12 respectively). The crash reductions on arterial roads were statistically significant.

Discussion and conclusion

This study was a retrospective before and after analysis of gateways at 102 treatment sites across New Zealand's road network with a control group consisting of 62 sites. The aim of the analysis was to determine the impact, magnitude and statistical significance of rural urban gateways on crash frequency and severity and whether the effect differed by gateway type and feature.

The analysed crash data covered five years before gateways were installed. This provided detailed information on the

Table 4. Crash frequency by rural-urban transition speeds

Gateway type	Rural urban transition speed (km/h)	Control		Treated		CMF
		Before	After	Before	After	
Sign only	100 80	0.6	1.8	1.2	1.2	0.33
	100 70	18.4	14.5	9.4	8.3	**1.12**
	100 50	18.6	17.5	4.4	4.2	**1.01**
Pinch point	100 80	1.6	0.4	5.6	4.5	3.18
	100 70	8.8	11.0	24.8	14.4	**0.47**
	100 50	33.6	38.0	21	23.2	**0.98**
	80 50	1.2	2.4	2.4	0.0	0
	70 50	7.4	4.0	1.4	1.2	1.59

Bold indicates result was statistically significant at α = 0.005 significance level

Table 5. Crash frequencies by vehicle movements and gateway type

Gateway	Crash cause	Control		Treatment		CMF
		Before	After	Before	After	
Sign only	Head on	3.4	2.9	1.4	0.5	**0.38**
	Lost control or off road	4.8	6.4	1.6	1.2	**0.54**
	Pedestrians crossing road	6.6	1.4	1.0	1.0	4.71
	Pedestrians other	1.0	0.2	-	0.2	-
Pinch point	Head on	6.6	4.2	4.2	5.1	1.89
	Lost control or off road	7.6	8.5	7.0	7.5	**0.96**
	Pedestrians crossing road	3.6	4.8	4.8	1.8	**0.28**
	Pedestrians other	0.6	1.4	0.6	0.5	0.32

Bold indicates result was statistically significant at α = 0.005 significance level crash trends in the before period. However, the after period consisted of different numbers of years. The analysis indicated crash reductions at the treatment sites in the before after analysis.

The findings are consistent with past research on the effectiveness of gateways in lowering crashes. In a study on the effectiveness of traffic calming measures in lowering crashes, Taylor and Wheeler found that gateways (without downstream traffic calming) led to a 43% reduction in fatal and serious crashes while minor crashes increased by 5%. On the other hand, fatal and serious crashes fell by 70% and minor injuries by about 30% with an overall reduction of 45% where downstream traffic calming was also implemented [6].

This study found that gateways led to a 26% reduction in all crashes and 23% reduction in fatal and serious crashes. There was a 35% reduction in all crashes at pinch point gateways with fatal and serious crashes falling by 41%. This indicates that gateways, particularly pinch point gateways, are a useful measure for addressing crash reductions at transition zones.

This evaluation was part of a larger Austroads research project on effective speed management techniques on rural roads (engineering treatments). The information in this paper provides one possible solution for managing speed at rural urban transition zones. Further information on other evaluated treatments is outlined in the project report [7].

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Human body modelling of motorcyclist impacts with guardrail posts

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Abstract

Recent research into motorcyclist collisions with roadside barriers has indicated that while they are infrequent events, they often result in severe injury outcomes. Impacts with steel guardrail (W-beam) barrier posts have been identified as significant contributors to such injuries. Thoracic injury has been revealed as the body region most frequently seriously injured (AIS 3+), amongst fatal and non-fatal collisions. One approach to help reduce such trauma is to perform numerical simulations of motorcyclist-barrier collisions, and to develop and assess barrier types and barrier modifications and their impact on injury outcomes.

The aim of the present study is to validate a human FEM model of a motorcyclist impact with a guardrail post, specifically focusing on the incidence and severity of thoracic injuries. Field-observed cases of motorcyclist-barrier collisions in Australia are identified, where a collision of a motorcyclist sliding into a steel guardrail barrier was fully reconstructed. A numerical model of the THUMS human body model sliding into a steel guardrail barrier is developed using LSDYNA. The biomechanical response of the THUMS model is validated against cadaver experiments of blunt anterior-posterior and lateral impacts to the chest, and against the field-observed collisions. The validated model will be a useful tool to develop and assess