# Cycle Lane Performance: Road Safety Effects

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## 1 Introduction

Christchurch City Council has been following a program of strategic implementation of cycle lanes. A point has been reached where it is essential to review the effectiveness of the various treatments in place. This paper looks at the effect that cycle lanes have on safety.

Since 1994, mid-block cycle lanes have been included in the "*Manual of Traffic Signs and Markings, Part 2: Markings*", which is the guideline for road markings in New Zealand. LTSA is the co-author of this document.

Establishing a method for measuring the safety effects of cycle facilities will allow comparison between facilities. Further monitoring of the effects over a number of sites in different environments will allow the selection of appropriate treatments and the refinement of existing facilities to provide the most effective treatment.

Cycle lanes were selected for analysis, as they are the only standard roading treatment to cater for cyclists. Other treatments such as off road cycle paths and advance stop boxes are not a standard feature and therefore are subject to layout variations between sites. This report deals with the problems faced when trying to determine the safety effects of cycle lanes.

## 2 General Issues

### 2.1 Definitions

Safety falls into two general categories, perceived and actual.

Actual safety relates to the frequency of crashes experienced. This aspect of safety can be measured through the use of LTSA (Land Transport Safety Authority) crash records, but is subject to a high under-reporting rate. In order to fall in line with this procedure, this report utilises the crash data available from the AIS (Accident Investigation System) database, which is managed by LTSA.

The perceived safety is felt by the road user. In the case of cyclists, this can be measured through tactile characteristics, such as separation between cyclists and cars and relative velocities. In the Christchurch Strategy, these features have been monitored in tracking surveys and will not be dealt with in this paper.

### 2.2 Observation Period

Crashes are considered to be a rare event statistically. The annual accident rate is related to the underlying true accident rate (UTAR). In order to get a realistic idea as to the UTAR, safety analyses must be carried out over a number of years. In most cases the recommended observation is both 5 years before and after the implementation of a treatment.

The crash rate is sensitive to many variables. Following treatments, user behaviour can be temporarily effected as users become accustomed to the new demands.

To further examine the effectiveness of treatment, a control site may be used. Control sites are effective, as they are able to minimise the variation in crash rates caused by noise such as changes in reporting rate, reductions in patronage or a general change in crash rates (e.g. due to improvements in driver behaviour).

### 2.3 Environmental Variation

Safety can be effected by a number of variables at every site. In light of this, control sites must be carefully selected to ensure that they are as similar to the test site as possible.

Some features to be considered when selecting control sites are:
Urban environment,
Road Layout and
Traffic Volumes.

Environmental variations cause behaviour to vary within a site. This can occur when treatments, other than those being examined, are implemented.

### 2.4 Information Available

The ability to measure safety effects is dependent on the information available. The information in the publicly available AIS database is subject to many sources of error.

The first of which is the reporting rate. Only crashes involving injury are required to be reported on the database. Until 1988, there were no facilities for recording non-injury crashes. The reporting rate is proportional to the severity of crash. Reporting rates are estimated through comparison of reported crashes with hospital records. This estimate is then extrapolated to determine the reporting rates for each severity of crash.

Aside from severity, the road user group also effects reporting rate. By law, only crashes involving motorised vehicles are required to be reported. Consequently many crashes involving cyclists are not included in the database. Some such crashes are:
Cyclists vs. Pedestrians;
Cyclists vs. Cyclists,
Cyclist only crashes and
Cyclists vs. Objects (e.g. tram tracks).

Many of the statistical methods used in determining safety effects require a minimum crash rate prior to treatment in order to determine any change on safety. One such method is the chi-square test. Another is a change in UTAR test. This utilises graphs that require a minimum crash rate to determine any effect.

## 3 Method Used

### 3.1 Site Selection

Considering variations due to environmental factors, the sites used in our study were of a similar nature. Three roads leading from the edge of the CBD to the urban areas were selected for analysis. These streets had been progressively marked with cycle lanes since 1993. The marking dates were determined through discussions with City Streets staff, aerial photographs and City Streets project consultation brochures.

Tuam Street had also been marked in this period. Tuam Street is subject to vastly different environmental factors and was therefore kept separate from the other streets in the analysis. To check the effects on Tuam Street, Manchester Street was used as a control. Manchester Street was considered to be an appropriate control as it has a similar geometry, traffic volumes and location.

**Table 1: Site Descriptions**

| Site | Hierarchy | Environment |
|---|---|---|
| **Tuam Street** | Collector / Local | Central Commercial, Retail |
| **Ferry Road** | Minor / Major Arterial | Urban Commercial, Residential |
| **Linwood Avenue** | Major Arterial | Urban Commercial, Residential |
| **Main Road** | Minor Arterial | Urban Residential |

### 3.2 Observation Period

To examine the safety effects relative to previous conditions and environmental conditions, it was necessary to look at a before period that was of similar length to the after period. In some cases, the after period was approximately two years in length. In order to utilise the maximum amount of data, the before period was measured to the month before the treatments and the after period taken from the month of the treatments. This allows information from recently marked sites to be utilised.

The streets were divided into sites by their marking dates. To obtain an idea of the overall effect, the statistical method used for analysis had to be able to combine and make use of data sets that had different before and after periods.

### 3.3 Statistical Test

A number of statistical tests are available for the crash data analysis.

The reported cyclist crash rates were too low for the Chi-square test to be appropriate. In many cases the number of crashes before or after was less than the threshold of 5, suggesting that Fisher’s exact test would be more suitable. The results for all sites could not be combined using Fisher’s exact test due to the variation in test periods for each site.

A change in the Underlying True Accident Rate (UTAR) is measured by the UTAR Test. The test makes it possible to differentiate between changes in crash rate as a result of the treatment and changes due to an overall trend (UTAR). This test relies on the use of graphs. The low reported crash rates for cyclists were often outside the region of significance; hence this method is unsuitable.

A log ratio test was chosen as the most appropriate form of statistical analysis for the lane marking[1].

The log ratio test examines the ratio of actual crash frequency to expected frequency. This ratio does not have an upper bound, while the lower bound is zero. Therefore a log distribution is used to describe this ratio.

The mean effectiveness is measured by $\lambda$ and the standard error of this estimate is measured by e (see Appendix for calculation details). A confidence interval for the effectiveness of the treatment is created using these parameters. Confidence intervals describe the range that the actual mean effectiveness is expected to lie within. The confidence level describes the percentage of such intervals that the mean will be in. A negative effect indicates a possible increase in crash rate and a positive effect indicates a possible decrease in crash rate. A

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[1] This method is based on those covered in the University of Canterbury course “Accident Reduction, Prevention and Investigation” co-ordinated by Alan Nicholson. Details of this calculation are outlined in the Appendix.

treatment can, within the set limits of confidence, have different degrees of effectiveness, depending on the confidence interval.

These confidence intervals can be constructed with, or without a control site. A control site is useful, as it can reduce the effect of a change in UTAR and reporting rate on the confidence interval. The control site must be similar to the treated site in geometry, traffic volumes and flow composition. These features make it difficult to find a control site in many instances. For this paper, the central city site was examined in relation to a control site. The UTAR may be subject to these variables and therefore, they should be considered. No control sites are used for most of the sites.

### 3.4 Safety Effects

It was hypothesised that cycle lanes may have safety effects beyond those relating to cyclists. In order to examine these possible effects, the crashes in four categories were considered.

#### Pedestrians

One category for analysis was crashes involving pedestrians. By providing a buffer zone between parked cars and vehicles, cycle lanes have an effect on the perceived safety of pedestrians. The data were tested to see if this perceived safety increase translated into an actual effect.

#### Mid Block

The safety of vehicles in mid-block sections may be effected by the reduction in lane width caused by cycle lanes. To investigate this effect, the crash rates for mid-block sections were analysed.

#### Excluding Signalised Crashes

The safety of vehicles at signalised intersections is a complex issue. In many cases the cycle lane marking varies at signalised intersection and in some cases, terminate in the signal approaches. This complication was avoided in the analysis of overall crash rates by eliminating all crashes within 15m of signalised intersections.

The remaining category for analysis was crashes involving cyclists.

### 3.5 Information Available

The analysis relies on publicly available information and therefore does not go beyond the AIS database to look at the CAS (Crash Analysis System) records of each crash. CAS is a commercially available investigation system that, like AIS, is maintained by LTSA. Information regarding the trends in reporting rates was not available at the time of analysis and therefore not taken into consideration in the results.

The data was sorted using MS Excel. The delimited AIS data were sorted into crash type, marking site and before and after periods. Mechanisms for double checking selection were set up such as cross-referencing the entry of a cycle under vehicle involved and cyclist’s age to ensure that all cycle crashes were accounted for.

# 4 Results

## 4.1 CBD Site

Although there are some differences between Tuam and Manchester Streets, the latter was selected the most comparable street with Tuam Street within the CBD.

**Table 2: Summary of Aggregated Results, containing only the CBD Sites**

| | Tuam Only | | Using Control | |
|---|---|---|---|---|
| **Safety Effect** | **Min Effect** | **Max Effect** | **Min Effect** | **Max Effect** |
| Cyclist Crashes | -123% | 89% | -30% | 97% |
| Pedestrian Crashes | 26.4% | 97% | 6% | 99% |
| Excluding Signalised Intersections | -12.1% | 38% | -17% | 52% |
| Mid-Block Crashes Only | -275% | -67% | -158% | 24% |

During the period following the treatment, there was a significant reduction in the crash rate for pedestrians at the Tuam Street site. The safety effects on the remaining crash categories are not significant.

## 4.2 Aggregated Results for All Sites

The table below shows the upper and lower bounds of the confidence intervals for the four groups of crash records. The results have not been checked against a control site. The use of a control site or set of control data will reduce the effect of underlying trends on the measured effects of treatments.

**Table 3: Summary of Aggregated Results, containing both CBD and non-CBD Sites**

| Safety Effect | Confidence Interval | |
|---|---|---|
| | **Min Effect** | **Max Effect** |
| Cyclist Crashes | -9.06% | 62.77% |
| Pedestrian Crashes | -54.43% | 67.64% |
| Mid-Block and Unsignalised Intersection Crashes | -4.46% | 27.49% |
| Mid-Block Crashes Only | 1.83% | 35.62% |

### Cyclist Crashes

In the period following the treatment, there was a significant reduction in crash rate at three of the eleven sites. The aggregated data shows that cyclist crash rates are **almost conclusively reduced** in the period following treatment.

### Pedestrian Crashes

The number of reported pedestrian crashes was lower than that of cyclists. In the period following the treatment, there was a significant reduction in crash rate at two of the eight individual sites. One of these two sites was outside a school and subject to the implementation of crossing facilities during the trial period. The aggregated data shows that pedestrian crash rates are **not significantly effected** in the period following treatment.

### All Road Users at Mid-Blocks and Unsignalised Intersections

In the period following the implementation of cycle lanes, there was a significant reduction in non-signalised crash rates at two of the eleven sites. The aggregated data shows that unsignalised crash rates are **almost effectively reduced** in the period following the implementation of cycle lanes.

### All Users at Mid-Blocks

In the period following the implementation of cycle lanes, the mid-block crash rate was significantly reduced at two of the eleven sites. The crash rate was almost conclusively reduced at one other site. Overall, the crash rate was **almost conclusively reduced** in the period following the treatment.

## 5 Discussion

Given the unique constraints provided when considering cycle lane effectiveness, the log ratio confidence interval test is the most appropriate means for establishing effectiveness. This method is suitable, given to its ability to analyse treatments that have been progressively implemented. Most other methods require the same before and after period for all sites. As cycle networks grow, progressive implementation allows the strategy to become sensitive to road user demands.

The low reported crash rate relating to cyclists lends itself to confidence interval testing. This method is able to deal with both low numbers of crashes and aggregate the results or numerous sites in order to establish an overall effect.

The need to consider simultaneous environmental changes was highlighted by one of the sites that experienced a reduction in pedestrian crash rate. A pedestrian crossing was replaced with refuge islands at this site and hence it was not a suitable location to establish the effect that cycle lanes have on pedestrian safety.

Since this analysis was undertaken, the LTSA have brought many other factors to our attention.

During the period analysed, the reporting rates have reduced significantly, as too have many crash rates. These significant trends have not been accounted for in the analysis of Linwood Avenue, Ferry Road and Main Road. These trends could have been accounted for by using a large control group. As discussed previously, cyclist behaviour is very sensitive to environmental factor and therefore it is very difficult to determine an appropriate control group. It has been suggested that the overall number of reported crashes be used as a control group in an attempt to reduce the bias created by underlying trends. This poses problems with respect to the categories into which the data is sorted; for instance the data for all crashes excluding signalised intersection is not readily available. By eliminating these categories from our analysis, it becomes hard to determine the effect that cycle lanes have on all road user groups.

Using city-wide crash rates poses problems with respect to simultaneous strategies. In the case of pedestrian crashes, a city-wide initiative has been taken to replace pedestrian crossings with refuge islands. Assuming that this has some effect on the overall pedestrian crash rate, considering its city wide implementation, a safety effect of a specific treatment may be misinterpreted as an underlying trend. A reduction may be occurring at enough sites to cause reduction in overall rate yet this safety effect has little connection to the effect of cycle lanes on pedestrians and therefore the effectiveness may be monitored against a safety effect rather than an underlying trend.

Other possible criticisms relating to this study are levelled at the crashes themselves. For some of the streets over 500 crashes were filtered and sorted in order to obtain the data. Considering the number of crashes, it would be incredibly time consuming and unproductive to check the CAS record for every crash. In this instance, only the delimited categories used in AIS were used for sorting and errors in recording were assumed to cancel themselves over the total number of crashes. Double checking markers were used where possible to limit the inclusion of recording errors in the analysis.

The analysis of central city sites becomes sensitive when underlying trends are considered. It can be seen that the use of a control site reduces the size of the confidence intervals. Careful consideration must be used when determining suitability of control sites. In this case, Manchester Street was used as it was in a similar environment with similar volumes and carriageway widths. Upon closer inspection it can bee seen that the trends in crash rates on Manchester Street go against the trends over the CBD as a whole. This suggests that Manchester Street may have some unique problems of its own. It is possible that in the case of Tuam Street, the entire CBD might have been a more appropriate control group.

## 6 Conclusions

Determining the safety effects of cycle lanes is complex and subject to many unique constraints. The confidence interval test seems to be the most appropriate for the consideration of cycle lane safety effects as it allows comparison between all sites and safety effects.

Underlying trends in crash rates must be identified wherever possible to remove bias in results. This can be done through the use of city-wide control groups and adjusting the data to consider further variations in reporting rate. The LTSA should also be contacted with regards to any other trends that have not been publicised.

The data as publicised in this report are subject to the constraints as outlined in the text. In light of the additional information supplied by the LTSA, further research is necessary in order to validate or adjust the findings. At this stage, it seems that Christchurch City Council could prove the effectiveness of cycle lanes.

## Appendix

Calculation Details

Using a control site,
B = control site crash total, before treatment
A = control site crash total, after treatment
b = Test site crash total, before treatment
a = Test site crash total, after treatment
$\lambda = \ln(aB/bA)$ if $a,b,A,B > 0$
$\lambda = \ln [ ((a+0.5)(B+0.5)) / ((b+0.5)(A+0.5)) ]$ otherwise
$\lambda > 0$ indicates apparent reduction in crash frequency
$\lambda < 0$ indicates apparent increase in crash frequency

$$e = \min\left\{\sqrt{2}, \sqrt{(a+1)^{-1} + (b+1)^{-1} + (A+1)^{-1} + (B+1)^{-1}}\right\}$$

$$z = \frac{(x-\lambda)}{e}$$

$$CI = 1 - \exp(\lambda \pm ze)$$

To create a confidence interval for a combination of sites the following formulae are used:

$$\lambda_i and, e_i, i = 1, \ldots N$$

The minimum variance estimate of the overall effect is:

$$\bar{\lambda} = \frac{\sum_{i=1}^{N}(\lambda_i / e_i^2)}{\sum_{i=1}^{N}(1/e_i^2)}$$

The associated standard error is:

$$\bar{e} = \sqrt{e^*}$$

$$e^* = \max\{\bar{e}_a, \bar{e}_b\}$$

$$\bar{e}_a = \frac{1}{\sum_{i=1}^{N} (1/e_i^2)}$$

$$\bar{e}_b = \frac{\sum_{i=1}^{N} (1/e_i^4) \sum_{i=1}^{n} [(\lambda_i - \bar{\lambda})^2 / e_i^2\}}{\left[\sum_{i=1}^{N} (1/e_i^2)\right]^3}$$