TECHNICAL PAPER

INVESTIGATING AND MODELING THE EFFECTS OF TRAFFIC CALMING DEVICES

Author and presenter:

Jing (Ellen) Mao, MET (Masters graduate)

Contact: Ellen Mao, Maomao85714@yahoo.co.nz

Co-Author:

Glen Koorey, PhD MIPENZ (NZTA Senior Lecturer in Transportation)

Department of Civil & Natural Resources Engineering

University of Canterbury

Christchurch, New Zealand

ABSTRACT

This research investigated the effects on traffic volumes, speeds and crashes of traffic calming devices on urban local streets. Eleven sites in Christchurch with street calming devices were evaluated using field surveys and network modeling using TrafikPlan, and compared with findings from a literature review.

The main findings of the studies were:

- At seven sites that used vertical devices for treatment, five of them had reduced traffic volumes and speeds.
- At ten sites that used horizontal devices, eight of them had experienced reductions in volumes and speeds.
- From the crash history, it was found that road safety has been noticeably improved after installation of the traffic calming devices, with average crash reductions of 15-20%.
- In terms of network performance, TrafikPlan modelling seems promising for estimating traffic volume and speed changes on treated local streets and adjacent arterial roads.

This paper will discuss these findings and speculate on how the devices investigated affect traffic behaviour. It is recommended that further research be conducted at more sites and for longer time periods to build up a comprehensive local database of traffic calming treatments. Future studies should also investigate the effectiveness of environment impacts of the devices, i.e. noise and air pollution.

INTRODUCTION

With a growing population and developing urban sprawl throughout New Zealand, the number of vehicles has increased on roads. High traffic volumes and speeds, especially on residential streets, reduce the quality of life for residents because of concerns about safety, noise, and pollution (Huang & Cynecki, 2001). As a result, local area traffic management (LATM) is used to manage the neighbourhood areas for decreasing the vehicle's dominance.

The effects of traffic calming devices used on local roads have been fairly comprehensively researched in the past. There are over 20 types of common traffic calming devices, each with advantages and disadvantages. For example, a significant reduction in vehicle speeds will tend to discourage through traffic and improve pedestrian safety. Conversely, traffic noise levels may increase due to deceleration and acceleration. Some devices may adversely affect emergency and commercial vehicles. The details of these effects will be discussed later.

This paper describes a framework to evaluate the range of traffic calming devices such as road humps, intersection platforms and centre blisters[1]. It particularly focuses on evaluating their effects on road safety and amenity on urban local roads in Christchurch. It is based on recent research undertaken at the University of Canterbury (Mao, 2009).

Objectives of Research

The objectives of this research project were:

1. To investigate the effectiveness of traffic calming devices on urban local roads in Christchurch. The effects of traffic calming devices on the following three aspects will be analysed:
    - Vehicle's operating speed
    - Traffic volume and types
    - Severity and number of crashes

2. To analyse the reliability of transport modeling software regarding prediction of the effects of traffic calming devices

It was also hoped to evaluate the environmental impacts of traffic calming after implementation, focusing on noise pollution due to acceleration or deceleration of passing vehicles. However, time constraints meant that this couldn't be undertaken.

LITERATURE REVIEW

Traffic calming is defined as *"…the combination of mainly physical measures that reduce the negative effects of motor vehicle use, alter driver behaviour and improve conditions for non-motorised street users*" (TAC, 1999). The main objective of traffic calming is to provide a speed that is appropriate to the local environment and other road users. Ideally, it produces a road network that is driven calmly, smoothly and safely by drivers.

Features of traffic calming schemes include physical roadway design changes, traffic control devices and perceptual measures. Holler (2003) reported that traffic calming measures can be broken into two basic groups; one is volume control, the other one is speed control. Speed control schemes are used to reduce traffic speed by providing physical barriers. It should be noted that many speed control devices also have a significant effect on deterring

[1] A Centre Blister is a concrete island positioned at the centreline of a street that has a wide oval plan shape that narrows the lanes, and can be used to provide pedestrians with a refuge (Austroads, 2008)

motorists and providing volume control. Volume control schemes are used to reduce traffic volume by blocking streets or diverting traffic to other streets. Table 1 shows the classification of traffic calming devices.

Table 1 Classifications of Traffic Calming Devices [2]

Speed Control		Volume Control
Vertical Deflection Devices (1) Road Humps (2) Raised Tables (3) Raised Crosswalks (4) Road Cushions (5) Raised Intersection Platform (6)“Thumps” (7) “H” and “S’ Humps (8) Mechanical humps (9) Rumble Devices	**Horizontal Deflection Devices** (10) Kerb Extensions (11) Carriageway Narrowing (12) Slow Points - Chicanes (13) Centre Blister (14) Impellor (15) Centre Islands / Mid-Block Medians (16) Roundabout (17) Traffic Circles (18) On-Street Parking Management (19) Driveway links	**Diversion Devices** (28) Full Road Closure (29) Half Road Closure (30) Diagonal Road Closure (31) Modified ‘T” Intersection (32) Left-in / Left-out Islands
Signage and Lane marking (20) Speed Limit Signs (21) One-Way Signs (22) Stop Signs (23) Give Way Signs (24) “Zebra” Crossings (25) Shared Zones	**Surface Treatment** (26) Perimeter Threshold Treatment (27) Tactile Surface Treatment	

Effects on Travel Speed

Traffic calming is a speed-based design scheme. It is used to reduce traffic speeds along streets so that vehicle speed does not exceed target street speeds at any point. The speed profile reflects the physical nature of the streets and driving behaviour of the road users (Brindle, 2005). The ranges of operating speed for a number of traffic calming devices have been studied by Brindle (1999).

Figure 1 shows that vertical deflection devices have a greater impact on vehicle speeds than any other measures. After providing road humps or ramps with sufficient close intervals along the streets, the 85^{th} percentile speed has been found to be less than 30km/h (Harvey, 1992). Spacing should not be greater than 60m, and generally the height of vertical shifts should be 100mm. Tolley (1989) found that ramps with a shallow gradient need to be placed closer together than steeper gradients to achieve the same effect. These studies have also found that the ramps with a 1 in 10 gradient at 40m intervals have the same effects on the speed reduction as the ramps with a 1 in 7 gradient at 60m intervals.

[2] Terminology for some of these devices may vary between jurisdictions; detailed definitions for the terms used above can be found in Austroads (2008) and Hummel et al. (2002).

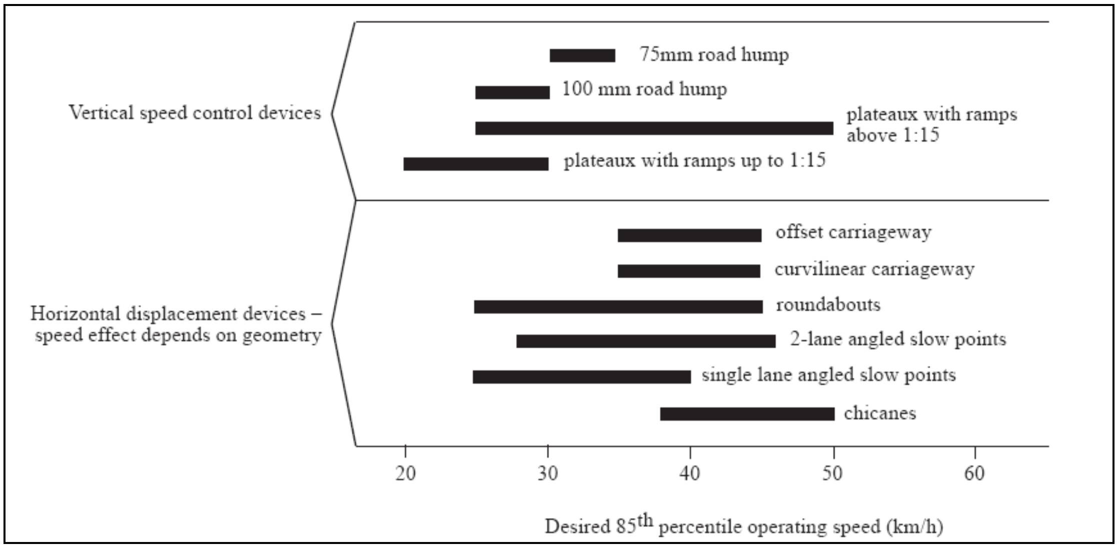

Figure 1 Reported operating speeds for selected device types

(Source: Brindle, 1999)

Table 2 shows the typical results of a number of traffic calming measures in reducing speed with a 48km/h (30 mph) speed limit (Harvey, 1992).

Table 2 Expected Reduction effect of various traffic calming measures

	Upper limit of maximum speed (km/h)		Upper limit of 85^{th} percentile speed (km/h)		Range of average speed (km/h)	
	Before	**After**	**Before**	**After**	**Before**	**After**
Vertical shifts in the carriageway	100	40	75	30	45-65	18-25
Lateral shifts in the carriageway	100	65	75	45	45-65	22-35
Road narrowing to a single lane	100	65	75	45	45-65	22-35
Roundabout	100	65	75	45	45-65	22-35
Road narrowing to a reduced width	100	95	75	70	45-65	40-55
Central islands	100	95	75	70	45-65	40-55

(Source: Harvey, 1992)

Effects on Road Safety

Traffic calming is now a major part of the treatments available to safety engineers to reduce road crashes in urban areas (Hummel et al., 2002). Harvey (1992) reported slower vehicle speeds not only reduce the crash frequency but also have significant effects on the crash severity. Table 3 shows the relationship between speed reductions and accident frequencies.

Table 3 Relationship between speed reduction and accident frequency

% Changes in Injury Accident Frequency by 85^{th} Percentile Speed Reduction	
Speed Reduction	**Change in Crashes all severities**
0 – 2.5 mph (0 – 4.0 km/h)	- 10%
2.5 – 4.5 mph (4.0 – 7.2 km/h)	- 14%
4.5 – 6.5 mph (7.2 – 10.4 km/h)	- 32%
> 6.5 mph (> 10.4 km/h)	- 47%

(Source: IHT/CSS, 2005)

Generally, the crashes in residential areas are scattered over large areas but not concentrated in black spots. Therefore, an area-wide approach should be used for crash prevention in residential areas. The area-wide safety effects of traffic calming have been researched in a large number of studies.

Webster & Mackie (1996) reported that the reductions of crashes in residential areas are large. It was found that there is up to a 60% reduction in all injury crashes and up to 78% reduction in serious injuries.

A meta-analysis of 33 studies from 8 different countries on area-wide effects of traffic calming (Elvik 1999) showed an average reduction of 15-20% in the number of crashes (injury and damage-only). It also showed a 25-55% reduction of crashes on local roads whereas an 8-15% reduction was seen on main roads.

The effects of traffic calming measures on road safety were also been studied in six towns in Germany. Brilon & Blanke (1993) found an average reduction of 63% in the number of seriously injured persons. In the same study, a 50% reduction was observed in the number of injury crashes in the traffic calming areas.

Hummel et al. (2002) pointed out the most impressive results of area-wide traffic calming were found in a Danish study, where traffic calming devices produced a 78% reduction in the number of serious crashes.

All of the above studies showed that the effects of traffic calming measures on safety are positive. The devices produced a significant reduction on the number of traffic crashes (both injury and damage-only).

Environmental Impacts – Noise

The environmental effects need to be considered carefully for measuring the effectiveness of traffic calming devices, including noise, vibration and air quality. The environmental impacts can be positive and negative. They are dependent on the changes in traffic volume and vehicle speeds after using the traffic calming devices.

Traffic noise pollution levels will generally decrease if there is reduction in traffic speeds. However, it may increase as a result of vertical deflections such as road humps. In residential areas, speed reductions from 50 to 30 km/h typically reduce noise levels by 4 to 5 decibels, or more in some circumstances (Abbott et al., 1997). Taylor & Wheeler (1998) noted that an overall reduction in speed resulted in a reduced noise level; they also found a reduction in noise level of around 10%.

However, van Schagen (2003) reported that the noise level is negatively affected when more noise can be produced in areas with or near traffic calming devices. This is due to increases in the number of accelerations or decelerations.

Van Schagen (2003) reported that the net effects of traffic calming measures are positive, although traffic calming devices can result in some undesirable side effects in relation to traffic noise of individual cars, and are due to decreased traffic volumes.

Overall, it can be concluded that the changes in environment are dependent on the traffic calming schemes applied, the traffic volume, the reductions in travel speed and any changes in driving style.

Modelling the Effects of Traffic Calming Devices

Modelling traffic calming requires consideration of the multi-variate nature of local area traffic behaviour, including:

- Traffic volumes and speeds through the area
- The physical layout of the area and the topological layout of the street network
- Characteristics of behaviour of road user groups
- Institutional influences for the implementation of traffic management plans
- Environmental impacts
- Traffic safety and perceptions of danger

The research investigated options for modelling the effects of traffic calming on road networks. One particularly relevant package identified was Trafikplan (Taylor 1992). TrafikPlan is a network traffic model that has the capability to design and evaluate the effects of traffic management schemes and to assess the traffic impacts of individual land use developments. It was therefore tested against a particular local road network (the "Flockton cluster") to assess its usefulness and accuracy.

Taylor (1992) reported that TrafikPlan package comprises details of the road layout, traffic control system, and traffic movements in the area. Proposed changes to the area such as new local area traffic management and control schemes can be tested by TrafikPlan, to predict their likely traffic and environmental impacts. Taylor (1997) stated that the model was used to examine the effects on mobility, energy consumption and air pollutant emissions of different speed limits on suburban roads.

METHODOLOGY

Sites Selection

This research relied heavily on the results of case studies. Therefore, a set of local roads from around Christchurch were selected to investigate the effects of traffic calming devices. They are shown in Figure 2.

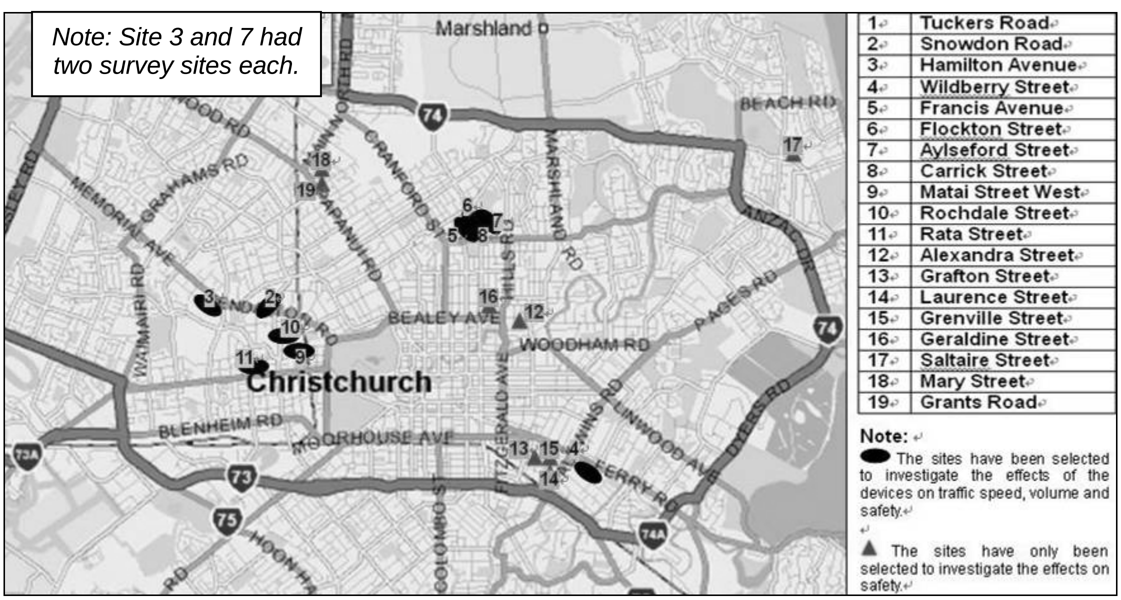

Figure 2 Location of Study Sites

Data Collection

In order to analyse the effects of traffic calming devices on the selected sites, the data that needed to be collected included:

(1) Traffic data
The main function of using traffic calming devices is to reduce traffic volumes and traffic speed on the treated routes. The traffic flow rate and speed before installing of traffic calming devices were collected from Christchurch City Council's (CCC) database and the traffic data after the installation was gathered from field survey work by the University of Canterbury. The data collecting tools were MetroCount and PeekTraffic traffic counters.

(2) Accident data
One of the purposes of traffic calming devices is to improve road safety. Crash data (from before and after implementation) was extracted from the NZTA CAS database, which included the date and time, the location and the types of crashes.

Data Analysis

Some of the relevant steps in data processing and analysis are listed below.

(1) Determine Annual Average Daily Traffic

Traffic Design Group (2001) describes the procedure for estimating the Annual Average Daily Traffic (AADT) from observed count data:

1. Determine the week number of the year (1-52) when the traffic was counted.
2. Determine the Weekly Average Daily Traffic (WADT) for the week counted and any holiday factor.
3. Estimate the AADT = WADT × week factor × holiday factor (if any)

(2) Estimate traffic volume growth rate

Figure 3 illustrates the traffic volumes on the selected control sites from year 2001 to year 2009. The average growth rate of traffic flow was about 2.13% per year.

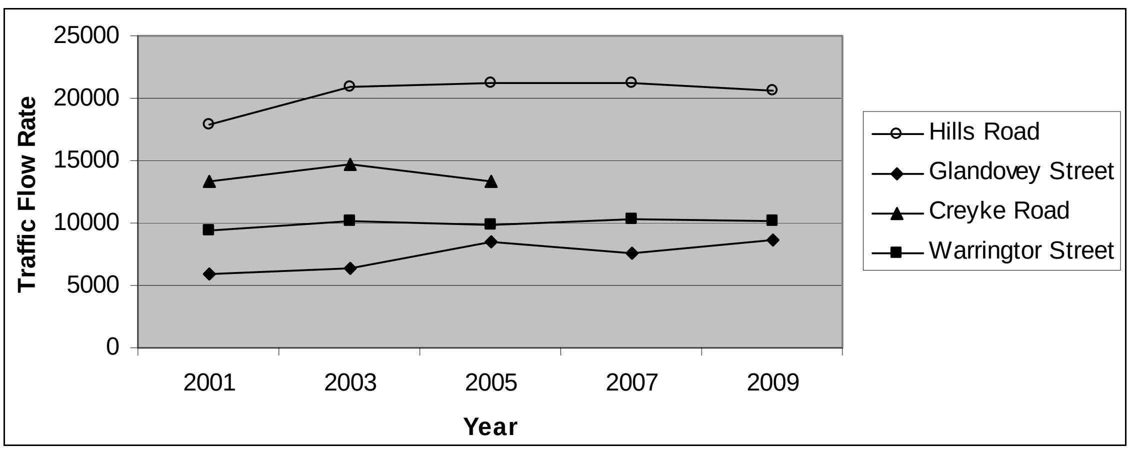

Figure 3 **Traffic Flow Growth Rate**

From this information, AADTs at the selected sites from earlier "before" periods could be scaled up to estimate what should be the expected AADT now (the "after" period), and this could be compared with the actual observed "after" count.

(3) Establish growth rate of traffic crashes

Figure 4 shows the trend of crashes on urban local roads in Christchurch over the past decade. This information was used to estimate the likely change in crashes at the selected sites from the "before" period to the "after" period in the absence of any treatment.

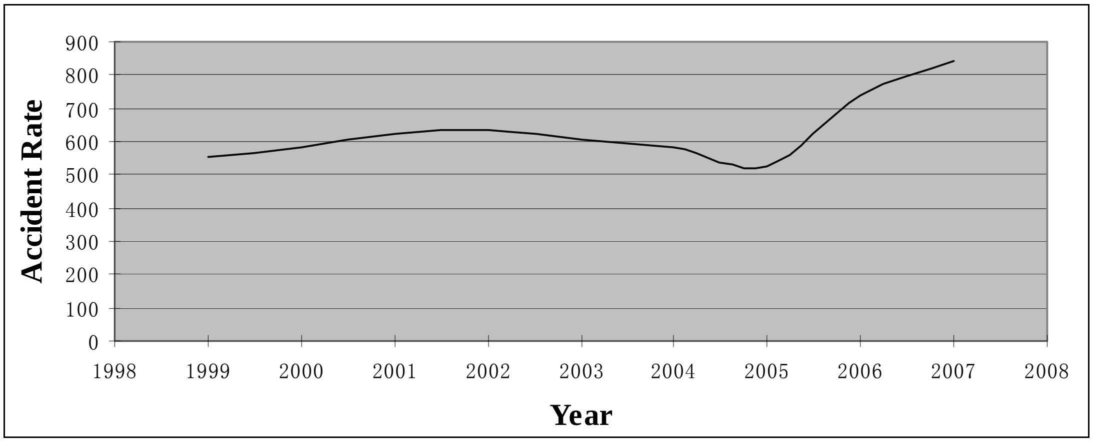

Figure 4 Trend of Crashes on Christchurch Urban Local Roads

(4) Set up networks in TrafikPlan

Figure 5 shows the Flockton Cluster network created in TrafikPlan. The study area is bordered by the arterials Innes Rd (north side), Cranford St (west), Warrington St / Shirley Rd (south) and Hills Rd (east).

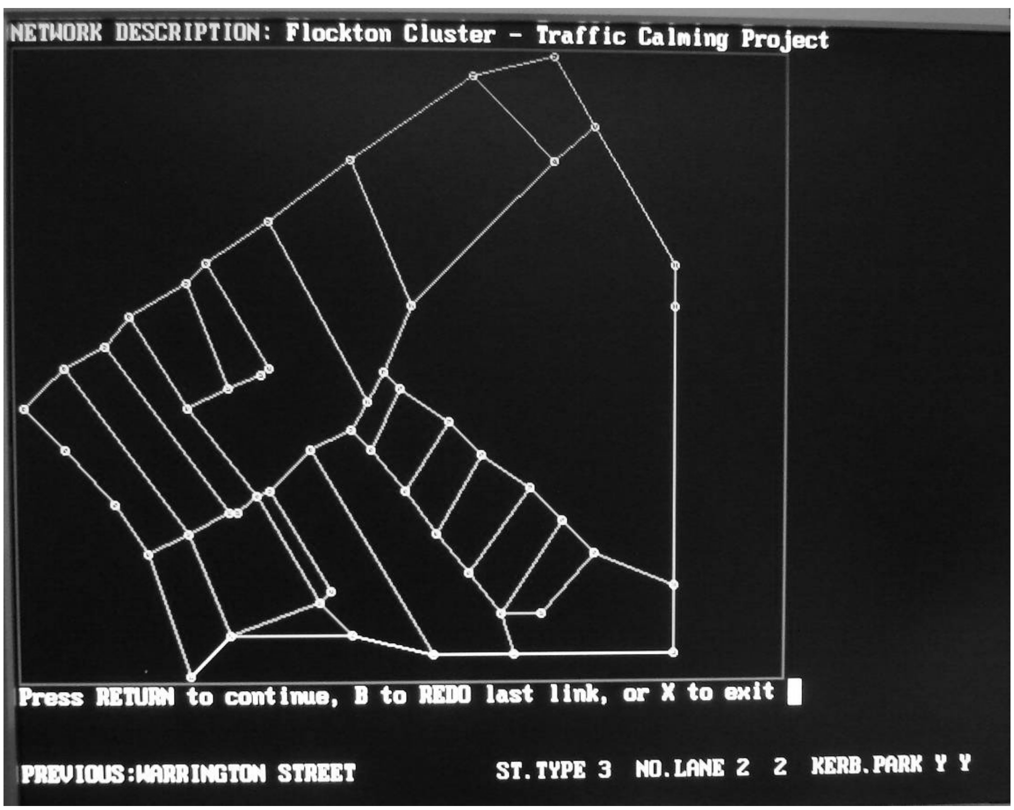

Figure 5 Flockton Cluster Study Area in TrafikPlan

CASE STUDIES

Table 4 lists the survey locations and treatment types of each site investigated in the study for speed and traffic volume changes (other sites were also included in the crash study). A mix of horizontal and vertical devices featured in the sites studied. The resulting changes observed in traffic speeds and volumes are shown in Table 5.

Table 4 List of Case Studies

No.	Street Name	Location of Survey	Horiz'l / Vert'l Devices?
1	Tuckers Road	Between Raised Tables (two-lane)	Vertical
2	Snowdon Road	At Narrow Raised Hump (two-lane)	Both
3a	Hamilton Avenue	Between Roundabout and Intersection Platform	Both
3b	Hamilton Avenue	Between Pinch-Point (two-lane) & threshold	Horizontal
4	Wildberry Street	At Pinch-Point (one-lane)	Horizontal
5	Francis Avenue	Between Raised Tables (two-lane)	Vertical
6	Flockton Street	Between Pinch-Points (two-lane)	Horizontal
7a	Aylesford Street	At Raised Tables (two-lane)	Vertical
7b	Aylesford Street	Between Raised Tables (two-lane)	Vertical
8	Carrick Street	At Chicane (one-lane)	Horizontal
9	Matai Street West	Between Intersection Platform & Pinch Point	Both
10	Rochdale Street	At Pinch-Point (two-lane)	Horizontal
11	Rata Street	At Pinch-Point (two-lane)	Horizontal

Table 5 Results of Traffic Surveys

No.	Effects on Traffic Flow	Effects on Traffic Speed		
		Mean Speed	85 %ile Speed	St'd Deviation
1	-12%	-17% *	-17%	-1.6 km/h
2	-19%	-11% *	-8%	+0.6 km/h
3a	No change	-3% *	-2%	-0.4 km/h
3b	+2%	-2% *	-2%	+0.9 km/h
4	-15%	-3% *	-3%	-1.4 km/h
5	+3%	+6%	+5%	+0.2 km/h
6	-11%	-1% *	-5%	+1.8 km/h
7a	-6%	-18% *	-6%	+2.1 km/h
7b	-6%	+8%	+8%	No Change
8	+5%	+5%	No Change	-0.6 km/h
9	+2%	-13% *	-10%	-0.2 km/h
10	+2%	+13%	+13%	+0.1 km/h
11	-9%	-7% *	-2%	+1.4 km/h

Note:
- "+" means increase
- "-" means decrease
- * means that the reductions in the mean speeds were statistically significant at the 0.05 test level.

Effects on Traffic Flow

As indicated in Table 5, seven out of 13 survey results show that there are notable (>6%) reductions in traffic volumes after the installations of traffic calming devices (with four > 10%). The other six survey results show slightly increased or negligible changes in traffic flows after providing traffic calming treatment. While traffic increases are generally inconsistent with the findings of the literature review, this may be due to:

- The natural variation in traffic volumes (especially as the "after" surveys were undertaken over relatively short periods of about 24 hrs each).

- The periods for the "before" and the "after" surveys being in different seasons and not being fully captured by the AADT adjustments.

- The interval between the "before" and the "after" surveys being up to 6 years apart, during which traffic growth at these sites may have been different from the norm.

Effects on Traffic Speed

Referring to Table 5, the key survey results were:

- Nine out of 13 survey results show that there were (statistically) significant reductions in mean traffic speeds after the treatment, with similar changes in 85th percentile speeds.

- The results of the other four case studies are inconsistent with the findings of literature review where it is identified that the devices will reduce traffic speed. This may be due to the following reasons:
    1. The spacing between the devices is inappropriate. For example, the spacing between the raised tables installed along Francis Avenue (Site 5) is about 140m but the spacing is recommended to be less than 100m between the tables. A longer spacing provides more opportunities for drivers to speed up after crossing the devices.
    2. The devices are not high enough. For instance, the heights of the raised tables provided along Francis Avenue are only 75mm, but the literature review recommended the raised tables should have a range of 90 – 100mm in height.

- No clear trend could be discerned from the change in standard deviations about any change in the spread of speeds.

From the test results of Sites 7a and 7b along the same street, it was noted that the traffic speeds decreased at the the devices themselves but increased in between the devices. This suggests that driver behaviour is a factor. Drivers may be trying to speed up after slowing down for the device in order to catch up on lost time due to deceleration. This may also explain the increased speed result at Site 5 (located between devices) but doesn't appear to make sense for Sites 8 and 10 (located at narrowing devices).

Effects on Road Safety

Typically, local streets have relatively few crashes, so it is difficult to discern any significant safety trends from traffic calming treatments of individual streets. Therefore an aggregate study was used to examine the overall crash patterns on a range of treated local streets.

Table 6 summarises the crash data before and after traffic calming treatments for a range of local Christchurch streets (note that in some of the more recent treated sites there is still only a relatively short time period to work with).

The results show that the average crash frequency has decreased from 1.33 to 1.11 crashes/year per site, despite the general trend of increasing crash numbers on Christchurch local roads (Figure 4). This indicates that the road safety has been improved after using the traffic calming devices, although the improvement is not statistically significant. This evidence supports the findings of the literature review.

Table 6 Effects on Road Safety

Site Name	Crash Rate	
	"Before" Period *crashes (years)*	**"After" Period *crashes (years)***
Wildberry Street	8(5)	5(4)
Snowdon Road	3(5)	1(3)
Flockton Street	3(5)	2(1)
Carrick Street	0(5)	0(1)
Rochdale Street	1(5)	0(0)
Rata Street	2(5)	0(1)
Hamilton Avenue	36(5)	13(1)
Tuckers Road	8(5)	5(4)
Francis Avenue	7(5)	1(1)
Aylseford Street	13(5)	3(1)
Matai Street West	5(5)	1(1)
Alexandra Street	1(5)	3(4)
Grafton Street	4(5)	0(1)
Laurence Street	2(5)	0(3)
Grenville Street	2(5)	0(3)
Geraldine Street	4(5)	5(4)
Saltaire Street	4(5)	1(3)
Mary Street	13(5)	6(4)
Grants Road	10(5)	3(4)
Total for all sites	**126(95)**	**49(44)**
Average Crashes per site	**6.6(5)**	**2.6(2.3)**
Average Frequency per year	**1.33**	**1.11**

MODELLING STUDY

In this research project, the Flockton Cluster (Sites 5-8) was used to evaluate the reliability of TrafikPlan modeling software by comparing the observed results and the modelling results. The study area for the modelling investigations was that area bounded by Innes Road, Cranford Street, Warrington Street and Hills Road.

Observed Results

The Flockton Cluster was treated with various traffic calming devices for reducing traffic volume, speed and improving road safety in 2007. Table 7 shows the changes in traffic volume on the roads after installing the devices.

Table 7 Observed Results – Changes in Traffic Flow Rate

Traffic Volume (AADT) in 2009	Surrounding Arterial Roads				Treated Local Roads			
	Innes Rd	Cranford St	Warrington St	Hills Rd	Francis Ave	Aylesford St	Flockton St	Carrick St
Without the Devices	13024	21444	10535	22633	1572	2039	2133	166
With the Devices	12702	20451	10197	20648	1626	1908	1907	174

According to the literature review, traffic in a network will be diverted from the treated local roads to the surrounding arterial roads. However, Table 7 shows that the traffic volume has decreased on both the treated local roads and the surrounding arterial roads. Suggested main reasons why traffic volume has decreased on the arterial roads are:

- The petrol price increased since 2007 and was very high in 2008, causing many people to use other transport modes.
- Introduction and improvement of facilities for sustainable transportation for the public, which encourages use of alternative modes

Modelling Results

The TrafikPlan model was successfully fitted to the traffic network for the Flockton Cluster study area, and could thus be applied to study the traffic effects of proposed changes to the network and its control system.

According to the modelling results, TrafikPlan predicted that traffic volumes would increase on the surrounding arterial roads and decrease on the treated roads. This result is the same as the findings of the literature review but inconsistent with the observed results.

Although only preliminary, the practical experience of testing TrafikPlan using this case study suggested that such modelling seems promising for estimating traffic volume and speed changes on treated local streets and adjacent arterial roads. It would be desirable however if the old “DOS” interface were upgraded to work better on modern Windows PCs.

CONCLUSIONS

The objectives of this research project were:

- To investigate the effects of traffic calming devices on traffic speed, volume and road safety on urban local roads
- To analyse the reliability of the transport modelling software

A series of recently traffic calmed locations around Christchurch were studied to determine what effects the treatments had. “Before” and “after” field surveys of traffic volumes and speeds were complemented with analyses of crashes at each site.

After reviewing many modelling software packages, the researcher decide to use only TrafikPlan to evaluate the effectiveness of traffic calming devices in diverting traffic flows from the treated local roads to the surrounding arterial roads.

Case Studies

The case studies highlighted that:

- In the seven case studies that use vertical devices for treatment (or a combination of horizontal/vertical devices), five have reduced traffic volume and speed, while the other two have experienced increases. Although increases in traffic speeds may be due to inappropriate device design (spacing, height, etc), there is also the suggestion that drivers may be speeding up in between devices to make up lost time.

- In the ten case studies that use horizontal/combined devices, eight have experienced a reduction in volume and speed, while two have increases. The ineffectiveness of the devices on the two sites may be due to the carriageway width not being narrowed enough to slow down vehicles. However, there is insufficient information to indicate any other reasons for the non-performance of the traffic calming devcies.

- According to the crash history, it would appear that the road safety has improved following installation of the traffic calming devices. On average, this reduction appears to be about 15-20%.

- In terms of network performance, the modelling results predict that the traffic volumes on the treated local roads will be diverted to the adjacent arterial roads. This differs from the observed results. This may be due to other activities affecting travel demand and the effectiveness of the traffic calming devices.

- TrafikPlan modelling seems promising for estimating traffic volume and speed changes on treated local streets and adjacent arterial roads, but more factors need to be considered after getting the modelling results (e.g. the recent economic situation).

Recommendations for future research

Based on the research and analysis undertaken, the recommendations for further research are as follows.

- More research should be conducted to determine why some traffic calming devices failed to achieve reductions in traffic volumes and/or speeds. Longer observation survey periods would also help to confirm long-term trends.

- More research should be done to evaluate the effects of each kind of treatment on road safety. This should also include what types of crashes have reduced after installing traffic calming devices.

- Future research should be undertaken on the environmental impacts of the devices, i.e. noise and air pollution.

Ultimately, a local "good practice" guideline could be produced for implementing traffic calming devices by local authorities in New Zealand, which expands on existing guidance such as Austroads (2008) by providing additional local evidence of the effectiveness of different treatments.

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