Some cost-effective approaches to moderate vehicle speeds in high pedestrian activity environments.

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Abstract

Victorians have enjoyed substantial reductions in the annual numbers of pedestrians killed after 1989. Despite these excellent gains, the overall problem remains a serious community concern and pedestrian crashes in high activity/commercial centres still represent a long-standing problem for which few effective solutions have been found. A study was undertaken to evaluate a number of innovative and more comprehensive approaches to moderate excessive vehicle speeds in high pedestrian areas. Large reductions in average vehicle speeds and more moderate reductions in *free-flowing* vehicle speeds were found. These reductions were associated with substantial estimated reductions in fatal and serious injury risk for pedestrians. Furthermore, significant reductions in the proportions of vehicles travelling at speeds that are threatening to pedestrians were found. This evaluation demonstrated that small speed reductions can lead to very valuable reductions in the risk of road trauma for pedestrians and that innovative countermeasures that appear to provide a cost-effective approach to moderate vehicle speeds, resulting in general benefit to all road users.

INTRODUCTION

Pedestrians are a group especially vulnerable to injuries sustained in a road crash and calls have been made to improve pedestrian safety through programs aimed at reducing the incidence and severity of crashes to pedestrians of all ages. While Victorians have enjoyed substantial reductions in the annual numbers of pedestrians killed after 1989, pedestrian safety remains a serious community concern with 76 persons killed and some 736 persons seriously injured in 1999.

Pedestrian crashes in high activity/commercial centres are a particular problem and one that needs to be addressed, however, few effective solutions have been found. Notwithstanding that there are a number of countermeasure options available for reducing the risk of death or serious injury to pedestrians in these areas, few traditional countermeasures have achieved success in ensuring safe passage for pedestrians. One alternative is to develop ways of achieving more moderate vehicle speeds. The nature of the relationship between vehicle speeds and the risk of fatal injury to pedestrians is both powerful and well understood. Past research provides a compelling case for moderating vehicle speeds in high pedestrian areas (1,2,3). The safety benefits of reducing or moderating vehicle speeds in high pedestrians activity areas are evident, as are the benefits for all road users.

A concerted and innovative approach is required if real and lasting gains are to be made to pedestrian safety in Victoria's hazardous commercial environments. Denmark and The Netherlands are known for their innovative and enlightened approaches to pedestrian safety and amenity, and some of their philosophies have been considered for application in Victoria and elsewhere in Australia (4). If such approaches can be introduced without seriously affecting travel times, they may offer a cost-effective solution to address this problem. This paper presents an evaluation of a number of innovative countermeasures with the potential to moderate vehicle speeds in a strip shopping centre on an arterial road with a high pedestrian crash history.

METHOD

Study design – This research utilised a 'before' and 'after' quasi-experimental design where speed profiles and vehicle travel times were compared before and following the implementation of speed moderating treatment(s) at a treatment site (Clarendon Street, South Melbourne) and a control site (High Street, Northcote). Clarendon Street is fairly typical of the type of arterial road, suburban strip shopping centres found in Melbourne. The treated section was approximately 793 metres in length, undivided and has trams running along its full length. The first surveys comprised the 'before' survey when no treatments were installed. The first 'after' surveys occurred after a traffic control measure in the form of a 50 km/h speed zone was introduced on Clarendon Street

(Figure 1). The last 'after' surveys occurred after a second set of physical countermeasures including a painted strip between tram tracks, coloured crosswalks at signalised intersections and pram crossings were installed on Clarendon Street (Figure 2).

Figure 1: 50 km/h speed limit implemented along the survey site on Clarendon St.

a) **b)**

Figure 2: Physical countermeasures installed on Clarendon Street: a) pram crossings and coloured crosswalks installed at signalised intersections; b) painted strip between tram tracks.

<u>Survey method</u> – Three surveys were conducted at both the treatment and control sites to collect information on travel speeds and travel times through the designated treatment and control strip shopping areas.

Vehicle speeds were collected in two ways. First, using travel time data, average speeds over the entire length of the shopping centre were determined from the distance travelled and the time taken to travel that distance. Second, *free-flowing* vehicle speeds were recorded for all vehicles at two mid-block locations approximately one-third and two-thirds of the way through the study area at each site using laser speed measuring equipment.

Travel times of vehicles were collected at both sites via the origin-destination survey technique. Vehicle number-plates were recorded at both extremes of the study area along with the time they passed. Number-plates and times were matched at both ends of the study area, with the travel time being estimated by calculating the difference between the entry and exit times.

All types of vehicles formed the sample for the data, although travel time data were collected for red and white passenger cars only because it was impractical to sample all vehicles passing the survey points, and red and white passenger cars make up a high proportion of the vehicle population.

RESULTS

The evaluation method involved a quasi-experimental design, that is, using measurements of driver behaviour at a control site as well as a treatment site and adjusting the data for observed driver behaviour in the traffic system. This method was chosen to ensure that any observed effects of treatment implementation on Clarendon Street could be attributed to the treatments themselves rather than other factors. For this type of evaluation to be successful, an appropriate site needs to be selected. Although High Street was chosen as the most suitable site, some problems in the data collection (e.g., congestion due to a tram crash) became apparent during analysis of the data that raised some concerns about the validity of the control analyses. For this reason, the control data were excluded from the overall analysis and the results are presented without adjusting the figures for the control site with the assumption that speed behaviour in the road-traffic system, as a whole, did not change through the study period.

Vehicle Speeds

Average speeds through the study area were calculated for those vehicles passing through the survey site in three minutes or less from travel time data as it was assumed that these vehicles travelled through the survey site, without stopping for reasons other than normal traffic flow interruptions (Table 1).

Table 1: Average speed of vehicles travelling through the survey site before treatments, after first treatment and after all treatments were installed.

Survey Period	Average calculated vehicle speed (km/h)
Before treatments installed	28.30
After FIRST treatment installed (50km/h speed limit)	28.50
After ALL treatments installed (physical measures)	20.80 *

* $p < 0.001$

Before any treatments were installed, the average speeds of vehicles travelling through the survey site was 28.3 km/h. Average speeds remained stable at 28.5 km/h after installation of the 50 km/h speed zone, but a significant reduction of 7.5 km/h to 20.8 km/h after all treatments were installed was found, $F(2,379) = 27.91$, $p < 0.001$. These measurements are coarse indicators of vehicle speeds and do not fully control for the possibility that vehicles had stopped for a short period of time for traffic-related reasons. Nevertheless, they do provide strong evidence of the effect of treatment implementation on overall travel speeds.

Free-flowing vehicle speeds at mid-block locations within the shopping strip were recorded and are presented in Table 2. An overall effect of treatment implementation on measured vehicle speed was found for the combined speed measurement locations, $F(2,8314) = 10.65$, $p < 0.01$. Before treatment implementation, the mean vehicle speed was 44.95 km/h. After installation of the 50 km/h speed limit, vehicle speeds reduced significantly by 0.67 km/h to 44.28 km/h. This trend continued after installation of all treatments, with a further mean reduction in vehicle speed of 0.63 km/h. Overall, a statistically reliable mean reduction of 1.3 km/h was found from before treatment implementation to after all treatments had been installed, $p < 0.001$.

Table 2: Mean *free-flowing* vehicle speeds at mid-block locations within the survey site on Clarendon Street before treatments, after first treatment and after all treatments were installed.

	Mean vehicle speed (km/h) BEFORE treatments installed	Mean vehicle speed (km/h) AFTER FIRST treatment installed	Mean vehicle speed (km/h) AFTER ALL treatments installed
Entry to survey site	41.04	39.98**	39.15***
Exit from survey site	48.50	49.04	46.55**
Combined entry and exit	44.95	44.28*	43.65***

* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

An overall effect of treatment implementation on measured vehicle speeds as vehicles entered the survey site was also found, $F(2,3940) = 10.94$, $p < 0.001$. There was a mean reduction in vehicle speeds of 1.06 km/h between before treatment implementation and after installation of the 50 km/h speed limit, $p < 0.01$, and a mean reduction of 1.89 km/h from before treatment implementation to after all treatments were installed, $p < 0.001$.

The mean reduction in vehicle speed of 0.83 km/h between first and second treatment implementation did not reach significance.

Vehicle speeds as vehicles exited the survey site were markedly higher than as they entered. On average, vehicles travelled approximately 8 km/h faster as they left the shopping precinct, compared to their entry speed. This was not unexpected as vehicles often travel more slowly as they enter shopping areas and increase as they leave. Like for vehicle speeds as vehicles entered the survey site, an overall effect of treatment implementation on measured vehicle speeds was found for vehicles exiting the survey site, $F(2,4371) = 37.38$, $p < 0.001$. Vehicle speeds decreased by 1.95 km/h from before treatment installation to installation of all treatments, $p < 0.01$. Surprisingly, vehicle speeds increased marginally after installation of the 50 km/h speed limit compared to before implementation, but decreased significantly after implementation of other treatments, a mean reduction of 2.49 km/h.

Proportion of vehicles travelling at speeds unsafe for pedestrians

Given the importance not only to reduce average vehicle speeds, but also to reduce the number of vehicles travelling at fast speeds (those most likely to result in a severe injury outcome if a pedestrian collision occurs), the proportions of vehicles travelling at high speeds before and after implementation of treatments were compared. Figure 3 shows the proportion of vehicles travelling at 60 km/h or over, at 50 km/h or over and at 40 km/h or over on Clarendon Street. If it were assumed that these were the speeds at impact with a pedestrian, the corresponding estimates of the probability of death to a pedestrian are 100%, 84% and 26%, respectively (1).

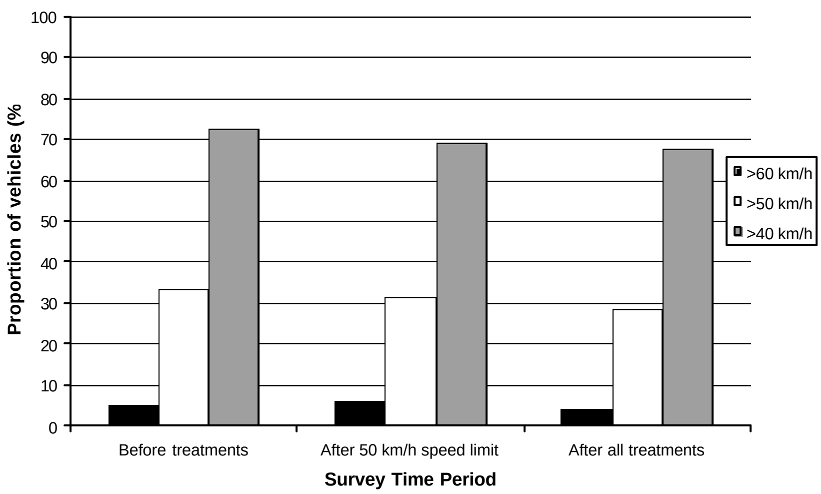

Figure 3: Proportion of vehicles travelling over 60 km/h, over 50 km/h and over 40 km/h on Clarendon Street before treatments, after first treatment and after all treatments were installed.

Only small proportions of vehicles travelled at or over 60 km/h during all survey time periods and little difference was found, however, the proportion did fall from 5 percent before treatment installation to 4 percent after installation of all treatments (i.e., a 20% reduction). For those travelling at or over 50 km/h, the analysis revealed an overall reduction of 4.9 percent from before treatment implementation (33%) to after all treatments were installed (28%), $p < 0.01$, a 15 percent reduction. There was a reduction of 1.7 percent from 33.3 percent before installation of treatments to 31.6 percent after installation of the 50 km/h speed limit, $p < 0.05$. The proportion of vehicles travelling at these speeds was reduced by a further 3.2 percent to 28.4 percent after installation of all treatments, p-values < 0.05. Similar reductions were found for the proportion of vehicles travelling at or over 40 km/h.

Relationship between impact speed and pedestrian death/injury

The severity of a pedestrian crash depends largely on the collision speed of the vehicle, especially in the range of the speeds usual on arterial roads in Melbourne. In order to draw some meaningful conclusions from the findings, reductions in average and *free-flowing* vehicle speeds were related to previous studies that have estimated this relationship. For instance, Anderson et al (1) estimated the likely effect of reduced impact speeds on the incidence of fatal pedestrian crashes and predicted that small reductions in travelling speeds are likely to result in large reductions in injury risk to pedestrians.

Average speeds over the full length of the survey site fell from 28.3 km/h to 20.8 km/h. Table 3 shows the associated reductions in pedestrian fatal and serious injury predicted by the various previous studies (1,2,3).

Table 3: Associated reductions in probability of fatal pedestrian crashes for mean speed reductions on Clarendon Street

	Impact speed of 28.3 km/h	Impact speed of 20.8 km/h	Overall reduction of 7.5 km/h
Probability of fatal pedestrian crashes (%) as predicted by Anderson et al	6.4	4.2	2.2
Probability of fatal pedestrian crashes (%) as predicted by Ashton & Mackay	3.1	0.7	2.4
Probability of fatal pedestrian crashes (%) as predicted by Pasanen & Salmivaara	5.0	2.2	2.8
Probability of serious injury pedestrian crashes (%) as predicted by Pasanen & Salmivaara	20.0	4.6	15.4

The reduction of 7.5 km/h average travel speed is expected to result in a reduction of between 2.2 percent and 2.8 percent in probability of fatal pedestrian crashes and a reduction of 15.4 percent in probability of serious injury pedestrian crashes.

Mean *free-flowing* travel speeds (combined entry and exit speeds) fell from 44.95 km/h to 43.65 km/h, a reduction of 1.3 km/h. Nilsson's (5) speed and safety relationship model was applied to these data and the outcomes of this analysis are summarised in Table 4.

In terms of the relationship between reductions of mean *free-flowing* vehicle speeds and pedestrian injury risk, the following may be predicted. Installation of the 50 km/h speed limit has the potential to reduce fatal pedestrian crashes by 5.8 percent, serious injury crashes by 4.4 percent and casualty crashes by 3 percent. Installation of all treatments has the potential to reduce fatal pedestrian crashes by 11.1 percent, serious casualty crashes by 8.4 percent and casualty crashes by 5.7 percent.

Table 4: Expected reductions in pedestrian crashes on Clarendon Street due to changes in mean *free-flowing* speed measurements (combined entry and exit locations).

	Net reduction in average speed	Expected reduction in pedestrian crashes (%)		
		Fatal	**Serious injury**	**Casualty**
Before vs. after all treatments installed	-1.30 km/h (a 2.9% reduction)	11.1	8.4	5.7
Before vs. after 50 km/h speed limit installed	-0.67 km/h (a 1.5% reduction)	5.8	4.4	3.0
After installation of 50 km/h speed limit vs. after all treatments installed	-0.63 km/h (a 1.4% reduction)	5.6	4.2	2.8

Travel times

Travel times were collected for vehicles passing through the survey site and data were examined for vehicles that took 3 minutes or less to travel through the survey area. On average, vehicles took 1.8 minutes to travel through the survey area before treatments were installed. Travel times remained stable after installation of the 50 km/h speed limit, but increased significantly by 0.6 minutes to 2.41 minutes after installation of all treatments, $p < 0.001$. This analysis shows that increases in travel time, of the order of half a minute, were only apparent when all treatments were installed.

DISCUSSION

It has been argued that an innovative and more comprehensive approach to moderate vehicle speeds in high density pedestrian areas offers an acceptable and potentially cost-effective solution to the pedestrian problem in these areas (4). This evaluation was conducted to evaluate the potential of practical new approaches to moderate vehicle speeds without seriously affecting travel times with the view that the most cost-effective measures may be introduced at other hazardous locations in Victoria's urban areas. This study highlighted a number of important findings for pedestrian safety in strip shopping centres on arterial roads.

Average vehicle speeds calculated from travel time data provided the most encouraging results. It seemed that installation of treatments resulted in sizeable reductions in average vehicle speeds throughout the shopping precinct. These reductions were observed after all treatments were installed, compared to before treatment installation. Further, the reduction of 7.5 km/h was associated with estimated reductions of 2-3 percent in fatal pedestrian crashes and of 15 percent in serious injury crashes.

Mean *free-flowing* vehicle speeds provided further evidence that treatment implementation resulted in reducing vehicle speed on Clarendon Street, particularly as vehicles entered the shopping precinct. The overall reduction of 1.3 km/h was associated with expected risk reductions of 11 percent in fatal, 8 percent in serious injury, and 5 percent in casualty pedestrian crashes.

The finding that proportions of vehicles travelling at speeds threatening to pedestrians decreased as a result of treatment implementation also provided strong evidence of the benefits to pedestrians. While there was only a minor effect of treatment implementation on travel speeds of vehicles travelling at or over 60 km/h, there was a reduction of 15 percent in proportion of vehicles travelling at or above 50 km/h after treatments were installed, compared to before treatment installation. In terms of real numbers of vehicles, this means a reduction from 4 vehicles to 2.5 vehicles every minute, or 240 to 150 vehicles every hour, that travelled through the shopping precinct at speeds which pose a high risk of death or serious injury to a pedestrian if struck.

Interestingly, there was only a marginal change in speed behaviour after installation of the 50 km/h speed zone, however, larger reductions in average and smaller but significant reductions in *free-flowing* speeds within the shopping precinct were found as a result of installation of all treatments were found. It should be noted that this treatment was introduced without any change in Police enforcement or site-specific publicity and if the general awareness of the change in speed limit was raised, stronger effects of this treatment on vehicle speeds may have been found. Nevertheless, the finding seems to provide some support to the suggestion that traditional countermeasures by themselves have limited success in reducing pedestrian casualty rates in strip shopping areas. An innovative approach that combines a range of countermeasure applications may be more successful in moderating vehicle speeds in areas of high pedestrian activity.

While travel time increased marginally, considering the large expected reductions in the injury risk for pedestrians, it would seem that the benefits far outweigh the minor cost of just over half a minute to motorists. An increase of this size would not greatly affect traffic flow for motorists, or indeed, be noticed by them.

It should also be noted that, although the treatments evaluated in this study were not particularly aggressive and that treatment costs were relatively low, significant reductions in vehicle speeds were still found. Any installation of more aggressive countermeasures supported by Police enforcement and publicity, could be expected to result in larger reductions and, therefore, provide even greater safety benefits for pedestrians.

CONCLUSIONS

This evaluation demonstrated that small gains in speed reduction can lead to very valuable reductions in the risks of road trauma for pedestrians in environments where there is high pedestrian and vehicle activity. Innovative countermeasures, such as those evaluated here, provide a cost effective approach to moderate vehicle speeds, resulting in general benefit to all road users, and especially pedestrians. Considering the high safety effects possible for pedestrians for relatively small changes in speed and travel times, this is a potentially important area of countermeasure development to pursue.

REFERENCES

1. Anderson, R., McLean, A., Farmer, M., Lee, B., & Brooks, C. (1997). Vehicle travel speeds and the incidence of fatal pedestrian crashes. Accident Analysis and Prevention, 29(5), 667-674.
2. Ashton, S., & Mackay, G. (1979). Some characteristics of the population who suffer trauma as pedestrians when hit by cars and some resulting implications. IRCOBI: Biomechanics of Trauma, 4th International Conference Papers, 39-48.
3. Pasanen, E., & Salmivaara, H. (1993). Driving speeds and pedestrian safety in the City of Helsinki. Traffic Engineering and Control, 1993, 308-310.
4. Corben, B., & Duarte, A. (2000). Injury reduction measures in areas hazardous to pedestrians. Stage 1: Countermeasure options. (Report 169). Monash University Accident Research Centre, Melbourne.
5. Nilsson, G. (1984). Speed, accident rates and personal injury consequences for different road types (Hastigheter, olycksrisker och personskadekonsekvenser i olika vagmiljoer, In Swedish with summary in English). VTI Rapport 277, Lidköping.

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