Modifications to Traffic Signal Operation to Improve Safety for Alcohol-affected Pedestrians

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Alcohol-affected pedestrians are among the highest-risk groups involved in pedestrian casualty crashes. A range of treatments and programs have been implemented to increase safety for intoxicated pedestrians, with limited widespread success, including pedestrian fencing, alcohol accords, responsible serving of alcohol course, and the use of designated drivers. This paper investigates the opportunities to use a modified form of traffic signal operation during high-risk periods and at high-risk locations to reduce alcohol-affected pedestrian crashes and the severity of injuries that might otherwise occur. The 'Dwell-on-Red' treatment involves displaying red to all vehicle directions during periods when no vehicular traffic was detected by the signals, so that drivers approach high-risk intersections at a lower speed than if a green signal were displayed as they approached. Once detected, drivers would receive a green signal in the normal way, and when vehicle demand has ceased, the signals would revert to red in all directions. This paper presents the preliminary outcomes from an evaluation of this candidate treatment in Ballarat. These preliminary analyses show that the treatment led to significant reductions in vehicle speed. Further analyses will explore the effect of the treatment on the proportion of vehicles travelling at threatening speeds for pedestrian crash and injury risk.

BACKGROUND

Intoxicated pedestrians in 2002 made up approximately 15% of the Victorian road toll with over 30% of pedestrians killed having a BAC level above 0.05% and a majority more than three times the legal limit for driving. The reductions of speed past areas where intoxicated pedestrians may be present are important if we are to further reduce the road toll in this area, as speed is directly related to the severity of injury in all crashes. A range of programs to reduce speed have been introduced in Victoria, including a default 50 km/h limit in built-up areas, a time-based 40 km/h limit in selected strip shopping centres, a 50 km/h limit in selected country town main streets and school speed zones.

In an earlier study by Monash University Accident Research Centre, a number of possible countermeasures were identified, among them the idea of displaying red to all vehicle directions during periods when no vehicular traffic is being detected by the signals, so that drivers approach high-risk intersections at a lower speed than if a green signal were displayed as they approached (Corben, Diamantopoulou, Mullan, & Manika, 1996). There is some evidence that modifications to traffic signal operation reduce the risk of crashes involving pedestrians and bicyclists (Retting, Chapline, & Williams, 2002), however the benefits to intoxicated pedestrians require further evaluation.

The aim of this project was to trial the introduction of a 'Dwell-on-Red' phase for traffic signals at a selected location where there is evidence of crashes involving pedestrians during high alcohol times.

The reprogramming of the rest phase to show red in all directions when there is no demand from vehicles (which would typically operate in the early hours of the morning) would require vehicles to slow down and stop when approaching traffic lights, until the vehicle is detected and the lights change to green for their direction of travel. The change in behaviour to comply with the red signal should improve the driver's awareness of pedestrians on approach to intersections in the vicinity of licensed venues, and reduce the speed of approach to levels whereby the crash and injury risks for pedestrians are significantly reduced.

METHODOLOGICAL ISSUES

Dwell-on-Red Operation

An important issue to specify at the outset was the times of day and hours of the day that the Dwell-on-Red treatment could become active. Only 5% of pedestrians involved in crashes have the Blood Alcohol Concentration (BAC) recorded, therefore BAC cannot be relied upon for an accurate measure of alcohol-related pedestrian crashes. As a result a surrogate measure of the alcohol-involvement in crashes, known as 'high alcohol hours', was used to identify alcohol-related crashes. High alcohol hours are defined to be those time-periods when the proportion of known drivers or riders killed or seriously injured was greater than 15% (Jacques & Corben, 2003).

The first report as part of this project identified: the high alcohol hours of each day; the spatial clustering of pedestrian crashes for metropolitan Melbourne and country Victoria during the high alcohol hours; and nine prospective sites for the Dwell-on-Red project in metropolitan Melbourne and nine prospective sites in country Victoria, which provided re-programmable traffic signals (Jacques & Corben, 2003).

For Melbourne, research by Shtifelman, Cameron, and Diamantopoulou (1998) defined 96 hours of the week (57% of the week) as high alcohol times. Drivers killed or seriously injured during high alcohol times were nearly seven times more likely to have BAC readings over 0.05g/100ml in both Melbourne and country Victoria. Using the time of day/day of week tabulation and the 15% criterion for the proportion of drivers or riders with a BAC over 0.05g/100ml, the high alcohol times reported are:

- Sunday 4pm – Monday 6am
- Monday 6pm – Tuesday 6am
- Tuesday 6pm – Wednesday 6am
- Wednesday 6pm – Thursday 6am
- Thursday 6pm – Friday 6am
- Friday 4pm – Saturday 8am
- Saturday 4pm – Sunday 10am

These high alcohol hours can also be indicative of pedestrian drinking behaviour as the general consumption of alcohol is high during these times. Further, about half of pedestrian casualty crashes between 6 pm and 6 am are alcohol-related (Corben et al., 1996). While the proportion of alcohol-related crashes (compared to non-alcohol crashes) is greater on Friday to Sunday, it was recommended that data be collected for each day of the week.

Ballarat was one of the regional sites identified by MUARC to have a high number of police-reported casualty crashes that occurred during the defined high alcohol hours. It was decided by VicRoads, the project sponsor, to conduct the Dwell-on-Red pilot study in Ballarat. After consultation with MUARC it was determined that the Sturt St/Doveton St and Sturt St/Lydiard St intersections would be the control and treatment sites respectively (speed limit 50 km/h). With vehicle speed data only being collected for traffic movements in an easterly direction, the result was that drivers would pass through the control site before the treatment site. This is a more scientifically robust approach because behaviour at the control site is not influenced by prior exposure to the treatment.

Components of the study design

An earlier part of this project involved undertaking a targeted review of the scientific literature to assist with the selection of appropriate dependent variables for the Dwell-on-Red evaluation study (Lenné, Mulvihill, & Corben, 2004). This report also reviewed literature demonstrating the importance of a number of fundamental design issues, including the use of before-after data collection designs and the use of control sites. The use of a control site helps to ensure that observed effects are attributable to the treatment rather than other extraneous influences. The essence of designing this type of evaluation is to increase the likelihood that the measured effects are valid and can be attributed to the treatment rather than the effect of any other factors.

In terms of measuring pedestrian safety, vehicle speed is the most critical factor, and the link between travel speed and crash risk, and impact speed and injury severity, for pedestrians is well documented (Anderson, McLean, Farmer, Lee, & Brooks, 1997; Nilsson, 1984). The aim of the Dwell-on-Red treatment is to reduce vehicle speeds, and thus this variable was incorporated in the study design. In accordance with methodologies adopted in previous research conducted by MUARC, the data were expressed as mean speeds at both locations, and also as a proportion of vehicles travelling at threatening speeds near the crossing. Reductions in any one of these measures can reasonably be expected to lead to reduced crash and injury risk at the treatment site. In particular, reductions in average vehicle speeds should have a significant impact on road safety in terms of the number of injury crashes, severe injury crashes and fatal crashes. Only changes to mean vehicle speeds are reported in this paper.

The literature reviewed indicated that free vehicle speed should be measured at 30-40 m on approach to the intersection and close to the stop-line. This approach allows for estimations of the effect of Dwell-on-Red operation on vehicle speeds on approach to the crossing and in the immediate pedestrian impact zone. Speeds observed at these distances are also indicative of the crash risk and injury severity to pedestrians, respectively.

Driver exposure to the Dwell-on-Red operation was also measured, and can primarily be estimated through two measures, being frequency and duration of operation. The frequency of all-red operation was measured as the number of times the all-red mode was activated by hour, and the mean activation duration by hour.

In summary, key elements of the methodology were that:

- data were collected at two time points, before and after the activation of the treatment;
- data were collected at both a treatment and control site, to account for any non-treatment factors that might also influence vehicle speed;

- data were collected within the estimated high alcohol hours for pedestrians, being 22:00 hrs to 05:00 hrs. These times were chosen after an analysis of traffic volume data at the sites and an estimation of the likelihood that the treatment phase would be activated;
- data were collected seven days per week; and
- data were collected at two points, 30 metres on approach and at the stop-line at the control and treatment sites, to reflect crash and injury risk to pedestrians.

RESULTS

The analyses reported here address the issue of whether speed differed between the control and treatment sites, whether speed differed between the before and after periods, and whether there was an interaction between the two factors. It is worth reinforcing here that the control site had normal signal operations throughout the entire trial. While the treatment site had normal signal operations during the before data collection period, the Dwell-on-Red mode was activated for a ‘settling in’ period and for the duration of the after data collection. The minimum activation duration for the all-red mode was 15 seconds.

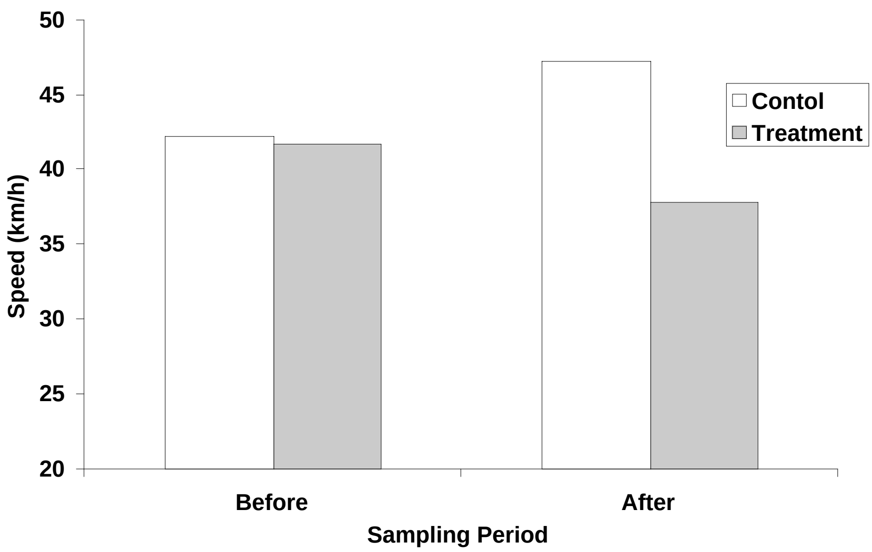

Figure 1. Mean speed 30 metres on aproach to the intersection

Figure 1 presents data collected 30 metres on approach to the control and treatment intersections, and shows little difference between sites in the before period, but for the after period speed was lower at the treatment site. The Analysis of Variance conducted for data collected at the 30 metre collection point confirmed that there was an interaction between the two factors, condition (treatment, control) and sampling period ($F(1,41170) = 373.9$, $p < 0.001$). Post-hoc analyses confirmed that this interaction is driven by the large difference in mean speed in the after period between the control (47.3 km/h) and treatment (37.8 km/h) sites. Mean speed was 3.9 km/h lower at the treatment site in the after period, when Dwell-on-Red was activated, compared to the before period.

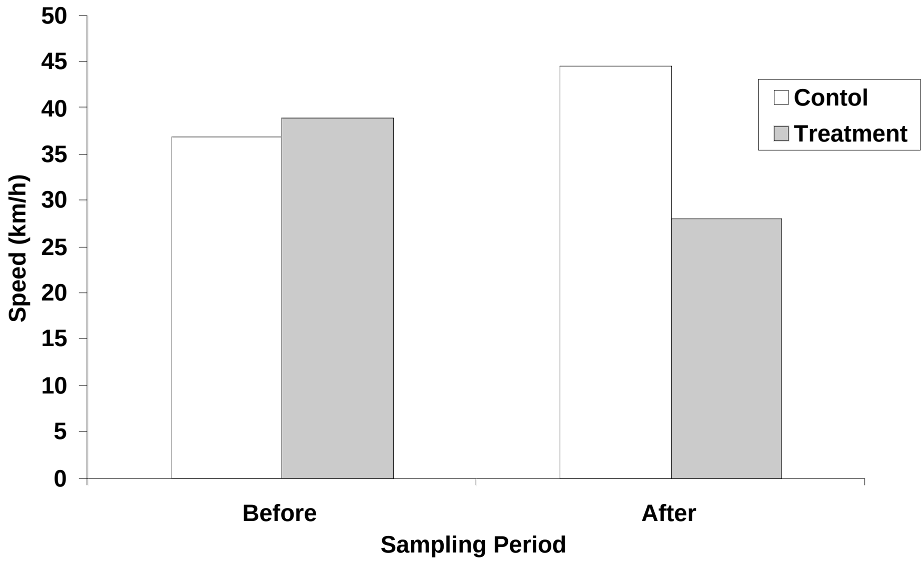

Figure 2. Mean speed at the stop-line.

Figure 2 presents data collected at the intersection stop-line for the control and treatment site. Similar to the results for the 30 metre point, there appears to be little difference between sites in the before period, but for the after period speed was lower at the treatment site. The Analysis of Variance for data collected at the stop-line confirmed that there was an interaction between the two factors, condition (treatment, control) and sampling period ($F(1,46582) = 1086.8$, $p < 0.001$). Post-hoc tests again confirmed that this interaction was driven by the large difference in mean speed for the control and treatment sites in the after period (44.6 km/h & 28.1 km/h respectively). Mean speed was 11 km/h lower at the treatment site in the after period, when Dwell-on-Red was activated, compared to the before period.

The data presented in Figures 1 and 2 show that mean speed for the treatment site dropped in the after period at both the 30 metre and stop-line points. Surprisingly, mean speed for the control site increased in the after period at both collection points. Subsequent analyses will determine the precise magnitude of the treatment effect accounting for the changes in the speed at the control site.

Table 1 shows the number of Dwell-on-Red activations that occurred across each hour of the period of Dwell-on-Red operation, as well as the mean duration per activation. These data clearly show that the frequency of operation was higher, and the mean activation duration lower, for those times of day with the higher traffic volumes, namely 22:00 hrs to 01:00 hrs. The influence of these factors on vehicle speed is being considered in further analyses.

Table 1. Dwell-on-Red Activation by time of day

Time of Day	Activations per Hour	Mean activation duration	Traffic Counts
22:00 - 22:59	71	14.9	2769
23:00 - 23:59	72	17.8	1830
00:00 - 00:59	60	22.0	1075
1:00 - 1:59	49	36.8	622
2:00 - 2:59	42	56.3	330
3:00 - 3:59	44	58.2	263
4:00 - 4:59	41	63.5	232

DISCUSSION

This paper reports on the preliminary analyses from the evaluation of the Dwell-on-Red countermeasure for intoxicated pedestrians. While subsequent analyses will be conducted, the results reported show a clear reduction in vehicle speed at the times at which the Dwell-on-Red treatment was operational.

Vehicle speed was chosen as the measure most indicative of pedestrian safety. The reason for this is because speed is a fundamental determinant of crash and injury risk. The faster the travel speed, the more rapidly information from the traffic environment must be processed. For example, driving at 70 km/h requires processing of information at a rate 40% greater than at 50 km/h. When the information processing demands in any given driving situation approach the limits of an individual's capacity, the potential for a crash rises substantially.

Further, the faster one drives, the less control one has over the vehicle and the greater is the distance required to stop. Stopping distances are comprised of two parts, the reaction distance and the braking distance. The reaction distance is the distance travelled by the vehicle from the moment there is a need to brake to the moment when braking commences, and is linearly related to speed. The braking distance is the distance travelled from the moment braking commences to the moment when the vehicle stops, and is related to the square of the speed. These facts help to explain the powerful relationship that exists between speed and crash risk. For example, assuming typical driver reaction times and typical dry road friction values, a car travelling at 40 km/h instead of 50 km/h can stop in a distance that is around 10 metres shorter. Such distances can be vital in situations of crash avoidance.

Of even greater importance are the relationships between speed and injury risk in the event of a crash. According to these relationships, the outcome of a change in mean speed may be described in terms of power functions, with the size of the power increasing as crash severity increases. Research has shown that travel speed and fatal injury risk are related through a fourth power relationship, serious casualty crashes through a third power relationship and casualty crashes through a second power (or squared) relationship (Nilsson 1984). According to Nilsson's laws, travelling at 50 km/h instead of 40 km/h results in an approximate 2-to-3 fold increase in the risk of fatal crashes of all types. In many common crash types, the speed at impact is well within the speed limit but beyond the biomechanical tolerances of humans and the capacity of vehicles to protect their occupants. On the basis of the laws of motion and the findings of research on speed, it can be concluded that even small reductions in travel speed or of impact speed will lead to substantial reductions in crash and injury risk. Subsequent analyses in this Dwell-on-Red study will examine the proportion of vehicles travelling at threatening speeds near the crossing. Reductions in any one of these measures can reasonably be expected to lead to reduced crash and injury risk at the treatment site. For pedestrian crashes there is evidence that the risk of death to a pedestrian rises rapidly at impact speeds above 30 km/h (Anderson et al., 1997). To illustrate, the probability of pedestrian fatality increases from about 25% at an impact speed of 40 km/h to between 80-90% at an impact speed of 50 km/h.

In conclusion, alcohol-affected pedestrians are among the highest-risk groups involved in pedestrian casualty crashes. A range of treatments and programs have been implemented to increase safety for intoxicated pedestrians, with limited widespread success, including pedestrian fencing, alcohol accords, responsible serving of alcohol course, and the use of designated drivers. The preliminary results reported here show that the Dwell-on-Red modification to traffic signal operation in Ballarat significantly reduced vehicle speeds within the assumed high alcohol hours for pedestrians.

Further research should explore the potential safety benefits that could be gained through the application of this treatment to other regional and metropolitan locations, while longer-term evaluations should examine the effects of pedestrian crash rates over time. Many other road safety concerns may also benefit from this form of traffic signal modification, and it is recommended that other areas of application be explored.

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REFERENCES

Anderson, R. W., McLean, A. J., Farmer, M. J., Lee, B. H., & Brooks, C. G. (1997). Vehicle travel speeds and the incidence of fatal pedestrian crashes. *Accident Analysis & Prevention, 29*, 667-674.

Corben, B., Diamantopoulou, K., Mullan, N & Manika, B, (1996). *Environmental Countermeasures for Alcohol-Related Pedestrian Crashes. Report No. 101*. Monash University Accident Research Centre.

Jacques, N., & Corben, C. (2003). Dwell on Red intoxicated pedestrian project: Site identification research. Contract report prepared the Monash University Accident Research Centre for VicRoads.

Lenné, M., Mulvihill, C., & Corben. B. (2004). Dwell on Red intoxicated pedestrian project: Targeted literature review to inform study design. Contract report prepared the Monash University Accident Research Centre for VicRoads.

Nilsson, G. (1984). *Speed, accident rates and personal injury consequences for different road types (In Swedish with summary in English)*. Linkoping: VTI.

Retting, R. A., Chapline, J. F., & Williams, A. F. (2002). Changes in crash risk following re-timing of traffic signal change intervals. *Accident Analysis & Prevention, 34*(2), 215-220.

Shtifelman, M., Cameron, M., & Diamantopoulou, K. (1998). *"Update of alcohol times as a surrogate measure of alcohol-involvement in accidents in Melbourne and country Victoria during 1990-1997"*. Research Note. Monash University Accident Research Centre.