TECHNOLOGY TO ENHANCE SPEED LIMIT COMPLIANCE

By Corben B., Lenné M., Regan M. and Triggs T.
Accident Research Centre, Monash University

Abstract
The role of speed in crash and injury risk is well established in road-transport system safety. This paper reviews the technologies available world-wide to enhance speed limit compliance. Speed indicator displays are a promising technology to reduce vehicle speeds, and have been shown to reduce average vehicle speeds in European trials. The benefit-cost ratios for using speed indicator displays in Victoria were calculated for a range of common scenarios in Victoria. These calculations show that very attractive benefit-cost ratios can be realised from reductions in vehicle speeds, through the use of speed indicator displays in such circumstances.

INTRODUCTION

Intelligent Transport System technologies are rapidly being introduced in Australia and overseas. Research being conducted at the Monash University Accident Research Centre (MUARC) for the Transport Accident Commission suggests that a wide range of IT systems will be available in locally-manufactured vehicles within the next three years. These include navigational displays, advanced telematic systems (e.g., trauma notification with known location), adaptive cruise control for limiting speed and headway distance, and collision warning systems. In addition, a wide range of out-of-vehicle technologies are already being introduced (e.g., advanced traveller information systems, advanced traffic management systems, etc.) and are about to be deployed. The use and further development of new technologies is going to result in significant benefits to road safety (1).

Two specific situations for which new technologies might be beneficial are speed compliance and stop signal compliance. Although the original study (2), addressed both situations, this paper focuses primarily on speed compliance. Excessive speed is currently one of the major contributors to road trauma in Victoria. While countermeasures such as speed cameras and improved traffic engineering are having a positive effect in reducing the role of excessive speed, it is likely that the development of new technologies to further enhance speed compliance will have significant road safety benefits.

Speed is an important contributor to crash *causation* (i.e., reported to be a contributing factor in around 20% of all fatal or injury-producing crashes (3). Thus, 80% of fatal or injury-producing crashes occur when “speeding” is **not** regarded as the cause of the crash. But, speed is **the critical factor** in *injury severity* (i.e., in 100% of fatal or serious injury crashes). That is, when a crash *does* occur, people are killed or seriously injured only when the impact speed (and hence the energy absorbed by the human) exceeds the human tolerance to violent forces.

Research conducted by Nilsson (4) and others shows that the increase in the risk of death when a crash occurs is related to impact speed by power functions. The size of the power relationship rises with crash severity. For fatalities, an increase in impact speed has a power function of approximately four while for serious injuries the power is about three. These relationships help to explain why small reductions in travel speed (of only 4-5 km/h) can result in very substantial reductions in the risk of death or serious injury. For example, a reduction in average speed of 5 km/h in a 100 km/h speed zone is predicted to result in reductions in fatal crashes by 18%, serious injury crashes by 14%, and minor injury crashes by 10%. The reductions are, of course, greater for a 10 km/h reduction in average speed in a 100 km/h zone: 34% for fatal crashes, 27% for serious injury crashes, and 19% for minor injury crashes. Clearly, the relationship between speed and injury severity is a powerful one. Therefore, it is essential that speed be addressed as a determinant of injury severity when a crash does occur.

The purpose of this project was to assess the potential of new technologies related to speed limit (and stop signal compliance), and to put forward a brief protocol for evaluating, trialling, and implementing promising new technologies.

STUDY APPROACH

Relevant literature was reviewed, and a strategy for VicRoads to further evaluate, trial and/or implement new technologies was developed. A number of reports have been published recently, both by MUARC and by other research organisations and individuals in the field of ITS and technologies which can be used to augment enforcement of traffic laws (1, 5). Collectively, these reports contain some relevant information about the safety potential of new technologies related to speed limit compliance.

ITS TECHNOLOGIES FOR ENHANCING SPEED COMPLIANCE

There are a number of out-of-vehicle and in-vehicle technologies with the potential to enhance speed compliance. This report focuses on the out-of-vehicle approaches. Traditional speed limit and warning signs tend to be static, which can reduce their impact on road users. Dynamic messaging, in the form of speed warning signs, variable message signs, or a combination of the two, is more vehicle-specific and so has the potential to have a much greater effect on the driver (6). Two such dynamic displays are active speed warning signs and variable message signs, which are discussed below.

Active speed warning signs

Research on speed warning signs has progressed significantly from static speed limit signs. Advisory speed signs that display the speed of individual vehicles have been developed. Speed warning signs have also been used in a traffic management sense with the aim of enhancing traffic flow and reducing road trauma by having variable speed limits within sections of freeway. These two applications will be discussed in turn.

Displaying the vehicle speed

Active speed warning signs are predominantly used to make the driver aware of his/her own speed as a means of reinforcing the speed limit. Speed Indicator Displays (SIDs) can record the number and speed of vehicles, as well as vehicle headways for analysis, and data can be retrieved remotely. While mostly used to display drivers' speeds, permanently mounted SIDs have also been used to display mandatory speed limits up to 90 km/h.

SIDs are primarily used in permanently mounted positions. Detector loops are embedded in the roadway 70 metres before the SID. This provides a firm distance from which to calculate the leeway time, which is the time between detection of the vehicle on the detector loops and when the vehicle passes the SID. Unlike radar technology, the detector loops will only detect each vehicle once and so is more suited to displaying the speed for individual vehicles. More portable trailer-mounted SIDs can also be deployed for temporary use such as during periods of road works, although use of radars rather than embedded detection loops is recommended for ease of temporary installation (7).

Olsen (7) discusses the effectiveness of active speed warning signs based upon previous studies and trials. Olsen reviews studies conducted by the Danish Traffic Authorities, the Institute of Transport Economics in Norway, and the Touring Club of Switzerland, providing the following results when SIDs were installed:

?? Average speed of cars was reduced by 4-8 km/h

?? Average speed of heavy traffic was reduced by 11 km/h, and

?? Average speed of oncoming traffic where no sign was installed fell by 3-5 km/h.

While the speed zones for these studies are not apparent, reduction in mean vehicle speeds of 5 to 10 km/h could be expected to result in dramatic reductions to serious and minor road trauma. These benefits are usually expected to be observed after the SIDs have been installed for one week (7). Trials conducted in Denmark suggested that SIDs reduced average speed by 3 km/h and nearly halved the number of motorists travelling at excessive speeds. Fifty-two SIDs are now installed in Vejle County Council in Denmark.

Displaying variable speed limits

A study was recently conducted in France to assess the effects of variable speed limits on motorways (8). This study had four aims; to delay motorway widening; to improve safety and convenience; to test a new type of variable message annunciator panel; and to reduce pollution factors. While the variable message panels have the capacity to display emergency messages, only the speed displays were evaluated in this study.

As described by Lassauce (8), speed limits were displayed on a variable message panel installed in the median strip at a height of 3.5 metres. A display diagram of 1.5 by 1.5 metres was used. Sensors embedded in the road transmit information regarding the number of vehicles on the road, their average speed over a one minute period, and the gap between vehicles, to the local monitoring stations located at the roadside. Data are then transmitted to a central control unit.

Every minute the local monitoring station collates data on traffic flow, average speeds, and vehicle interval, and every six minutes determines whether or not a speed limit should be displayed. The central control unit assimilates data from the local monitoring units and a speed limit is introduced when there are at least three positive local responses. The speed displayed is determined by the central control unit.

The French trial comprised 11 local stations along a 12 km stretch of motorway. Media campaigns advised drivers of new variable speed limits. While survey results indicated improved traffic conditions with the variable speed limits, the speed signs themselves also seemed to be effective. Almost all of the sample (98% of 350) indicated that the signs were easy to read, and 59% indicated that speeds displayed were appropriate. Throughout the trial there was a rise in the percent of traffic flow in excess of 3,000 vehicles/hour. There was also a reduction in speeds between 90-110 km/h, an increase in speeds between 70-90 km/h, and a reduction in speeds below 50 km/h suggesting less traffic congestion. The variable speed signs used in this study, while not rigorously evaluated, suggest improved traffic flow, speed of travel, and safety (8).

Variable speed limits have also been trialled in the United Kingdom (9). Originally the speed limit was calculated using speed and flow threshold algorithms. At the time of publication more sophisticated algorithms involving queue prediction and lane-by-lane speed limits were being evaluated. A Dynamic Traffic Speed Management (DTSM) algorithm has been developed, and field trials and driver surveys were proposed (9). The DTSM algorithm can dynamically adjust the speed displayed by taking into account the downstream traffic, the prevailing traffic flow and speed, and in consideration of the downstream traffic conditions, the degree of traffic congestion. The system is similar to that trialled in France in that is comprises of vehicle detectors in the road, variable speed limit signs, a local (out-station) control unit, and a central control centre. It is hoped that the results of the field trials (if completed) will be available shortly.

Variable message signs

Variable Message Signs (VMS) represent an extension from the active speed warning signs in that they can display a short text message alone or in combination with other symbols, such as speed signs. VMS need to provide drivers with enough information to make decisions, and the length of the message displayed is affected by the limited reading time available to drivers. This technology can be used for general information messages, advisory messages, and advance messages. In considering where to position VMS on the road, it is important to strive for maximum exposure to motorists and minimum impact on the environment. As discussed by Goudens (10), to be effective VMS must:

?? Attract the motorist's attention,

?? Be legible and provide sufficient legibility to be read by drivers at the relevant speeds,

?? Cause minimal visual discomfort to the driver, and

?? Be effective under a variety of lighting conditions.

While fibre-optic signs performed better than LED signs in most conditions, both sign types are recommended for freeway use.

While not thoroughly evaluated, this technology is likely to have significant implications for well-designed road systems. Specifically with regard to speed compliance, VMS could be used to reinforce mandatory speed limits or advise of reduced speed limits due to road works or an accident ahead. VMS can also act as speed warning signs to advise speeding drivers of their speed. While some of these technologies are already in use in Victoria, the further use and development of height detectors and speed sensors, in combination with VMS, is likely to enhance the level of information to drivers about weather conditions and possible hazards ahead, which will flow on to have positive effects for road safety.

Systems have also specifically been developed for trucks, namely, the Downhill Truck Speed Advisory Systems (10). As a truck approaches a steep decent, the individual truck weight and configuration is computed via sensors embedded in the road, and the maximum safe decent speed for that truck is calculated. A VMS can then be used to display safe decent speeds for individual trucks.

The content, presentation, and location of signs have important consequences for the effectiveness of VMS and speed displays (11). Some research has indicated that drivers pay more attention to fibre-optic VMS signs than fixed road signs, and have better recall of content contained on fibre-optic signs (12). Furthermore, the placement of VMS signs, after a fixed sign, has been found to result in better recall (of the speed limit on the fixed sign) than if the VMS appears before the fixed sign. So while VMS have potential road safety benefits, there are human factors and engineering issues that should be addressed.

New technologies in this area have very recently been piloted within Australia. Dudgeon (13) described the use of the German LAVEG laser speed detection unit in conjunction with a VMS. If a car was travelling below the speed limit, the vehicle speed was displayed in green. If travelling on the speed limit, the display colour was yellow, and if travelling above the speed limit, the display was red. This was accompanied with a short message such as “slow down”. It is hoped that the outcomes of this trial will be available shortly.

Speed Cameras

Speed cameras have been used in countries such as the USA, UK, Norway, Australia, and New Zealand since the early 1990s as an effective means of speed compliance and enforcement (14-17). A recent evaluation in Norway reported that the use of speed cameras had a cost benefit ratio of 7.95, indicating that the costs associated with operating the speed camera program were far outweighed by the benefits from the reduced number of crashes (18). Hidden speed cameras, as opposed to visible cameras, have been found to be even more effective in reducing speed, accidents and casualties (19).

Recent developments in the use of speed cameras include new digital cameras (20). These cameras, which have recently been introduced in Victoria, can image at four frames per second or better, with high resolution images able to be sent from the field for rapid processing and issuing of infringement notices.

Summary

Recent technology developments to enhance speed compliance show potential for improving road safety. While both active speed warning signs and message systems are being trialled independently, a more promising approach involves a combination of both technologies. That is, displaying either the speed limit or drivers’ actual speeds in combination with a symbol or short text message.

As previously discussed, VMS are being trialled as a means of reinforcing speed limits, by displaying either the mandatory speed or drivers’ actual speeds. The next step might be to incorporate VMS with speed enforcement approaches. A speed camera could perhaps transmit drivers’ actual speeds to a local control unit which, in turn, could display a message to speeding drivers on a VMS. Such a message could incorporate the driver’s actual speed, the speed limit, and perhaps even a comment regarding a speeding fine. For example, the message on the VMS might be “Your speed = 120 km/h, Speed Limit = 100 km/h, Your fine = $165”. This type of message may also influence surrounding road users to reduce their speed.

RECOMMENDATION

There are few field-tested new technologies that could be used to improve driver compliance with speed limits in Victoria. In light of this lack of available technologies, the recommendation of this study was that “*… trials be conducted to evaluate the effectiveness of new speed compliance technologies*”.

There is a clear need to conduct trials to evaluate the effectiveness of new speed compliance technologies. These trials should be conducted at appropriate road segments and/or intersections. Research efforts should initially focus on technologies having the most potential in terms of road safety benefits in Victoria.

In regard to speed compliance, as the combination of VMS and active speed warning signs appears to be the most promising approach, research efforts to enhance speed compliance should focus on this combination of technologies. This includes displaying the speed limit and/or the driver’s actual speed in combination with a symbol or short text message. Further research could perhaps take the next step and incorporate VMS with speed enforcement approaches. For example, speed cameras could be used in conjunction with VMS and active speed warning signs. The message displayed to the driver could be of a type noted above.

PROPOSAL FOR THE INSTALLATION OF SPEED INDICATOR DISPLAYS TO REDUCE CRASH OCCURRENCE AND INJURY SEVERITY

This section presents estimates of the effects of installing SIDs in a range of cases in Victoria and assumes speed reductions of around 4 km/h. While the estimates which follow are illustrative in nature and tend to be conservative in terms of their road safety benefits, they are, of course, subject to revision if technology cost estimates vary substantially from those used in the analysis presented here.

SIDs have been found to reduce average speeds in Europe by 4-8 km/h, which translates to significant reductions in crash severity. The illustrative approach presented here for the installation of SIDs in Victoria could be expanded to include higher speed environments than addressed here (e.g., 110 or 100 km/h zones).

SIDs are likely to be effective in modifying vehicle speeds, and thereby reducing crash severity, in busy stretches of road that incorporate signalised intersections. To estimate their effectiveness in this context, and to achieve the maximum degree of experimental control, it is proposed that SIDs be installed along several kilometres of a specific stretch of road. By placing SIDs between and/or in the vicinity of intersections along a route, the effects of SIDs on speeds and, hence, on crash occurrence and severity can be examined for each intersection and also across the entire route. It would also be possible to determine the effectiveness of several types of short message that can be displayed in conjunction with the local speed limit. The analyses would incorporate variables pertaining to the types of crash, road users and vehicles involved.

A number of possible sites in Victoria were considered for a trial: Case 1 involved a National Highway, on the outskirts of the Melbourne Metropolitan area, Case 2, a State Highway passing through a township in regional Victoria and Case 3, a State Highway passing through a large provincial city. Baseline crash data for these sites were used to predict reductions in crash severity that will result from reduced vehicle speeds.

The possible Benefit to Cost Ratios (BCRs) associated with the use of SIDs in these three cases were calculated to illustrate the possible benefits of this form of technology. For Case 1, the calculations are based on the assumption that vehicles travelling at 90 km/h in an 80 km/h speed zone would be the targeted using the SIDs. For Cases 2 and 3, it is assumed that vehicles travelling 70 km/h in a 60 km/h zone would be targeted using the SIDs. In Europe the reductions in average vehicle speed associated with the use of SIDs are between 4 and 8 km/h. This paper presents the results for the more conservative scenario (i.e., 4 km/h).

The costs of fatal, serious injury and other injury crashes used in the evaluation were those adopted by Austroads, namely, $1,110,000, $269,000 and $21,000, respectively, for 80 km/h speed zones, and $981,000, $201,000 and $22,500, respectively, for 60 km/h speed zones. Predicted reductions in fatal, serious injury and other crashes were estimated from the relationships developed by Nilsson (4), while estimates of capital and recurrent costs of the SIDs were made in consultation with VicRoads. Estimates of costs are indicative only and would need to be refined if the devices are to be implemented and evaluated in the field.

Using actual reported casualty crash histories over five years from 1996 to 2000, for each of three scenarios examined, the estimated present values of the social benefits (over the life of the project, assumed to be ten years) ranged from $0.4 million to $7.5 million. The estimated present values of the costs ranged from $0.2 million to $0.6 million. These estimates produced BCRs of 12.2 for Case 1 and 3.5 for Cases 2 and 3.

These calculations clearly illustrate the substantial benefits associated with the use of SIDs in all three cases. Due to the strong relationship between speed and crash severity, the benefits are substantially greater assuming an 8 km/h reduction (2). The benefits are also considerably greater for Case 1, by virtue of the fact that a much higher number of crashes have occurred at this site. The potential benefits from SIDs were also calculated using the crash cost estimates proposed by the BTE (21). The resultant BCRs for 4 km/h speed reductions were 45.6 (Case 1), 7.9 (for Case 2), and 7.7 (Case 3). If the 8 km/h reduction is assumed, the BCR values approximately double.

CONCLUSION

The role of speed in crash and injury risk is well established in road-transport system safety. This review of technologies available worldwide to enhance speed limit compliance found that speed indicator displays are a promising technology to reduce vehicle speeds. Benefit to Cost Ratios for speed indicator displays in Victoria were estimated for a range of common scenarios. Using conservative assumptions for the cost of casualty crashes and the likely effect of SIDs on driver speeds, BCR estimates ranged from 3.5 to 12.2 for the circumstances examined. BCR estimates are many times larger if less consertive assumptions are used.

Acknowledgments
The authors wish to acknowledge the important contributions of Nick Szwed, Steve Bean, Bob Harris and Chris Coghlan of VicRoads, Terry Tillotson of the City of Monash, and Kathy Diamantopoulou and Chantel Duncan of MUARC. We also thank VicRoads for approval to publish this work.

REFERENCES

1. Regan, M. A., Oxley, J. A., Godley, S. T., and Tingvall, C. (2001). *Intelligent transport systems: safety and human factors issues. Royal Automobile Club of Victoria Research Report.* Melbourne: RACV.

2. Lenné, M., Corben, B., Regan, M., and Triggs ,T. (2001). *Technology to enhance speed limit and stop signal compliance*. Report prepared by the Monash University Accident Research Centre for VicRoads.

3. Haworth, N., and Rechnitzer, G. (1993). *Description of fatal crashes involving various casual variables* (Report No CR 119). Canberra: Federal Office of Road Safety.

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

5. Vulcan, P., and Corben, B. (1998). *Options for a National Road Safety Strategy. Report to National Road Transport Commission*. Melbourne: Research and Safety Services Pty Ltd.

6. Bushman, R., and Taylor, B. (2000). Dynamic safety solutions. *Traffic Technology International, 08/09*, 72-3.

7. Olsen, S.(1998). Informed to behave: Denmark's speed indicator display in action. *Traffic Technology International, June/July*, 83-5.

8. Lassauce, P. (1998) Variable speed limits on motorways. *Revue Generale des Routes, 768*, 16-19.

9. Garrett, A.(1997). Dynamically variable speed limits: Overseas experience and local initiatives. *Third International Conference of ITS Australia*. Brisbane: ITS Australia.

10. Goudens, R. (1996). Variable message signs and their use on main roads. *Technology Transfer Forum*. Brisbane: Department of Main Roads, Queensland.

11. Rama, P., Luoma, J., and Harjula, V. (1998). Distraction due to variable speed limits. *Traffic Engineering and Control, 39*, 428-30.

12. Luoma, J., and Rama, P. (1998). Effects of variable speed limit signs on speed behaviour and recall of signs. *Traffic Engineering and Control, 39*, 234-7.

13. Dudgeon, M. (1998). Using technology to increase speed awareness on the roads. *Local Government Road Safety Conference*. Coogee Beach, Sydney: Roads and Traffic Authority.

14. Cameron, M. H., Newstead, S. V., and Gantzer, S. (1995). Effects of enforcement and supporting publicity campaigns in Victoria, Australia. *Road Safety in Europe and Strategic Highway Research Program*. Prague, The Czech Republic: VTI.

15. Cameron, M. H., and Vulcan, A. P. (1998). *Evaluation review of the supplementary road safety package and its outcome during the first two years*. Wellington, New Zealand: Land Transport Safety Authority.

16. Mara, M. K., Davies, R. B., and Frith, W. J. (1996). Evaluation of the effect of compulsory breath testing and speed cameras in New Zealand. *The combined 18th ARRB Transport Research Conference and Transit NZ Land Transport Symposium*. Christchurch, New Zealand.

17. Stark, D. C. (1996). Urban speed management; 2: Automatic speed enforcement. *Traffic Engineering and Control, 37*, 633-6.

18. Elvik, R. (1997). Effects on accidents of automatic speed enforcement in Norway. *Transportation Research Record, 1595*, 14-19.

19. Keall, M. D., Povey, L. J., and Frith, W. J. (1999). The relative effectiveness of hidden versus visible speed cameras. *Proceedings of the Road Safety Research, Policing, and Education Conference*. Canberra, Australia.

20. Coulstock, B. (1999). *Traffic technology international '99*. Dorking, UK: UK and International Press.

21. Bureau of Transport Economics (2000). *Road casualty crash costs in Australia*. Report No 102, Bureau of Transport Economics. Canberra: Australian Federal Government.