Report on Passive Speed Control Devices

Task 20: Speed and Traffic Operations Evaluation

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<td>This document highlights various passive speed control measures used in the U.S. and around the world. Divided into two sections, the report includes research on longitudinal and transverse pavement markings.</td>
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INTRODUCTION

Speeding is one of the most prevalent factors contributing to traffic crashes. In 2002 in the United States, speeding played a role in 31 percent of all fatal crashes; this percentage translates to 13,713 lives lost in speeding-related crashes. The estimated annual cost to society of speeding-related crashes is $40.4 billion (1). In 2002, out of 459 traffic fatalities that occurred in Massachusetts, 176 occurred in speed-related crashes, representing 38 percent of all Massachusetts crash-related fatalities (2).

Traditional regulatory measures used to control speed are typically setting speed limits and enforcing them. Traffic calming efforts such as speed bumps, roundabouts, and pavement textures are also used to persuade road users to reduce their speeds, especially in residential areas. An alternative way to reduce excessive speeds is to target speed perception, one basic aspect of the driving task. Perceptual countermeasures, or passive speed control measures, serve to alter drivers’ perceptions of the correct speed for a particular road so drivers may assume a lower speed is more appropriate (3). While regulatory measures require enforcement, traffic calming and passive speed control measures are intended to be self-enforcing.

PASSIVE SPEED CONTROL MEASURES

Passive speed control measures attempt to change the fundamental sensory information available to drivers to influence their speed behavior. By adding markings to the road, drivers’ perceptions can be distorted creating the illusion that they are driving faster than they really are, persuading drivers to slow down (4). Additionally, the new road markings can serve as a warning sign; because these pavement patterns are mostly unfamiliar to road users, they violate driver expectancy causing motorists to decelerate (5, 6).

Passive speed control measures have several advantages over traditional speeding countermeasures. First, they have the potential to reduce driving speeds without the driver being aware of their purpose. Their benefits are expected to be long term because they are unobtrusive measures less likely to frustrate drivers. Additional advantages include that pavement markings are typically inexpensive, easy to implement, and can easily be removed (4).

Both longitudinal and transverse pavement markings can be used to perceptually modify the spatial geometry of a roadway encouraging drivers to slow down by altering their perception. Examples of passive speed control measures include lane narrowing, painted centerline widening, painted strips on the edge of roads, transverse lines, and chevron markings (6, 7).
RESEARCH STUDIES

Longitudinal Pavement Markings

Various aspects of lane delineation can be used as a perceptual countermeasure to speeding. Modifying edgelines and centerlines, especially to reduce the perceived lane width of the road, can influence driving speed. Narrower lanes require more accurate steering behavior and increase perceived risk of running off the road or colliding with another vehicle (3). More driver concentration is typically required when driving in narrower lanes as the driver focuses harder to stay in the lane; therefore driving speed usually decreases as lane width decreases. Although numerous studies have been conducted to evaluate the effects of lane width on speed, this relationship seems to be unclear. Before describing related research, it is worth noting the difference between actually narrowing lane widths and creating the perception of a narrower lane without reducing the pavement width. There is relatively little research on speed control using perceptual changes in lane width; therefore, this review includes some studies that evaluate the effects on speed reduction by altering lane widths even though it is not strictly considered a passive speed control measure but more a traffic calming measure (3).

A few studies evaluated the effects of changing lane widths. A positive relationship between vehicle speed and actual lane width was found by Vey and Ferreri in 1968 on two similar bridges in Philadelphia (8). In 1977, Marconi evaluated the effects on speed reduction when narrowing six sites on three different streets. Before and after studies were conducted at the locations concluding that the reduction in width had minimal, if any, effect on deterring speeding motorists. A decrease in the 95th percentile speed was found at four of the sites; at three of them the 95th percentile decreased between one and three mph while the fourth one showed a decrease of 5 mph (9). In 1983, Yagar and Van Aerde conducted a study of the effects of geometric and environmental factors on speed finding a reduction in speed when lane width was narrowed (10).

The influence of road markings on driving speeds has also been studied. In 1984, Lum tested passive traffic control devices in Orlando, Florida, to reduce speeding in residential areas. Solid white edgelines were added to the road and raised pavement markers were installed at the broken centerline to create the impression of a narrower street. The study showed that these longitudinal pavement markings combined with raised pavement markers have no effect on the mean speeds or the speed distributions of drivers (11). Using marking patterns to narrow lanes has also been examined on freeway exit-ramps. Retting et al. found successful results on speed reduction when installing an experimental pavement marking pattern that narrowed the lane width of four exit-ramps (12). Figure 1 shows longitudinal pavement markings.

![Figure 1 Before and after experimental pavement markings used by Retting et al.](image)

1 Note that the two pictures are taken from a different angle
In 1985, Cottrell et al. found no difference in speed on straight roads for wide edge lines; however they indicated that edge lining provided aid on maintaining a safe position within the lane itself (13). This suggests that road markings may be an effective speed reducing measure if they narrow, perceptually or actually, the lane width; but in some cases, adding markings to the road may enhance the visual guidance to follow the road, making higher speeds more comfortable for drivers and therefore canceling out the speed reduction due to the narrowing effect (3).

Some interesting findings were reported by Davids et al. in 2003 about the guiding function of pavement markings. They found that adding longitudinal markings to a previously unmarked roadway provided visual guidance leading to higher speeds. However, adding edge lines to a roadway that was already marked with a centerline led to a decrease of the driven speed. The explanation may be that the initial markings already provided some kind of guidance (14).

Based on this idea, an innovative experiment in Wiltshire, Great Britain, set out to demonstrate that removing pavement lines on the road would decrease speeds and improve safety. The hypothesis is that removing the cues that make drivers feel safe at higher speeds would reduce these speeds. Wiltshire County Council says that serious crashes have dropped by one third and speeds have dropped by up to 7 mph since the lines were removed (15).

Researchers have also examined the link between lane width and safety. Creating the perception of narrower lanes, or actually reducing pavement width, can be a measure to decrease speed. However, when pavement width is actually narrowed the possibility of increasing crash risk exists. Even though extensive research has been conducted to relate lane width to safety, there is not strong evidence about this relationship as isolating the safety effect of lane width is usually unfeasible (16).

The earliest safety study of pavement widening was conducted by Cope in 1955. He found dramatic reductions in crash rates when widening the roadway (17). Zegger et al. studied the safety effect of lane and shoulder widths merging data for about 17,000 crashes in Kentucky. They focused on run-off-road and opposite-direction crashes as being associated with narrow lanes and shoulders. Although they found that with lane widening the rate of run-off-road and opposite-direction crashes decreased, other types of crashes did not, perhaps due to increased speeds (18).

Al-Masaeid et al. investigated the safety effectiveness of pavement markings on rural undivided highways. In their analysis, crash reduction frequencies were evaluated at 100 sites where roads had received pavement marking improvements in 1987 in Indiana. When all sites were evaluated, the results showed no clear evidence of safety improvement; some sites even had an increase in crash experience. This increase was typically located in sites with low crash rates, so it may be explained by the random nature of crashes. However, further analysis revealed that hazardous sites, those with the highest crash rates prior to pavement marking enhancements, showed a significant safety improvement following the implementation with an average crash reduction of 13.5 percent (19).

In summary, narrower lanes typically lead to lower speeds; however there exists a counter effect since adding markings to narrow the lane may provide extra visual guidance that could increase
speeds. In addition, when lanes are narrowed by actually reducing pavement widths, safety may be compromised; this should not happen, however, when only creating the illusion of narrower lane using pavement markings rather than actually reducing lane width. Consequently, using longitudinal pavement markings as a passive speed control device can be an effective way to reduce speeds without compromising safety.

**Transverse Pavement Markings**

Transverse road markings, placed across the road rather than down the side, can also be used to alter speeds by modifying drivers’ perception. Transverse markings most commonly used are transverse bars and transverse chevrons. These marking patterns may be an effective measure for reducing speeds when placed at decreasing distances so the spacing between markings is continuously reduced in the direction of movement. This layout of markings creates the illusion of acceleration that would cause the driver to slow (3). The idea is to space the lines in such a way that the driver who failed to slow would see the transverse lines at an increasing rate and when the driver decelerates appropriately, the lines would move past at a constant rate (20). Transverse marking patterns have proven particularly suitable for reducing speeds on the approach to a roundabout or sharp curve (20, 21).

The origin of this idea comes from an experiment by Denton in 1971. Using a simulator, Denton showed how installing transverse lines at gradually decreasing intervals placed across the lane led to significantly lower speeds (21). Another study by Agent in 1980 tested transverse bars before entering a sharp horizontal curve with high crash rates in Kentucky. During the six years prior to the installation of the new markings 48 crashes occurred at this site. Of these, 36 reported speed as a contributing factor. The results indicated a reduction in speeds and a reduction in crashes, proving that this type of pavement marking could be an effective speed control measure (20).

A comprehensive study of perceptual countermeasures to speeding using a driving simulator was conducted in the late nineties by Goldey at the Monash University Accident Research Centre. The study conclusions indicated that transverse lines as well as peripheral transverse lines appeared effective at reducing travel speeds (6). Examples of transverse marking treatments used in this simulator study are shown in Figure 2.

![Figure 2 Simulator scenarios of transverse bars and peripheral lines](image)

2 Note that you drive on the left-hand side of the road in Australia

In a Kansas study in 2000, Meyer installed transverse bars in a work zone using a layout of three different patterns to evaluate effects on speed. The first one, a “leading pattern,” consisted of 20
bars of constant width and at constant spacing intended to warn drivers. In the next “primary pattern,” bars varied in width and spacing to modify drivers’ perceptions of speed. The actual “work zone pattern” included four sets of six bars. The study results showed promising reductions in speed both in the leading and primary pattern indicating the existence of both warning and perceptual effects (4).

Chevrons are another type of transverse markings used to reduce traffic speeds and crashes. The arrow-shaped chevron resembles the roof of a house, derived from the French word *chevron* meaning rafter. Its directional aspect may reduce driver confusion in comparison with transverse bars. Only a few chevron implementations as a passive speed control device have been documented. A converging chevron pattern to create the illusion of traveling faster as well as the impression of narrower lanes was first used in Osaka, Japan in the early nineties (7). Although direct results from these studies are not available, research reviews cited that before and after studies in Japan indicated an effective reduction on speed when using chevron and comb markings (22). Figure 3 shows a layout of these patterns and Figure 4 shows the actual implementation of converging chevrons used in Japan.

![Figure 3 Arrow marking and comb marking used in Japan (22).](image)

![Figure 4 Converging chevron on the Yodogawa River Bridge, Japan (23).](image)

A different chevron layout was implemented in the U.K. by Helliar-Symons (Transport Research Laboratory). The markings consisted of chevrons painted every 40 meters (122 feet) in the slow and middle lanes of a three-lane rural highway in each direction. The markings were complemented with signs advising drivers to “keep your distance” and “keep apart 2 chevrons” intended to achieve vehicle headways of 2.4 seconds at 70 mph speeds. A public attitude survey
accompanying the experiment provided positive feedback from those members of the public questioned. The overall results were encouraging with a large reduction in crashes and in close-following behavior (24). Figure 5 shows a view of the chevron markings used in the United Kingdom (U.K).

![Chevron markings on the M1 Motorway, U.K.](image)

**Figure 5 Chevron markings on the M1 Motorway, U.K. (24).**

Successful applications of chevron patterns in Japan encouraged researchers in Wisconsin to implement this innovative device in 1999. No other application of the converging chevron had been implemented before in the U.S. Converging chevron pavement markings were installed on an urban high-speed freeway interchange directional ramp with the intention of reducing excessive speeds (23). A picture of the chevron markings on the ramp is shown in Figure 6.

![Converging chevron markings on an off-ramp in Milwaukee County, Wisconsin](image)

**Figure 6 Converging chevron markings on an off-ramp in Milwaukee County, Wisconsin (23).**
A before and after study in Wisconsin indicated an important speed decrease; a 14 mph reduction of the 85th percentile speed was reported. Crash reduction was also identified during the after period. Even though the difference was not statistically significant when all crashes were considered, when crashes considered irrelevant to the installation of the chevron markings were eliminated from the analysis (i.e. when ice was reported on the road), the crash reduction was statistically significant (22).

In summary, transverse pavement markings, such as optical speed bars and converging chevrons, implemented as a passive speed device have potential for reducing driving speeds as well as traffic crashes. As a simple and effective device, passive speed control measures can be a valuable tool for improving traffic safety.
REFERENCES


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