

The Effectiveness of Delineation Treatments

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Abstract

A literature review undertaken for Transit NZ has found that delineation has a significant effect on driver behaviour with, for example, shoulder rumble strips reducing run-off-the-road crashes by between 22% and 80% (average of 32% for all crashes and 44% for fatal run-off-the-road crashes). The concern that enhancing roadway delineation may sometimes be accompanied by an unwanted increase in drivers' speeds (known as behavioural adaptation) is not borne out by the research and appears to be a phenomenon associated with a few restricted situations (e.g. where a centre line is added to an otherwise unmarked road).

The preponderance of the evidence supports the conclusion that profiled edge lines and centre lines provide drivers with positive guidance and produce significant reductions in crashes as a result of improving drivers' lateral position. Further, unlike other safety measures that show decreased effectiveness over time due to a novelty effect, profiled lane delineation continues to work regardless of driver familiarity. There is no published research to suggest that profiled edge lines will decrease the effectiveness of a profiled centre line or will result in an increase in crash rates or an increase in the severity of crashes. However it has also been noted that local conditions have a major influence on the level of benefits that can be achieved through improved delineation.

Introduction

This paper summarises the findings of a detailed literature review undertaken for Transit NZ on the effectiveness of improved delineation technologies. A total of 57 articles were sourced from published journal articles, local and overseas transport engineers, and a search of reports posted on the internet. Many of those selected were review articles or reports that analysed the findings of many other articles. The articles were then grouped into analysis categories and articles over 10 years old, reports that were outside the scope of the review (e.g., illuminated pavement markings, RRPMs, UV headlamps, perceptual countermeasures, etc.), redundant articles, and articles with inconclusive findings were then removed. This resulted in a final set of 24 key reports (citing more than 500 source documents). These reports were then independently reviewed and summarized by two road safety researchers and an annotated review of each article was prepared. The general findings were then categorised into three groups: centre line and edge line

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delineation; rumble strips; and marking materials. There is some overlap in these categories and some of the articles address more than one of the categories. The general findings extracted from the literature review are presented in the following sections.

The Effects of Centre Line and Edge Line Delineation

Speed

The concern that enhancing roadway delineation may sometimes be accompanied by an unwanted increase in drivers' speeds (known as behavioural adaptation) is not borne out by the research for roads with both centre lines and edgelines. Adding an edge line to a road with a centre line sometimes decreases speed and speed variability. For roads with no delineation, when only a centre line or an edgeline are added, there can be an increase in speed. Edge lines and/or centre lines have been removed in some places, e.g., Sweden & the Netherlands, to reduce speeds by providing less guidance and optically narrowing the road. Continuous edge lines have been found to result in higher speeds than dashed edgelines and longer dashes produce higher speeds than short dash lengths. Where wider than normal edge and centre lines have been introduced there has been no evidence of increases in vehicle speeds beyond that produced by standard-width lines.

Lateral position

Owing to the wide variety of delineation methods and placement strategies the effect of enhanced centre lines and edgelines on drivers' lateral position is less clear-cut in the research literature. Studies of edgeline delineation generally have shown that edgelines' effects on lane position depends on the width of the road shoulder; when used on a road with wide shoulders (min 50 cm), the application of an edgeline shifts drivers' lane position toward the edge of the road. When used on roads with narrow shoulders, edgelines tend to shift drivers more to the centre of the road (van Driel et al, 2004). Perhaps the most robust finding is that enhanced delineation of centrelines and edgelines (in combination) tends to produce smaller steering wheel movements and lower lane position variability, particularly during night-time driving (Steyvers & de Waard, 2000; Gates & Hawkins, 2002; van Driel et al, 2004).

Edge lines and centre lines both decrease lateral displacement variability although the largest effect on lateral position is produced by centre lines. The effectiveness of edge lines depends on the shoulder width and the contrast between the road surface and road edge. Adding edge lines to a road with a wide shoulder (1 - 2m) moves drivers closer to the road edge. Adding an edge line to a road with a narrow shoulder (0.1 – 1m) moves drivers towards the centre of their lane (away from the road edge). Adding edge lines to a wide road with wide fields on either side moves drivers towards the centre (away from the road edge), whereas when applied to a narrow road lined with trees and houses, drivers move closer to the road edge. Adding edge lines to a road without road delineators (edge marker posts) moves drivers closer to the road edge than roads with delineators. Longer lane line dashes move drivers towards the centre of their lane, reduces position variability, and produces fewer lane encroachments. Wider edge lines and centre lines appear to produce fairly consistent improvements in lane keeping by drivers, particularly for intoxicated drivers, young drivers, and the elderly.

Crashes

A wide range of results have been reported for the effects of centre lines on crashes, ranging from 1% to 65% with an average of approximately 30% reduction across all crash types. A similarly wide range of results have been reported for the effects of edge lines on crashes, ranging from an 80% reduction to no effect. The wide range in the reported effectiveness of edge lines appears to depend on the type of crashes included in analysis of crash data (loss-of-control versus speed). When considering loss-of-control crashes only, a reliable 25% reduction in crashes due to edge lines appears to be common. The effect of wide edge lines and centre lines on crashes must be treated as inconclusive with some studies reporting decreases in total crash rate, total crash frequency and injury/fatal crash rate, but other studies reporting no change in crash rate.

Driver acceptance

Drivers uniformly prefer more delineation (roads with centrelines and edge lines are rated as requiring less effort) especially during nighttime. Perceived effort appears to match physical effort, verified by finding smaller steering wheel movements with edge lines. Elderly drivers appear to prefer delineation even more than young drivers. The use of wider edge and centre lines has been met with uniformly positive reactions by the driving public.

The Effects of Centre Line and Shoulder Rumble Strips

Rumble strips and profiled lines have been assessed in terms of their effect on speed, lateral position, driver overtaking and crash rates.

Speed

There is no reported evidence that the use of longitudinal rumble strips on centre lines or road shoulders produces any changes in vehicle speeds. Transverse rumble strips (placed across the vehicle path) have been shown to have a significant effect on traffic speed and stop sign observance and have been reported to reduce intersection crashes by 28%.

Lateral position

The use of centre line rumble strips has been shown to produce reliable movement of vehicles away from the centre line. The effect of shoulder rumble strips on lateral position is less clear-cut owing to the variety of placement strategies which range from strips placed on the edge line to strips offset from the edge line by as much as 0.76m.

Overtaking.

Because many drivers do not like driving on profiled centrelines, they also have the effect of decreasing overtaking attempts (Harder, Carmody, & Bloomfield, 2002).

Crashes

The preponderance of the evidence supports the conclusion that profiled edgelines and centrelines provide drivers with positive guidance and produce significant reductions in

crashes as a result of improving drivers' lateral position. Further, unlike other safety measures that show decreased effectiveness over time due to a novelty effect, profiled lane delineation continues to work regardless of driver familiarity (Perillo, 1998). We have found no published research to suggest that profiled edgelines will decrease the effectiveness of a profiled centreline or will result in an increase in crash rates or an increase in the severity of crashes. An additional precaution against the possibility of a profiled edgeline moving drivers closer to the centreline would be to increase the separation between the two no-passing lines (profiled centrelines) to provide drivers with more advance warning and a larger buffer zone between opposing traffic.

Reports of rumble strips' effectiveness ranges from a 2% to a 44% reduction across all types of crashes with an average reduction of over 27%. For rural two-lane roads, a number of carefully controlled field trials have recorded reductions in injury crashes averaging 25% (Persaud, Retting, & Lyon, 2004). One recent United States trial of a profiled centreline on a rural two-lane state highway with a historically high fatality rate resulted in a significant 90% reduction in the rate of head-on accidents and a 0% fatality rate during the post-installation study period, in spite of a 30% (4% yearly) increase in traffic. The total cost of the project was \$15,000 USD and resulted in a 2001 National Highway Safety Award from the Federal Highway Administration. (Delaware Department of Transportation, 2004).

Profiled edgeline treatments have been shown to produce significant reductions in crashes (albeit run-off-road crashes instead of head-on crashes). Trials of edgeline rumble strips and raised pavement markers on rural highways and turnpikes have reduced run-off-road crashes in the United States from 20-72 %: New York 72%; California 49%; Maine 20-50% (estimate); Pennsylvania 60- 65%; Massachusetts, 42%; Washington 18%; Kansas, 34%; New Jersey 34%. The transportation authorities in New York, Nevada and Maine reported benefit-cost ratios ranging from 30:1 to 182:1 depending on the location. (Corkle, Marti, & Montebello, 2001). One recent analysis of two-lane rural highways found that profiled edgelines reduced run-off road crashes by 26.7%, decreased the severity of such crashes by 18.9%, and reduced inattentive driving as a contributing factor in crashes from 33.3% to 10.7% (Marvin & Clark, 2003).

In summary when considering only run-off-road (ROR) crashes, shoulder rumble strips have been found to be very effective in reducing crashes by 20% to 80% (an average of 32% for all ROR crashes, 42% for fatal ROR crashes). The greatest benefits occur for high speed road segments associated with horizontal curvature (which are also associated with a higher ROR crash rate). Similarly, centre-line rumble strips have been found to produce significant reductions in head-on and sideswipe crashes ranging from 21% to 37% of reported crashes.

Driver and public acceptance

The effect of a vehicle passing over a rumble strip should produce a sound loud enough to be heard inside the vehicle and a strong vibration. Complaints have been received from residents when rumble strips have been applied in residential areas although moving

the rumble strips further from the lane edge has been suggested as an effective remedy. The installation of rumble strips on bridges, overpasses, and roads with structural reinforcement is also discouraged in urban, suburban, and residential areas because of noise concerns. Another concern is the possible contribution to metal fatigue and a shortened service life of bridges and structures from vibrations when rumble strips are installed on their decks. People riding bicycles and motorcycles have found it uncomfortable riding over rumble strips but there have been no reports of loss of control as a result. The use of discontinuous or “skip” patterns has been recommended wherever appreciable bike traffic exists and shoulders are less than 2440 mm.

Truck drivers have reported that they often have to drive over the edgeline rumble strips that have been installed in curves (personal communication). Avoiding the vibration caused by the edgeline forces them to drive closer to the centreline. Greater attention may need to be given to ensuring the marked lane in curves is wide enough to accommodate the off-tracking of heavy vehicles.

The Durability and Effectiveness of Marking Materials

Durability & retroreflectivity

There have been few differences reported in the effective retroreflectivity of the most commonly used marking materials, solvent-borne paint, water-borne paint, epoxy, thermoplastic, and tapes. Field measurements of the various marking materials produce inconsistent rankings (depending on the season, installation quality, and maintenance cycles) but all of the materials easily exceed the generally accepted minimum required retroreflectivity rate (100 mcd/m²/lx). Tape is the most expensive of the materials, but its service life is two or four times longer than paint, epoxy, or thermoplastic products. Paints (water-borne and solvent-borne) are the least expensive marking materials, but also have the shortest service life.

Crashes

We could find no statistically significant differences reported for the different marking materials in terms of crash data. This is perhaps due to the similarity in the average retroreflectivity rate of the materials.

Prioritising the application of delineation treatments

From the above it is clear that increased delineation, including the greater use of rumble strips, will improve road safety. However the costs involved need to be considered and Land Transport NZ has recently approved a research project that will assist with this. The project will include the development of a management tool that will enable road controlling authorities and their consultants to prioritise where and what types of treatments should be applied. The results of that project will be presented at next year's conference.

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