Research Need Literature Review

**Topic:** NS #536 – Pavement Marking Patterns and Widths - Human Factors Study
**Date:** 20 July 2018
**Prepared for:** Mitch Bartelt
**Prepared by:** Race MoChridhe
**Resources searched:** TRID, RiP, Internet, Library Catalog

**Summary:** Almost all recent research on pavement markings can be divided into three categories: 1) research on marking compatibility with automated vehicle, 2) research on qualities and durability of physical elements of markings, and 3) narrowly defined research projects addressing human factors of markings in very specific circumstances, such as in curves or tunnels. It is this last category, as pertaining to human elements, which is reviewed below. The specific factors addressed in the RNS—general line width, cycle patterns in contexts other than curves or tunnels, and efficacy of contrasts—appear to be relative lacunae in the recent literature, with most relevant studies being 15 or more years old. There may also be value in a metastudy bringing together insights from more specialized recent treatments into a broader consolidation of contemporary best practices.

**Results**
**(in order of relevance)**

<table>
<thead>
<tr>
<th>Title</th>
<th>Evaluating road delineation practices in Michigan</th>
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<tr>
<td>Source</td>
<td>Michigan Department of Transportation report, 118pp.</td>
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<tr>
<td>Abstract</td>
<td>This research was conducted to assist the Michigan Department of Transportation in assessing the State’s current delineation program. Opus International Consultants (Opus) and Western Michigan University (WMU) were retained to undertake this review and analysis, including a review of existing literature and current state-of-the-art, a delineation survey with follow-up of state and Canadian provinces, and finally a benefit-cost and alternatives analysis to consider potential changes to MDOT’s existing program. In the Michigan context, statistical analysis shows potential benefits for wider adaptation of polyurea pavement markings, snowplowable raised pavement markers on high-AADT roadways, and freeway lighting at interchanges.</td>
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<tr>
<td>Date</td>
<td>2017</td>
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| Title | Pavement marking retroreflectivity and crash frequency: segmentation, line type, and imputation effects |
This paper investigates the effects of segment length, line types, and imputed retroreflectivity values on pavement-marking retroreflectivity and crash frequency analyses. Road data, crash data, pavement condition data, and pavement-marking retroreflectivity data from Iowa Department of Transportation (DOT) databases were acquired and spatially integrated. Data sets for 1-, 3-, and 5-mi segments were prepared to investigate the effect of segmentation. Additional data sets with imputed and measured retroreflectivity data were prepared for comparison. A series of negative binomial regression analyses were run to estimate the expected number of crashes on varying segment lengths and data subsets based on the two retroreflectivity collection methods. The findings show that using smaller segments and data sets with measured retroreflectivity rather than imputed retroreflectivity leads to a more significant relationship between the retroreflectivity of longitudinal pavement markings and crash frequency. The findings also suggest that keeping longitudinal pavement markings in good condition has significant positive effects on safety. The results further suggested that the expected number of annual crashes significantly decreased with the increasing retroreflectivity of white-edge lines (WELs) and yellow-edge lines (YELs) for four-lane road segments. In addition, a significant relationship between pavement condition, measured with the International Roughness Index (IRI) and the expected number of crashes was found for all data sets.

Date 2016

Title Trialling best value delineation treatments for rural roads
Source New Zealand Transport Agency report, 100pp.
URL http://www.nzta.govt.nz/resources/research/reports/618/
Abstract Providing a safe, comfortable, cost-effective visual environment to help drivers navigate rural roads requires a better understanding of the strengths and limitations of different delineation devices, materials and treatment configurations. An international literature review examined different options to test on low-volume rural New Zealand road settings, and an expert panel prioritised four of these options to be trialled. Four on-road trials were run to examine delineation configurations and materials that could provide better value for rural roads. The key aspects to deciding treatments were to do with targeted delineation (to assist drivers in intuitively signalling more difficult parts of the road network), consolidation (where one configuration with a new product might replace two traditional products), and better delineation in rain, which is arguably a common poor visibility environment (where crashes are over represented). The findings provided new information about the importance of complementary devices, including edge marker posts and raised reflectorised pavement markings in different contexts. Finally, to help implement better delineation solutions on lower volume rural roads, the report offers practical updates of the rural road delineation guidance (RTS 5).

Date 2017
Title: Guidance on median and centerline treatments to reduce head-on casualties
Abstract: This report presents a compendium of local and overseas practice and experience in minimising the risk and severity of head-on crashes. It is intended to assist road safety practitioners identify effective actions that can be taken to reduce the incidence and severity of such crashes, with a focus on median and centreline treatments. In addition to discussing well-proven methods to address head-on crashes, this report also presents some innovative treatments for which there is currently insufficient data to confirm their benefits, but which may be effective in reducing head-on crashes where the crash history does not justify the expense of applying more established treatments.
Date: 2016

Title: Risk in our midst: centerlines, perceived risk, and speed choice
Source: Accident Analysis & Prevention 95, part A: 192–201.
URL: http://dx.doi.org/10.1016/j.aap.2016.07.019
Abstract: The idea that drivers’ perceptions of risk affect their decisions and choices, particularly as regards their speed, is at the heart of many years of our education, engineering, and enforcement strategies to improve road safety. The authors’ previous research has shown that horizontal curvature, road width, vertical curvature and separation from on-coming traffic are principal determinants to perceptions of risk on rural roads. The present study examined the relationship between drivers’ perceptions of risk and the speeds they choose to drive. Participants drove high definition videos of familiar rural roads in a driving simulator and a smaller group of participants drove the same roads in a university fleet vehicle similar to the one used in the simulator. The results showed that double yellow and wide centreline markings were associated with lower speed choices and higher perceptions of risk, an effect magnified under high traffic conditions. Similarly, in both the simulator and on the roads, driving on narrow roads was associated with significantly lower speeds and increased risk ratings, while wider roads showed a small but significant increase in speeds as compared to standard width control roads. Finally, a range of other road and traffic conditions such as one-lane bridges, level crossings, police cars, and crash area warning signs were also found to be associated with lower speed choices and higher risk perceptions.
Date: 2016

Title: The impact of rhythm-based visual reference system in long highway tunnels
URL: http://dx.doi.org/10.1016/j.ssci.2017.02.006
Abstract

As typical weak visual reference systems, highway tunnels have low illumination, monotonous environment and few references, which may reduce drivers' speed perception ability and thus easily cause over-speeding and rear-end collision accidents. This study performed psychophysical experiments to assess the effect of interior visual environment on the driving safety of drivers by using the 3ds Max software, driving simulator, and E-prime software. A rhythm-based marking system was proposed to improve the visual environment of tunnels by arranging rhythm curves on side walls and note symbols on pavements, as well as multi-frequency markings (high, medium and low frequency). The accuracy rate of speed judgment and reaction time of drivers were analyzed by statistical methods and the logistics curve fitting method. The results showed that: (a) single-color rhythm markings enhanced the accuracy ratio of speed judgment by 3.33–11.66%, while multi-color rhythm markings increase this parameter by 3.33–25%. The accuracy ratio was increased by 18.33% for the second change of color in multi-color rhythm markings (t = 72 s); (b) for common highway tunnels, the reaction time of drivers showed a significant association with the driving duration in the tunnel. For tunnels with improved visual environment by rhythm markings, no significant relationship between the reaction time and driving time was noted, with drivers' fatigue effectively released; and (c) the driver reaction time depended on both the visual environment and driving duration. Rhythm markings in tunnels could effectively reduce driver reaction time. Multi-color markings had better effects than monochrome ones.

Date 2017

Title Using road markings as a continuous cue for speed choice

Source Accident Analysis & Prevention 117: 288–297.

URL http://dx.doi.org/10.1016/j.aap.2018.04.029

Abstract The potential for using road markings to indicate speed limits was investigated in a driving simulator over the course of two sessions. Two types of experimental road markings, an “Attentional” set designed to provide visually distinct cues to indicate speed limits of 60, 80 and 100 km/h, and a “Perceptual” set designed to also affect drivers’ perception of speed, were compared to a standard undifferentiated set of markings. Participants (n = 20 per group) were assigned to one of four experimental groups (Attentional-Explicit, Attentional-Implicit, Perceptual-Explicit, Perceptual-Implicit) or a Control group (n = 22; standard road markings). The Explicit groups were instructed about the meaning of the road markings while those in the Implicit and Control groups did not receive any explanation. Participants drove five 10km simulated roads containing three speed zones (60, 80 and 100 km/h) during the first session. The participants returned to the laboratory approximately 3 days later to drive five more trials including roads they had not seen before, a trial that included a secondary task, and a trial where speed signs were removed and only markings were present. The findings indicated that both types of road markings improved drivers’ compliance with speed limits compared to the control group, but that explicit instruction as to the meaning of the markings was needed to realise their full benefit. Although previous research has indicated the benefit of road markings used as warnings to indicate speed reductions in advance of horizontal or vertical curves, the findings of the present experiment also suggest that systematically associating road
markings with specific speed limits may be a useful way to improve speed limit compliance and increase speed homogeneity.

**Date** 2018

**Title** Evaluation research of the effects of longitudinal speed reduction markings on driving behavior: a driving simulator study


**URL** [http://dx.doi.org/10.3390/ijerph13111170](http://dx.doi.org/10.3390/ijerph13111170)

**Abstract** The objective of this paper is to explore the effects of longitudinal speed reduction markings (LSRMs) on vehicle maneuvering and drivers’ operation performance on interchange connectors with different radii. Empirical data were collected in a driving simulator. Indicators—relative speed change, standard deviation of acceleration, and gas/brake pedal power—were proposed to characterize driving behavior. Statistical results revealed that LSRMs could reduce vehicles’ travel speed and limit drivers’ willingness to increase speed in the entire connector. To probe the impacts of LSRMs, the connector was split into four even sections. Effects of LSRMs on driving behavior were stronger in the second and the final sections of connectors. LSRMs also enhanced drivers’ adaptability in the first three quarters of a connector when the radius was 50 m. Drivers’ gas pedal operation would be impacted by LSRMs in the entire connector when the radius was 50 m. LSRMs could only make drivers press brake pedal more frequently in the second section with 80 m and 100 m radius. In the second quarter section of a connector—from the FQP (the first quartile point) to the MC (the middle point of curve)—LSRMs have better effects on influencing vehicle maneuvering and drivers’ operation performance.

**Date** 2016

**Title** The effect of pavement markings on driving behavior in curves: a simulator study

**Source** *Ergonomics* 60.5: 701–13.

**URL** [http://dx.doi.org/10.1080/00140139.2016.1200749](http://dx.doi.org/10.1080/00140139.2016.1200749)

**Abstract** This study investigates the effect of two pavement markings (transverse rumble strips (TRS) and a backward pointing herringbone pattern (HP)) on speed and lateral control in and nearby curves. Two real-world curves with strong indications of a safety problem were replicated as realistic as possible in the simulator. Results show that both speed and lateral control differ between the curves. These behavioural differences are probably due to curve-related dissimilarities with respect to geometric alignment, cross-sectional design and speed limit. TRS and HP both influenced mean speed and mean acceleration/deceleration but not lateral control. TRS generated an earlier and more stable speed reduction than HP which induced significant speed reductions along the curve. The TRS gives drivers more time to generate the right expectations about the upcoming curve. When accidents occur primarily near the curve entry, TRS is recommended. The HP has the potential to reduce accidents at the curve end. Practitioner Summary: Two pavement markings (transversal rumble strips and HP) nearby dangerous curves were investigated in the driving simulator. TRS generated an earlier and
more stable speed reduction than HP which induced speed reductions along the curve. The TRS gives drivers more time to generate right expectations about the upcoming curve.

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<td>Title</td>
<td>Following safely on curved segments: measure with discontinuous line markings to increase time headways</td>
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<td>URL</td>
<td><a href="http://amonline.trb.org/">http://amonline.trb.org/</a> (copies for order)</td>
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<td>Abstract</td>
<td>Statistics have indicated that rear-end collisions are more likely to happened on curved segments than on straight segments. In this study, the authors proposed a kind of ‘discontinuous line markings’ with consideration of drivers’ visual information on road surface, and exhibited them in a real world expressway in China. The results demonstrated that 1) the time headways on curved segments were found to be significantly smaller than that on the straight segment, and a smaller radius of curved segment resulted in a smaller time headway, 2) the time headways were significantly increased after installation of the discontinuous line markings, and 3) the time headways were gradually increased as the drivers passed through the area with the discontinuous line markings installed. Furthermore, the results were explained from drivers’ distance perception, speed perception, and time-to-collision (TTC) estimation. The findings of this study may provide decision makers and engineers a new thought and a substantial measure in coping with collision accidents on curved segments in highways.</td>
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<td>Title</td>
<td>The use of wider longitudinal pavement markings in the United States</td>
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<td>Source</td>
<td>16th Biennial Symposium on Visibility and Simulation, University of Iowa, Iowa City</td>
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<tr>
<td>URL</td>
<td>none provided</td>
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<td>Abstract</td>
<td>Over the past 2 decades, as more knowledge has been gained about driver visibility needs and aging driver population trends, some highway agencies have begun to use longitudinal pavement markings that are wider than the 4-inch minimum for standard centerline, edgeline, and/or laneline applications. The aim of this study was to provide an analysis of the use and benefits of wider markings in the U.S. and Canada. This was accomplished by use of a survey of transportation agency practices in the U.S. and Canada, and by conducting a thorough review of the relevant research literature. An analysis of the survey and literature findings is presented.</td>
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<td>Title</td>
<td>The effectiveness of signing and lining</td>
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<tr>
<td>Source</td>
<td>Traffic Engineering and Control 39.7: 444–5.</td>
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This article comments on a new analysis of the effectiveness of signing and lining treatments, in the report *Cosmetic or Crucial?*, jointly published by the Association for Road Safety and Traffic Management (ARTSM) and the Road Markings Association (RSMA). The article outlines the reasons for the report, and its findings, and argues that the case for improved signing and lining as a cost-effective road safety and accident reduction measure is more than proven. The report aimed to answer the following questions: (1) What is the future environment that will affect future road safety policy? (2) Do improved signing and lining techniques reduce accidents? and (3) What action should responsible authorities take in the light of the report's analysis? By 2000, the UK will have 12M driving licence holders aged over 55, who will face increased traffic levels at the same time as their mental and physical capabilities are declining. Their difficulties will be especially great at night and in poor weather. Improved signing and lining is one approach to addressing this problem. The article's tables show the results of analysis at five UK sites, showing clearly that the benefits of improved signing and lining greatly exceed the cost of implementing the corresponding road improvements.

Date 1998

Title Pavement markings and delineation for older drivers


Abstract The objectives of this project were: (1) to identify the needs of older drivers and to evaluate the situations in which older driver performance might be improved through enhanced pavement markings and delineation; (2) to identify the range of potentially useful enhanced treatments; (3) to determine the effectiveness of those treatments judged to be most useful for the older driver; and (4) to assess the costs and benefits of the treatment shown to be most effective. Following a literature review to identify older driver deficiencies, 25 delineation/pavement marking treatments (including several "control" treatments) were identified for testing. A laboratory simulator study was used as a means to determine the most effective among the group. The treatments shown to produce better recognition distance, along with several control treatments, were then subjected to field testing. The field tests were conducted on a closed test track facility, and recognition distance and visual occlusion time were used as dependent measures. Of the 66 subjects who participated in the field study, half were over 65 years of age and half were 45 years of age or less. All subjects were involved in both types of measures. Following the field test performance assessment, the treatments were subjected to a cost benefit analysis and recommendations were made regarding the treatments that could benefit older drivers.

Date 1996