June 20, 2017

Prepared for: Dan Warzala
Prepared by: Karen Neinstadt

Resources searched: Transport Database, TRB Research in Progress, MnDOT Library Catalog

Summary: Results are compiled from the databases named above. The results at the top specifically address the “Life Cycle” study of the signs. The remaining results focus on the variables that affect or are affected by the materials, human factors, or environment.

Most Relevant Results

Title: Value Assessment of Traffic Signs Retroreflection in Their Life Cycle.
Author: Banovic Branimir; Fiolic Mario; Babic Marko
Abstract: The retroreflective materials for traffic signs began to be applied from 1939 when the experts in the 3M company produced the first reflective traffic sign that is set at the intersection of State Road in Minnesota in the United States. Glass beads were applied to the substrate without external protection and were damaged by the atmospheric conditions. Over the last 30 years numerous studies were implemented and the different reflective materials (High Intensity Grade, Diamond Grade) have been developed. These have been used for making traffic signs with the aim of increasing the visibility, especially at night and under harsh conditions, and thus the overall traffic safety on the roads. This paper presents the analysis of the retroreflection value of traffic signs for a certain period of time and their impact on traffic safety. A survey was made on 13,387 traffic signs of different ages and different material classes which were located on 20 different road sections in the Republic of Croatia. This article present results of that analysis.

Title: SERVICE LIFE OF RETROREFLECTIVE TRAFFIC SIGNS. DRAFT REPORT.
Author: Black K L; McGee H W; Hussain S F; Rennilson J J
Abstract: The ability to predict coefficient of retroreflection values for inservice traffic signs is critical for the Federal Highway Administration's (FHWA's) Sign Management System (SMS). Within the SMS, tools for predicting inservice retroreflective performance of traffic signs and for determining the motorist's visual needs are required. The research which focuses on the motorist's needs in terms of traffic sign luminance, legibility distance, conspicuity, etc., is on-going by others. The project reported on here evaluated the effects of climatological and geographic variables on sign sheeting deterioration. A national data collection effort was undertaken. Data samples from 6,275 traffic signs were collected across the country. The data collected included: sheeting retroreflectivity, ground elevation, orientation to the sun, data of installation, sheeting type, etc. Mathematical equations were developed using the key deterioration variables to predict inservice coefficient of retroreflectivity and legend to background contrast ratios. The main difficulty in modeling sheeting deterioration was the result of the variation in the coefficient of retroreflectivity for new sheeting.
Title: Life Cycle Curves for Sign Management.
http://rip.trb.org/view/1229676

Abstract: One of the goals in the South Dakota Department of Transportation (SDDOT) Strategic Plan is to improve highway signs by: (1) adopting procedures for annual sign inspections and replacement plans, and (2) eliminating unnecessary signs and upgrading remaining signs to comply with the Manual on Uniform Traffic Control Devices on 20% of the highway network annually. To facilitate achieving these goals, it would be helpful to know approximately how many years the sign sheeting on our signs retain sufficient reflectivity, legibility and color before they require replacement. This can vary based on the direction the sign is facing and the overall weather conditions the sign is exposed to. An efficient, simplified and centralized sign inventory database, including a decision-making tool in the database which could flag signs approaching the end of their performance life for prioritized inspection and replacement, would greatly improve the likelihood of accomplishing the ambitious objectives above. We currently do not have a consistent approach to planning and budgeting for sign replacement. Knowing the approximate life cycle for a given sign type as well as the effects of sign location and orientation in either shortening or extending the expected life would provide a powerful tool in maintaining our sign inventory while at the same time improving the efficiency and cost-effectiveness of sign replacement procedures. The purpose of this research project is to develop and implement such a decision-making tool. The objectives of this research project are to: (1) determine the status and expected longevity of the current sign inventory in South Dakota based on color, retroreflectivity, orientation, age and geographical distribution; and (2) develop a systematic approach to decision-making with regard to inspection and planning for replacement of signing. Research tasks of this research project are as follows: (1) Perform a literature search on the durability and performance of sign sheeting materials. (2) Meet with the technical panel to discuss the project and scope of work, and also review a draft survey as outlined in Task 3. (3) Conduct a survey of surrounding states and Canadian provinces to determine current sign evaluation and inventory practices and sign replacement decision-making strategies. (4) Interview appropriate state personnel to evaluate the sign inventory database as well as data collection and sign evaluation procedures and discuss sign replacement strategies being employed. (5) Assemble a database of potential sign locations for field testing which will provide reliable data for developing life cycle curves for signs incorporating color, age, retroreflectivity, orientation and geographical distribution as factors in performance. (6) Submit a work plan for conducting field testing of signs, including the equipment to be used, scheduling requirements, both in spring and fall with measurements taken before and after cleaning, over a two year period which will provide a statistically valid basis for developing life cycle curves. (7) Collect data on the approved signs modifying site locations as needed over the course of the field-monitoring period. (8) Develop a series of life cycle curves, suitable for integration into the sign inventory database, which can be used for budgeting and inspection purposes. (9) Provide guidelines for sign data collection, inspection and testing and formulate recommendations for testing requirements, equipment, procedures and replacement scheduling. (10) Prepare a final report and executive summary of the literature review, research methodology, findings, conclusions, guidelines and recommendations. (11) Make an executive presentation to the research panel and the SDDOT Research Review Board at the conclusion of the project.

Title: Methodology for Estimating Life Expectancies of Highway Assets.
http://rip.trb.org/view/1232715

Abstract: The deterioration of highway infrastructure begins as soon as it is put into service. Effective management of highway system assets requires a good understanding of the life expectancy of each asset. Asset life expectancy is the length of time until the asset must be retired, replaced, or removed from service. Determining when an asset reaches the end of its service life generally entails consideration of the cost and effectiveness of repair and maintenance actions that might be taken to further extend the asset's life expectancy. Different types of assets, such as pavements, bridges, signs, and signals, will have very different life expectancies. Asset life expectancy also depends on the materials used; demands actually placed on the asset in use; environmental conditions; and maintenance, preservation, and rehabilitation activities performed. Effective management of highway system assets requires that agency decision makers design and execute programs that maintain or extend the life of the various types of assets in the system at low cost. Designers
use estimates of asset life expectancy in their lifecycle cost analysis to make design decisions, but those estimates depend on assumptions about maintenance practices, materials quality, service conditions and characteristics of the asset's use. If actual service conditions and maintenance activities subsequently differ from the designer's assumptions, the asset's life is likely to be different from initial estimates. Better information and tools for estimating asset-life expectancies are needed to guide in-service asset management programs. Research is needed to determine the life expectancies of assets for at least four potential cases: (1) when maintenance and preservation activities are performed as assumed by the designer in the lifecycle cost analysis, (2) when little or no maintenance is performed over the life of the asset, (3) when more aggressive maintenance and preservation activities are performed to extend the asset's life, and (4) when materials or designs that require no or very little maintenance are used. The objectives of this research are to (1) develop a methodology for determining the life expectancies of major types of highway system assets for use in lifecycle cost analyses supporting management decision making; (2) demonstrate the methodology's use for at least three asset classes, including pavement or bridges and two others, such as culverts, signs, or signals; and (3) develop a guidebook and resources for use by state DOTs and others for applying the methodology to develop highway maintenance and preservation programs and assess the impact of such programs on system performance.

Least Relevant Results

Title: A REVIEW OF KANSAS DEPARTMENT OF TRANSPORTATION'S REFLECTIVE SHEETING POLICY. FINAL REPORT.
Author: Russell E R; Rys M
1992/1. 183 p.(7 Apps., 9 Figs., 51 Refs., 35 Tabs.)
Abstract: The main objective of this study was to determine the best, cost-effective policy, consistent with safety, for sign sheeting material to be used on signs and construction work zone traffic control devices on State highways in Kansas. The investigation consisted of reviewing literature, contacting knowledgeable traffic engineers and research, conducting a survey of selected States' practice, conducting a life-cycle cost analysis, and reviewing a previous reflective sheeting study conducted for the Kansas Department of Transportation (Bellomo-McGee Inc., 1988). Among the conclusions of this study are the following: (1) Kansas (or any State) should not change any policy on sign reflectivity at this time due to the extensive FHWA research program underway. (2) The trend is toward high-performance sheeting on all or most traffic signs. (3) For traffic control devices in construction work zones, the trend is also toward high-performance devices. (4) There is a small but growing trend to use new reflective materials with three times the retro-reflective values of the present high-performance materials, at least for critical or special locations. (5) For high-speed highways, anywhere a critical vehicle maneuver is necessary and in areas of medium to high visual complexity, higher values of sign luminance are required for safety. (6) Older drivers are increasing in the U.S. driving population and their visual needs are greater than those of younger drivers. The higher retro-reflective properties of high-performance materials enhance safety, particularly of older drivers, by providing greater conspicuity distances and slightly increased legibility distances for any given sign size. (7) An analysis of recent bid data from KDOT showed a lower annual life-cycle cost for high-performance signs. (8) The conclusions of the 1988 Bellomo-McGee Inc. reflective sheeting study were valid and appropriately based on key available studies.

Title: OVERHEAD GUIDE SIGN VISIBILITY FACTORS, VOLUME I: FINAL REPORT.
Author: Stein A C; PARSEGHIAN Z; Allen R W; Wolf C E
Volume II, FHWA-RD-88-197, contains appendixes with detail data on each study. Publication Year 1989
Abstract: The project discussed in this report concerned the night use of overhead guide signs, including button and reflectorized copy and all practical combinations of reflectorized and opaque backgrounds. This project was a follow-up effort to the literature review by Gordon. Gordon's review found areas requiring further investigation, including the comparison of nonilluminated-nonretroreflectorized signs with both illuminated-nonretroreflectorized and retroreflectorized signs. The current project included the investigation of current
signing practices throughout the country, development of a set of in-use luminance values for current overhead guide sign materials, development of life cycle costs for current signing materials and practices, and determination of driver response characteristics for these overhead guide sign systems. These goals were met through review of the literature, field testing, and static and dynamic laboratory testing. While the results of the tests are presented, no attempt has been made to draw conclusions from these data.

Title: Evaluation of Overhead Guide Sign Sheeting Materials to Increase Visibility and Safety for Drivers.
Author: Obeidat Mohammed Said; Rys Malgorzata J; Rys Andrew; Du Juan
Citation: Applied Ergonomics. 2016/9. 56 pp 136-143(Figs., Refs., Tabs.)
Abstract: Overhead guide sign visibility must increase to improve driver safety on roadways. Two methods increase overhead guide sign visibility: sign illumination and use of retroreflective sheeting materials. This paper compares three types of retroreflective sheeting: Engineering Grade (type I), Diamond Grade (type XI), and High Intensity (type IV). A field experiment was conducted at night using licensed drivers to determine the optimum retroreflective sheeting material that increases sign visibility and legibility. Results showed that, of the three types of retroreflective sheeting, Diamond Grade (type XI) sheeting requires minimum illuminance to be visible, followed by High Intensity (type IV) sheeting. Cost analysis, including labor, maintenance, and material cost components of the three retroreflective sheeting materials, showed that High Intensity (type IV) could increase sign visibility and legibility at night for Departments of Transportation with limited budgets, consequently increasing driver safety on roadways.

Title: RETROREFLECTIVE SHEETING MATERIALS ON HIGHWAY SIGNS.
Citation: See also PB94-133659. Sponsored by Minnesota Dept. of Transportation, St. Paul, Office of Research Administration. Publication Year 1996
Abstract: In a road research project, older drivers were asked to read street names as soon as they were able as they were approaching an intersection. The signs were always on the farsides of the intersection but could be either on the right or left side. Intersections of three levels of complexity were used. A repeated measures design was used. All main effects and all but one of the interactions were significant. The legibility distances obtained from 864 trials using 18 subjects showed that Diamond Grade and VIP Diamond Grade sheeting were equivalent but that both were significantly superior to High Intensity Grade sheeting which was in turn significantly superior to Engineering Grade. The differences among sheeting grades were more apparent at the more complex intersections. The viewing conditions on some of the streets resulted in reduced visibility and conspicuity causing markedly reduced legibility distances. There were no performance differences based on gender. The implications for driving safety were discussed in the context of visual information processing workload, divided attention and multitasking.

Title: EVALUATION OF RETROREFLECTIVE SHEETINGS FOR USE ON ROADWAY TRAFFIC SIGNS. FINAL REPORT.
Author: Ahmed S A
Citation: 1994/9. 159 p.(7 Apps., 14 Figs., 5 Photos., 23 Refs., 93 Tabs.)
Abstract: The primary objectives of this research were to evaluate the Oklahoma Department of Transportation's (ODOT's) policy on use of retroreflective sheeting products, and to identify any necessary changes to this policy based on driver visibility needs, durability of sheeting materials, life-cycle cost, and other practical considerations. The scope of the study included three types of retroreflective sheetings (engineering grade, super-engineering grade, and encapsulated-lens high-intensity sheeting), five sheeting colors (white, red, yellow, green, and blue), and two sign fabrication methods (screening and overlay). To meet the objectives of this project, a research plan consisting of literature review, controlled field experiments, survey of ODOT field divisions, durability data collection and analysis, and life-cycle cost analysis was adopted. The findings of this study suggest that the specification of type III-A (high-intensity, encapsulated glass-bead sheeting) on all red and yellow signs, as well as green and blue signs on interstate highways and freeways is sound and defensible. The requirement that type II-A (super-engineering grade sheeting) be used on all other traffic signs, except orange colored signs, needs to be examined. Although the initial cost of sign face
fabrication for type III-A sheeting is 25% to 65% higher than that of type II-A, life-cycle cost analysis indicates that type III-A is more cost-effective than type II-A. Evidence from visibility distance analyses and subjective evaluations made by the test subjects suggests that, in addition to upgrading sign materials to provide greater luminance, larger sign size and letter size are needed to satisfy the minimum required visibility distances, particularly at high speed, high traffic volume, and high visual complexity locations.

Title: RELATIVE VISIBILITY OF INCREASED LEGEND SIZE VS. BRIGHTER MATERIALS FOR TRAFFIC SIGNS. FINAL REPORT.
Author: Mace D J; Garvey P M; Heckard R F
1994/12. 49 p.(12 Figs., 37 Refs., 2 Tabs.)
Abstract: Static and dynamic legibility studies were conducted to investigate the effects of level of reflectivity, letter series, stroke width, letter spacing, font, letter height, and driver age. The dynamic study also considered the effect of sign size and retroreflectivity on the level of conspicuity. As expected, driver age had the largest effect on both legibility and conspicuity. In fact, the daytime legibility for older drivers is almost as poor as night legibility. Level of retroreflectivity, letter series, and letter height all had a significant effect on legibility. Increases in letter height resulted in proportionate increases in legibility up to about 600 ft (183 m). In most cases, stroke width, letter spacing, and font were not significant; however, with fully retroreflective signs, a narrow stroke width significantly increased the legibility of high-contrast signs. Using spacing narrower than the standard spacing did significantly reduce legibility. With regard to conspicuity, 36-in. (0.91-m) signs with type I sheeting were found to have detection distances equivalent to 24-in. (0.61-m) signs with type VII sheeting. Black-on-white signs were found to have much shorter detection distances than black-on-orange or white-on-green signs. Cost comparisons (excluding life-cycle costs) using the data available suggested that larger signs with type I sheeting were less expensive than smaller signs with type VII material which provided similar performance. The effects of other materials with brightness between type I and type VII were not of significant magnitude to provide reliable cost evaluations.

Title: Guidelines for Guide Sign Visibility.
http://rip.trb.org/view/1232154
Abstract: A frequent dilemma facing highway agencies is deciding how to most effectively provide visible overhead guide signs. There are no guidelines that agencies can reference to help decide how to provide sufficient visibility of overhead guide signs. For instance, it seems that there is a general belief that it is adequate to turn off guide sign lighting in rural areas with flat terrain if highly retroreflective sheeting materials are used. However, there is little consensus in other areas such as suburban and urban areas where the visual background and roadway geometries are more complex. The only official national guidance in the Manual on Uniform Traffic Control Devices (MUTCD), which states "All overhead sign installations should be illuminated unless an engineering study shows that retroreflection will perform effectively without illumination. There are many factors that must be considered such as: (1) capital and maintenance costs of fixed sign lighting; (2) lighting technologies, lighting levels, lighting characteristics (e.g., SPDs); (3) retroreflective sign sheeting materials and colors; (4) visual complexity of the surrounding roadside environment; (5) presence and amount of roadway lighting; (6) traffic volumes; (7) sign position with respect to the approaching traffic; (8) roadway geometry; (9) minimizing unused uplighting; and (10) sign detection and sign legibility. Other influences that need to be considered include vehicle headlamp aim as newer headlamps provide less illumination to overhead guide signs, an increasingly older driver population, mixed vehicle types, sign spacing less than desirable (800') due to closely spaced interchanges, weather such as snow, dew, and fog, etc. Currently, agencies rely on unsubstantiated information or conduct non-scientific nighttime demonstrations with agency personnel. Because of the lack of guidelines, many agencies repeat these efforts in order to make decisions. There is typically little documentation provided and little control over the efforts. Research is needed to develop a set of guidelines that can be used by agencies trying to determine the most effective way to provide visible overhead guide signs (and overhead street name signs). The guidelines should be a comprehensive stand-alone document that agencies can use to assess the visibility of guide signs (and overhead street name signs) with currently available options and future technologies. The guidelines should be
independent of material properties and related to luminance or some other measure of visual performance. To the extent possible, the guidelines should be supported with relevant crash data and life cycle costs. To accomplish this objective, the following tasks are recommended: (1) conduct a literature review to document any state or other national guidelines and research regarding guidelines, legislation, policies, and practices regarding efforts to establish guidelines for visible overhead guide signs (including overhead street name signs); (2) assess the available measures of visual performance; (3) draft a summary report of the results of the literature reviews, providing an objective overview of the status of overhead guide sign visibility concerns and considerations, to include a recommended research plan for the second phase of the research that outlines the preliminary guidelines and identified research needs to complete the guidelines; (4) conduct the approved research plan to support the completion of the guidelines, including field testing with full scale signs with and without lighting, sign visibility, sheeting type and the interaction of sheeting type and lighting; (5) develop a metric for assessment of the sign performance; (6) develop recommended guidelines for visible overhead guide signs; and (7) develop a final report with revised guidelines and suggested updates to AASHTO's lighting policies.