



# Research Digest

---

## *Item 1*

**Life Cycle Cost Analysis and Discount Rate on Pavements for the Colorado Department of Transportation**  
*COLORADO DEPARTMENT OF TRANSPORTATION*  
*CDOT-2006-17 • 2006*

This report provides information on life cycle cost analysis (LCCA) as applied to CDOT's roadways. It describes the methodology CDOT uses to select discount rates to be used in LCCA calculations. It also summarizes pavement selection terminology for deterministic and probabilistic LCCA procedures.

Full-text PDF of this report is available for free download at

<http://www.dot.state.co.us/publications/PDFFiles/discountrate.pdf>

## *Item 2*

**Hot Mix Asphalt Voids Acceptance Review of QC/QA Data 2000 through 2004**  
*COLORADO DEPARTMENT OF TRANSPORTATION*  
*CDOT-DTD-R-2006-12 • 2006*

This report analyzes the Quality Control/Quality Assurance (QC/QA) data for hot mix asphalt using voids acceptance as the testing criteria for the years 2000 through 2004. Analysis of the overall quality of the HMA is accomplished by reviewing the Calculated Pay Factor Composite (CPFC) and Incentive/Disincentive Payments (I/DP). Analysis of each of the test elements: asphalt content, voids in mineral aggregate, air voids, mat density, and joint density is presented in tables, figures, and reports. Various data groupings are used to evaluate the data including: year, region, & grading. The specification and the projects are performing reasonably well. Over the five-year time period more projects have received incentive payments than disincentive payments. The average pay over the five years is 1.00848. The quality levels in the individual elements are at reasonable levels. Over the five-year time period the VMA element has the best quality levels with an average of 95.00. Mat density has the next best results with an average of 92.89. Air voids and percent asphalt are third and fourth with average quality levels of 90.41 and 89.86. Joint density testing has been a requirement beginning in 2003. The pay factor for this element is just under 1.0 but is expected to increase as contractors gain experience in this area.

Full-text PDF of this report is available for free download at

<http://www.dot.state.co.us/Publications/PDFFiles/Voids2006.pdf>

## *Item 3*

**Life Cycle Costing**  
*COLORADO DEPARTMENT OF TRANSPORTATION*  
*CDOT-DTD-R-2006-3 • 2006*

The research project was initiated by the Colorado Department of Transportation (CDOT) to develop guidelines for determining the long-term costs of adding additional capacity and other related transportation improvements to the state highway and bridge system. Future costs, including ongoing maintenance, rehabilitation, and replacement costs have not been traditionally considered when a project is advanced. At the planning level this project allows for CDOT to estimate the future cost of adding capacity to the transportation system and to assess the impacts that transportation related projects will have on future year budgets. In completing the project a methodology was proposed that would capture the incremental increase in long-term project costs associated with adding additional capacity to the system. Incremental costs were defined as not only geometric increases, but also include such things as roadway and bridge maintenance, ITS deployment and maintenance, and roadway and bridge rehabilitation. Incremental costs were identified as long-term projects costs that CDOT would have to account for in future budgets. As anticipated, research results reflect that long-term project costs associated with capacity improvements to the state transportation system will require additional financial resources in future years.

Full-text PDF of this report is available for free download at

<http://www.dot.state.co.us/Publications/PDFFiles/lcc.pdf>

# Research Digest

---

## **Item 4**

### **Evaluation of the Performance, Cost-Effectiveness, and Timing of Various Preventive Maintenances: Interim Report**

*COLORADO DEPARTMENT OF TRANSPORTATION*

*CDOT-DTD-R-2006-6 • 2006*

This research is being conducted to evaluate the performance of various preventive maintenance treatments over time and under different environmental conditions to assess the economics of each treatment type. The first three tasks of this research are nearing completion. Task 1 is a review of the state of the practice for preventive maintenance. This review includes a conventional literature survey and interviews of maintenance and construction personnel throughout the state. Task 2 is a draft manual of best practices of pavement preventive maintenance and Task 3 includes selection and construction of full-scale test pavements for field evaluation of various preventive maintenance treatments. Results of Task 1 indicate there are three primary techniques utilized in Colorado for preventive maintenance of asphalt pavements and three for concrete pavements. These are for asphalt pavements: 1) crack sealing, 2) chip seals, and 3) thin hot mix asphalt overlays and for concrete pavements: 1) joint resealing, 2) cross-stitching, and 3) micro-grinding. Task 2 has resulted in a preliminary draft of what will become a best practices manual for the preventive maintenance techniques currently used in Colorado as well as additional methods used by other agencies. Full scale test sections were constructed as part of Task 3 in 2005 and some additional test sections previously constructed were also included for measurement of future performance. These test sections include crack sealing, chip seals, thin overlays, joint resealing, cross-stitching and micro-grinding. Implementation: This in an interim report of research in progress. Implementation is not warranted at this time.

Full-text PDF of this report is available for free download at

<http://www.dot.state.co.us/Publications/PDFFiles/preventivemaint.pdf>

## **Item 5**

### **Application of a Micro-Simulation Model to Estimate the Effectiveness of Toll Pricing Alternatives on the Diversion of Traffic to Toll Facilities**

*FLORIDA DEPARTMENT OF TRANSPORTATION*

*FDOT DB-550 • 2005*

The main objectives of this project were to evaluate the effectiveness of alternative toll reduction scenarios on diverting traffic to Turnpike facilities such as SR 417. PARAMICS, a microscopic simulation software was validated using available data for a network of major highways and arterials in the surrounding Central Florida area to provide acceptable simulation accuracy based on pre-identified performance measures such as traffic volume and travel speed.

Full-text PDF of this report is available for free download at

[http://www.dot.state.fl.us/research-center/Completed\\_Proj/Summary\\_TPK/FDOT BD550 01 rpt.pdf](http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_TPK/FDOT BD550 01 rpt.pdf)

# Research Digest

---

## *Item 6*

### **Multimodal Optimization of Urban Freeway Corridors**

ARIZONA DEPARTMENT OF TRANSPORTATION

FHWA-AZ-06-582 • 2006

The findings of the study are two-fold: the results of what forms of multi-modal travel are used by other states and the results of the case study. Many states employ or are planning high occupancy vehicle (HOV) lanes (of all forms/types, but primarily of the concurrent flow variety) for use in urban freeway settings. High occupancy/toll (HOT) lanes were in the planning stages according to about half of the survey respondents while bus rapid transit (BRT) was being considered by two-thirds of the departments responding. Light rail transit (LRT) was only listed in 33% of the responses as being currently in use. HOT Lanes, Exclusive-Use Lanes, By-pass/Separation Lanes, Dual Facilities, and LRT had the highest number of responses for not being used as a multi-modal application within a freeway corridor. The SR 51 case study relied on existing data, modeled situations, and cost estimates to determine the most cost effective choice for multi-modal travel. Existing volume data was provided by Arizona Department of Transportation's Freeway Management System (FMS) and supplemented by a microsimulation study previously conducted for the Arizona Department of Transportation (AZDOT) concerning the operations of the existing HOV lanes. Cost data was coalesced from literature review material and transportation data sources exclusive to Arizona. The computations factored in traffic flows under different freeway scenarios depicting different forms of multi-modal travel that would be reasonable for the SR 51 freeway. The results, ranked from most cost-effective to least cost-effective, are as follows (Note: "GP" refers to general purpose lane, and the ranges of cost values are due to different calculation methods for the projected volume by mode): 1. HOT Lane (\$0.012 to \$0.027 per person-mile) 2. Fourth GP Lane (\$0.019 to \$0.042 per person-mile) 3. HOV (w/BRT) Lane (\$0.026 to \$0.057 per person-mile) (existing condition) 4. Exclusive BRT Lane (\$0.066 to \$0.147 per person-mile) 5. Light Rail Transit (\$0.161 to \$0.358 per person-mile)

Full-text PDF of this report is available for free download at

[http://www.dot.state.az.us/TPD/ATRC/publications/project\\_reports/PDF/AZ582.pdf](http://www.dot.state.az.us/TPD/ATRC/publications/project_reports/PDF/AZ582.pdf)

## *Item 7*

### **Price Trends for Major Roadway Inputs**

ARIZONA DEPARTMENT OF TRANSPORTATION

FHWA-AZ-06-622 • 2006

Fluctuations in construction costs make the tasks of estimating the price of a project and the overall highway program difficult. The objective of this research project was to examine the price fluctuations of the most heavily used construction commodities over both the short and long terms. An index for each of these commodities has been created. The implementation plan for this project is to generate a monthly update of these indices and distribute it to personnel charged with estimating future construction costs for projects and budgeting the highway construction and maintenance programs.

Full-text PDF of this report is available for free download at

[http://www.dot.state.az.us/TPD/ATRC/publications/project\\_reports/PDF/AZ622.pdf](http://www.dot.state.az.us/TPD/ATRC/publications/project_reports/PDF/AZ622.pdf)

# Research Digest

---

## *Item 8*

### **Modeling Hurricane Evacuation Traffic: Testing the Gravity and Intervening Opportunity Models as Models of Destination Choice in Hurricane Evacuation**

*LOUISIANA TRANSPORTATION RESEARCH CENTER*

*FHWA/LA.06/407 • 2006*

The test was conducted by estimating the models on a portion of evacuation data from South Carolina following Hurricane Floyd, and then observing how well the models reproduced destination choice at the county level on the remaining data. The tests showed the models predicted destination choice on the remaining data with similar accuracy. The Gravity Model predicted evacuation to friends or relatives in 110 different counties with an average error of 1.55 evacuations over all destinations, while the corresponding error for the IOM was 1.64. For evacuation to hotels or motels in 70 different counties, the Gravity Model gave an average error of 1.48 evacuations and the IOM an average error of 1.50. However, when the IOM was modified to make the sequencing of opportunities sensitive to the direction of evacuation relative to the path of the storm, the modified IOM performed slightly better than the Gravity Model with average errors of 1.55 and 1.43 evacuations to friends and relatives, and motels and hotels, respectively. The transferability of the Gravity Model for evacuations to friends and relatives was also tested in this study by applying the model estimated on the Hurricane Floyd data in South Carolina to data from Hurricane Andrew in Louisiana. Transferability was tested by comparing the trip length frequency distributions from the two data sets, the similarity of friction factors from models estimated on each data set, and the ratio of the Root-Mean-Square-Error (RMSE) of destination predictions of a locally-estimated model to a transferred model on the Andrew data. No significant statistical difference was found between the trip length frequency diagrams or the sets of friction factors at the 95 percent level of significance. The ratio of RMSEs on the Andrew data was 0.67, indicating that the average error of a locally-estimated model was 67 percent that of the transferred model.

Full-text PDF of this report is available for free download at

[http://www.ltrc.lsu.edu/pdf/2006/fr\\_407.pdf](http://www.ltrc.lsu.edu/pdf/2006/fr_407.pdf)

## *Item 9*

### **Preventive Maintenance Treatments of Flexible Pavements: A Synthesis of Highway Practice**

*MONTANA DEPARTMENT OF TRANSPORTATION*

*FHWA/MT-06-009/8117-26 • 2006*

An extensive literature review was conducted to synthesize past and ongoing research related to highway pavement maintenance and preservation techniques. The literature review was augmented with a web-based email survey that was distributed to all 50 U.S. states, Washington D.C. and 11 Canadian provinces, for a total of 62 recipients. The literature review and survey results provide interesting qualitative overviews of the state-of-the-practice of preventative maintenance treatments, and how these treatments are instigated, managed, and accessed by transportation department personnel throughout North America. This report focuses on studies that quantified the performance of various preventative maintenance treatments, including the effect these treatments have on pavement performance. The study indicates that ranges of reported life expectancies for treatment systems vary widely, as does reported unit costs. The lack of conclusive quantitative data is attributed to variations in the many aspects of treatment systems. Additional research is needed to quantify and enhance our understanding of the short and long-term effects that treatment systems have on highway pavement surfaces. State- or region-specific research is critically important to ensure that funds are wisely used for extending the life of a pavement section or for repairing ailing pavement surfaces.

Full-text PDF of this report is available for free download at

[http://www.mdt.mt.gov/research/docs/research\\_proj/prevent\\_maint/final\\_report.pdf](http://www.mdt.mt.gov/research/docs/research_proj/prevent_maint/final_report.pdf)

# Research Digest

---

## ***Item 10***

### **Anchor Bolt Behavior in ASR/DEF-Damaged Drilled Shafts**

*TEXAS DEPARTMENT OF TRANSPORTATION (TxDOT)*

*IAC 88-5DDIA004 • 2007*

The primary objective of this research is to evaluate the effect of Alkali-Silica Reaction (ASR) and Delayed Ettringite Formation (DEF) on the structural performance of High Mast Illumination Pole (HMIP) foundations and if needed, to recommend a possible retrofitting method to strengthen them and prevent further damage. To achieve this goal, six full-scale field tests were conducted in the Houston area. Two types of drilled shafts were examined: 16-anchor drilled shafts supporting 150-ft high HMIPs; and 20-anchor drilled shafts supporting 175-ft high HMIPs. One of the 20-anchor drilled shafts was repaired by wrapping with Carbon Fiber-Reinforced Polymer (CFRP) laminate. Observed performance under field tests was also evaluated in the context of the design wind loads of the AASHTO Specifications (2001) and ASCE 7-05 (2005). Failure modes and the related load-transfer mechanisms were investigated and some design recommendations were suggested for better design of drilled shafts.

Full-text PDF of this report is available for free download at

<http://library.ctr.utexas.edu/pdf/5DDIA004.pdf>

## ***Item 11***

### **Vegetation Establishment on Roadway Shoulders**

*NEBRASKA DEPARTMENT OF ROADS*

*NDOR P548 • 2006*

The impact of seed priming on stand establishment varied by species and location. Frequency scores of tall fescue generally were high at the Geneva and Wahoo sites regardless of priming treatment; tall fescue readily germinated and established even without priming. Tall fescue was the principal species in the seeding mixtures and dominated the stands at these two sites; therefore, priming did not appear to affect stand density. However, the establishment of biuffalograss and blue grama was generally enhanced by seed priming. The response of western wheatgrass to seed priming was mixed. Because of poor stand establishment, results from the Bartlett site did provide meaningful information on the Sandhills mixture. Overall, under roadside conditions, seed priming appears to positively impact the germination and establishment of warm-season shortgrasses in eastern Nebraska.

Full-text PDF of this report is available for free download at

<http://www.nlc.state.ne.us/epubs/R6000/B016.0110-2006.pdf>

# Research Digest

---

## *Item 12*

### **Restricted-Zone Requirements for Superpave Mixes Made with Local Aggregate Sources**

*NEBRASKA DEPARTMENT OF TRANSPORTATION*

*NDOR P556 • 2006*

The fine aggregate specification for Superpave hot mix asphalt (HMA) mixtures includes a restricted zone (RZ) that forms a band through which gradations were recommended not to pass, since mixtures passing through the RZ are believed to be rut-susceptible. However, the RZ requirement has long been a contentious issue, leading to many research efforts to investigate the effects of RZ on HMA performance. A generally agreed upon conclusion from the national research is that the RZ criterion is redundant and should be eliminated from the Superpave specification. Although the elimination of the RZ requirement is suggested today, it still remains questionable, since the research conclusion has often been made for a premium mix designed with high-quality aggregates, which is not the case for low volume Nebraska pavements. Therefore, this research was undertaken to evaluate the RZ effects on rutting-associated performance particularly for low volume local-road mixes (called SP2 mix in Nebraska). In addition, mechanical impact due to fine aggregate angularity (FAA) on HMA performance was also evaluated. Five mixes (one above-RZ mix, two through-RZ mixes with different gradations, and two below mixes with different FAA values) were designed and tested by using a simple performance testing device, the asphalt pavement analyzer (APA). Based on APA performance testing results, it can be concluded that finer-graded mixes are generally similar to or better than coarser-graded mixes. Consequently, the Superpave RZ requirements may not be a factor governing HMA mix design and performance. One more interesting fact observed from this study is that insufficient FAA in coarse-graded mixes might cause more severe rut-damage in HMA. Preliminary findings from this study can be strengthened with more laboratory data and additional work. Suggested follow-up studies conclude this report. Full-text PDF of this report is available for free download at <http://www.nlc.state.ne.us/epubs/R6000/B016.0108-2006.pdf>

## *Item 13*

### **Probe Sampling Strategies for Traffic Monitoring Systems Based on Wireless Location Technology**

*VIRGINIA TRANSPORTATION RESEARCH COUNCIL*

*VTRC 07-CR-12 • 2007*

Transportation agencies have become very interested in traffic monitoring systems based on wireless location technology (WLT) since they offer the potential of collecting travel time data across a wide portion of the road system. Prior tests of WLT-based systems have been unsuccessful, in part because they have treated the road network as a homogeneous entity. This "area-wide" method has inherent limitations, causing congested roadways to be over sampled and uncongested and low volume roads to be under sampled. This project developed a methodology to estimate sampling parameters based on localized traffic conditions in the network, termed a "zonal approach." In zonal WLT systems, the roadway network is disaggregated into smaller areas, termed "zones," based on cellular coverage areas. In this research, two zonal sampling strategies were examined and tested using three simulated networks. When the road network is complex, the zonal priority sampling strategy was found to distribute probes throughout the network and produced a larger number of speed estimates on uncongested and low volume roads. Moreover, the zonal priority strategy improved speed estimation accuracy by 10 percent over the other two sampling strategies. For networks with simple geometry or uniform congested traffic conditions, there were no significant differences among the sampling strategies. The results of this research indicate that the homogeneous approach used by earlier deployments has limitations, and results could be potentially improved by tailoring sampling parameters to a more localized level.

Full-text PDF of this report is available for free download at

[http://www.virginiadot.org/vtrc/main/online\\_reports/pdf/07-cr12.pdf](http://www.virginiadot.org/vtrc/main/online_reports/pdf/07-cr12.pdf)

# Research Digest

---

## *Item 14*

### **Evaluation of Truck Lane Restrictions in Virginia**

*VIRGINIA TRANSPORTATION RESEARCH COUNCIL*

*VTRC 07-CR11 • 2007*

A number of states have implemented truck lane restrictions in an attempt to improve safety and mobility on freeways. These restrictions typically prohibit trucks from traveling in the median lane, potentially increasing passing opportunities and reducing negative interactions between slow-moving trucks and other vehicles. Virginia currently has two forms of truck restrictions in place. The first type of restriction prohibits trucks from the median lane of interstates that have three or more lanes by direction, provided certain criteria on speed limit and location are satisfied. The second type of restriction prohibits trucks from traveling more than 15 mph below the posted speed limit in the left lane of two-lane directional interstate segments. This report documents the results of a safety and operational evaluation of Virginia's truck lane restrictions. Crash data were examined at a total of 43 sites with restrictions and 16 similar sites without restrictions. Likewise, operational data were collected at 7 sites with restrictions and 6 similar sites without restrictions. The results of the analysis showed that the restrictions on two-lane sites appeared to be having a positive impact on operations and safety. At these sites, crashes were reduced by 23 percent, and speeds were estimated to have increased by 5.5 mph. At the three-lane sites, no statistically significant increase in speed was observed. A breakpoint in crash performance appeared to occur at approximately 10,000 vehicles per day per lane. Roads below this threshold experienced significantly fewer crashes than anticipated, whereas roads above this level had significantly more crashes than expected.

Full-text PDF of this report is available for free download at

[http://www.virginiadot.org/vtrc/main/online\\_reports/pdf/07-cr11.pdf](http://www.virginiadot.org/vtrc/main/online_reports/pdf/07-cr11.pdf)

# Research Digest

---

## *Item 15*

### **Simulation Model Calibration and Validation: Phase II: Development of Implementation Handbook and Short Course**

*VIRGINIA TRANSPORTATION RESEARCH COUNCIL*

*VTRC 07-CR5 • 2006*

A previous study developed a procedure for microscopic simulation model calibration and validation and evaluated the procedure via two relatively simple case studies using three microscopic simulation models. Results showed that default parameters were unacceptable while calibrated parameters were able to replicate field conditions. Consequently, the study recommended that microscopic simulation models be calibrated and validated before they were used for any evaluations and analyses. A technical review panel determined that the previously developed procedure might not be readily adoptable by Virginia Department of Transportation (VDOT) traffic engineers due to its extensive use of advanced statistical tools and a lack of hands-on case study material. In addition, the proposed procedure needed to be tested with complex network conditions such as urban arterial networks and congested freeway systems. Consequently, it was concluded that what is now needed is (1) a handbook for simulation model calibration and validation that can be easily used by VDOT engineers, and (2) tests of the procedure for various network conditions. The purpose of this project was to develop a handbook for simulation model calibration and validation for VDOT traffic engineers to use for their simulation work and to develop and conduct a hands-on short course to instruct them in the use of the handbook. This study recommended the following: 1.) VDOT traffic engineers should calibrate and validate microscopic simulation models by using the enhanced procedure (i.e., multiple performance measures-based procedure) before using them for any engineering applications to ensure reliable results provided for better decision-making. 2.) When VDOT traffic engineers conduct microscopic simulation model calibration and validation, multiple performance measures collected for multiple days should be used to obtain more reliable results. 3.) Additional hands-on short courses should be offered to expose the procedure to more VDOT traffic engineers and possibly others including consultants who would work for VDOT in the future. VDOT's Learning Center and UVA Center for Transportation Studies Local Technical Assistance Program (LTAP) are possible avenue to offer such short courses. 4.) The handbook should be distributed to VDOT traffic engineers who currently use or plan to use microscopic simulation models for engineering applications. In addition, the prototype program and hands-on short course material (Park, 2006) should be accessible to VDOT traffic engineers. Full-text PDF of this report is available for free download at [http://www.virginiadot.org/vtrc/main/online\\_reports/pdf/07-cr5.pdf](http://www.virginiadot.org/vtrc/main/online_reports/pdf/07-cr5.pdf)

## *Item 16*

### **Microscopic Simulation Model Calibration and Validation Handbook**

*VIRGINIA TRANSPORTATION RESEARCH COUNCIL*

*VTRC 07-CR6 • 2006*

Microscopic traffic simulation models are widely used in the transportation engineering field. Because of their cost effectiveness, risk-free nature, and high-speed benefits, areas of use include transportation system design, traffic operations, and management alternatives evaluation. Despite their popularity and value, the credibility of simulation models falls short due to the use of default parameters without careful consideration. Improper model parameters prevent simulation models from accurately mimicking field conditions, limiting their ability to aid decision-making. Therefore, the user needs to pay more attention to fine-tune each model that they are using by calibrating the parameters inside the model. To summarize, we can define calibration as the adjustment of model parameters such that the model's output more closely represents field conditions. The intention of this handbook is to outline and explain the calibration and validation procedure for the parameters controlling human and vehicle characteristics for CORSIM and VISSIM.

Full-text PDF of this report is available for free download at [http://www.virginiadot.org/vtrc/main/online\\_reports/pdf/07-cr6.pdf](http://www.virginiadot.org/vtrc/main/online_reports/pdf/07-cr6.pdf)

# Research Digest

---

## *Item 17*

### **Pavement Marking Visibility Requirements During Wet Night Conditions**

*VIRGINIA TRANSPORTATION RESEARCH COUNCIL*

*VTRC 07-CR7 • 2006*

This study investigated the performance of pavement markings in wet night conditions. Typically, performance will decrease in wet conditions. The degradation is a result of flooding of the marking optics and a change in the optical media, thereby reducing retroreflectivity and the visibility distance. Several technologies are available to improve the visibility of markings under wet conditions. This study used four technologies and evaluated them in a dynamic situation. In the experiment, vehicles were driven by older participants and visibility was measured based on the detection distances of the beginning or ending of a continuous edge marking. The results indicate that a specifically designed wet retroreflective tape performed better than the currently used paint and glass bead technology. Paint with large glass beads and profiled thermoplastics also showed an improvement over the standard paint and glass bead technology. A relationship between retroreflectivity and the detection distance was found, which was used to postulate a minimum required value for visibility during wet night conditions. A value of 200 mcd/m<sup>2</sup>/lx appears to provide a reasonable detection distance for a minimum performance requirement.

Full-text PDF of this report is available for free download at

[http://www.virginia-dot.org/vtrc/main/online\\_reports/pdf/07-cr7.pdf](http://www.virginia-dot.org/vtrc/main/online_reports/pdf/07-cr7.pdf)

## *Item 18*

### **History of Early Bridge Specifications: a Reprint of a Paper by J. N. Clary**

*VIRGINIA TRANSPORTATION RESEARCH COUNCIL*

*VTRC 07-R10 • 2006*

This report is a reprint of an informed review of the specifications for iron and steel bridges, both railroad and highway structures, dating from the mid-19th through the early 20th centuries. It is reprinted with only minor editing as a companion to an earlier report, Best Practices for the Rehabilitation and Moving of Historic Metal Truss Bridges, VTRC 06-R31. The document was discovered in the files of VDOT's Structure & Bridge Division during research for the earlier study. The folder containing the paper ascribed its authorship to Mr. J. N. Clary, State Bridge Engineer from 1952 to 1972 and Chair of the Transportation Research Board's Structures Section from 1962 to 1969. It is a document that reflects the thinking and practice of the bridge engineering practice of the late 19th and first part of the 20th centuries and the gradual evolution of specifications for metal bridges during that period. It is believed that the document will be of interest to cultural resource personnel and bridge engineers interested in historic metal bridges.

Full-text PDF of this report is available for free download at

[http://www.virginia-dot.org/vtrc/main/online\\_reports/pdf/07-r10.pdf](http://www.virginia-dot.org/vtrc/main/online_reports/pdf/07-r10.pdf)

# Research Digest

---

## *Item 19*

**Investigation of Proposed AASHTO Rut Test Procedure Using the Asphalt Pavement Analyzer**  
*VIRGINIA TRANSPORTATION RESEARCH COUNCIL*  
*VTRC 07-R11 • 2006*

The Virginia Department of Transportation uses the Asphalt Pavement Analyzer with beam specimens to test and approve asphalt mixtures for rut resistance. Some agencies use cylindrical specimens that impart distinct testing advantages such as the ease of fabrication. This study attempted to develop a correlation between measurements using beams and cylindrical specimens. A secondary purpose was to locate and test mixes that had rutted in the field so that the precise laboratory criteria that define rutting could be determined. The tentative AASHTO procedure using cylindrical specimens with 4 percent air voids provided poor correlations with the conventional beam test results. A second testing using 8 percent air voids provided a better correlation, but the testing of cylindrical specimens was more variable than the testing of beam specimens. Therefore, the researchers recommended that VDOT continue testing beam specimens for approval and research. Correlations were developed that will allow the automated system of rut measurement to be used for future testing. VDOT pavements were found to develop negligible rutting, so the attempt to identify failed sections and ultimately failure criteria were not successful. Full-text PDF of this report is available for free download at [http://www.virginiadot.org/vtrc/main/online\\_reports/pdf/07-r11.pdf](http://www.virginiadot.org/vtrc/main/online_reports/pdf/07-r11.pdf)

## *Item 20*

**A Toolkit of Measures for Reducing Animal-Vehicle Collisions**  
*VIRGINIA TRANSPORTATION RESEARCH COUNCIL*  
*VTRC 07-R13 • 2006*

Animal-vehicle collisions are a growing concern in terms of human safety; costs related to injury, property damage, and disposal; and the viability of wildlife populations. These collisions are rapidly increasing throughout the United States, and Virginia is consistently ranked among the states with the highest number of deer-vehicle collisions, in particular. Federal and state agencies have consequently placed added pressure on transportation departments to implement measures to reduce these incidents. It is often unclear to transportation practitioners, however, which mitigation measures are effective and where, how, and under what circumstances to use a measure for a particular road project. Although determining a definitive solution for any particular situation is difficult, the toolkit developed in this study is intended as a "quick" guide to provide information on the latest research available on the effectiveness of various mitigation measures to reduce animal-vehicle collisions. More extensive information on one particularly effective technique, wildlife crossings, is provided to assist in implementation and design decisions. Full-text PDF of this report is available for free download at [http://www.virginiadot.org/vtrc/main/online\\_reports/pdf/07-r13.pdf](http://www.virginiadot.org/vtrc/main/online_reports/pdf/07-r13.pdf)

# Research Digest

---

## *Item 21*

### **Use of a GIS-Based Model of Habitat Cores and Landscape Corridors for the Virginia Department of Transportation's Project Planning and Environmental Scoping**

*VIRGINIA TRANSPORTATION RESEARCH COUNCIL*

*VTRC 07-R14 • 2006*

As important habitats are being lost to human development, transportation agencies are facing increased expectations that their road projects avoid or minimize further habitat destruction and adverse effects on wildlife populations. Wildlife linkage or landscape corridor analyses are being conducted in an increasing number of states, and more transportation agencies are using this information during the planning of proposed road projects. The Virginia Department of Conservation and Recreation's Natural Heritage Program is creating a GIS tool, the Virginia Natural Landscape Assessment (VANLA), that identifies large patches of natural land cover (habitat cores) and the habitat linkages connecting these areas (landscape corridors). This analysis can be integrated into the Virginia Department of Transportation's (VDOT) existing GIS applications for access by staff involved with transportation planning and environmental scoping activities. Analyzing a proposed project in the early stages of project development would allow VDOT to identify important natural resource areas and habitat corridors to avoid or for which mitigation may be appropriate or necessary. This can result in fewer project delays, promote collaboration between VDOT and state natural resource and regulatory agencies, and meet the directives of the new habitat conservation provision in SAFETEA-LU, the federal transportation legislation. In addition, basing particular project decisions on a project's location relative to a habitat corridor can decrease the risk of costly animal-vehicle collisions.

Full-text PDF of this report is available for free download at

[http://www.virginiadot.org/vtrc/main/online\\_reports/pdf/07-r14.pdf](http://www.virginiadot.org/vtrc/main/online_reports/pdf/07-r14.pdf)

# Research Digest

---

## *Item 22*

### **Design of a High-Binder–High-Modulus Asphalt Mixture**

*VIRGINIA TRANSPORTATION RESEARCH COUNCIL*

*VTRC 07-R15 • 2007*

Recent studies on long-life flexible pavements indicate that it may be advantageous to design and construct asphalt mixtures comprising the underlying layers in such a manner that very dense mixtures are produced. This will improve not only the fatigue characteristics but also durability through a decrease in air voids. A 19.0 mm mixture was designed and tested at asphalt contents (ACs) higher than the optimum design level. Stiffer binder and recycled asphalt pavement (RAP) were employed to help maintain stiffness in order to prevent instability. The field voids were predicted to decrease approximately 1.0 to 1.5 percent for each 0.4 percent increase in AC, which would improve durability. Flexural stiffness peaked for an 0.5 percent increase in AC, and fatigue life trended upward but needed approximately 1.0 percent additional asphalt for a major beneficial effect. Permeability improved slightly as AC was increased. The researchers think that the Hamburg test would have been more appropriate for this study than the tensile strength ratio test, which indicated no improvement in stripping susceptibility with an increased AC, because it might simulate field conditions better. In addition, the Mechanistic-Empirical Pavement Design Guide Software (Version 0.900) was used to evaluate trial pavement designs with several design alternatives, including varying the binder performance grade, effective binder volume, and air void content to determine the resultant changes in predicted fatigue cracking and rutting of hot-mix asphalt (HMA) layers. This theoretical pavement analysis indicated that increasing the binder content of the HMA intermediate layer beyond the design optimum and increasing the stiffness of the intermediate layer by increasing the high-temperature binder performance grade slightly decreased the predicted fatigue cracking and reduced the rutting of the HMA layers. The analysis also showed that more significant reductions in the predicted fatigue cracking could be realized by increasing the binder content of the HMA base layer slightly beyond the optimum and by reducing the in-place air void content of the HMA base layer. It was recommended that VTRC should further investigate the effects of higher binder contents and lower air voids on the performance of base mixes. Further study of current void criteria to verify optimum pavement performance is also recommended. This project provides a stepping stone to achieve long-lasting perpetual-type flexible pavement. Designs with a high binder content offer the potential to reduce fatigue cracking 20 to 60 percent by incorporating additional asphalt binder and reducing the void content of asphalt base. The use of RAP to maintain the necessary stiffness for high binder contents should provide comparable stiffness to an increasingly expensive PG 70-22 binder for base material. Some effort is taking place in 2007 for reducing voids in base mixes with high RAP content; however, quantification of the economic benefits from that endeavor will be a future goal.

Full-text PDF of this report is available for free download at

[http://www.virginia.gov/vtrc/main/online\\_reports/pdf/07-r15.pdf](http://www.virginia.gov/vtrc/main/online_reports/pdf/07-r15.pdf)

# Research Digest

---

## *Item 23*

### **Visibility of Steel Plates Used in Connection with Highway Repairs**

*VIRGINIA TRANSPORTATION RESEARCH COUNCIL*

*VTRC 07-R16 • 2006*

Steel plates are used primarily in urban areas where an excavation is made in the roadway for utility work, such as installing or replacing utility lines, pipes, and conduits. The steel plate is positioned on the roadway to cover the excavation and allow traffic to proceed when utility work is not underway. Motorcyclists are challenged when they traverse a plate unexpectedly. Although the Virginia Department of Transportation has policies and procedures in place that all but eliminate the use of steel plates on the roads it maintains, such plates are used frequently in urban areas. House Bill 408 passed by the 2004 Virginia General Assembly required the Virginia Transportation Research Council to examine best practices to improve the visibility of steel plates to help make motorcyclists more aware of their presence. Although the bill was vetoed by the governor because of a technicality on the timing of the two parts of the bill, VTRC proceeded with the examination. The purpose of this study was to examine best practices for the use of markings to improve the visibility of steel plates. As a secondary objective, the ancillary effects of such markings on skid resistance were examined. State and local transportation agencies were contacted to determine their practices. This information was compiled, and promising means of improving the visibility of steel plates were examined. A stakeholder task group was created to participate in this effort. Task group members included motorcyclists, VDOT and local government staff and representatives, and representatives of utility companies and utility contractors. No state DOT marked plates to improve visibility. Warning signs such as "BUMP" and "STEEL PLATE" were used by several agencies. The City of Richmond uses a "STEEL PLATE AHEAD" advance warning sign and a plate-marking pattern that delineates the corners of the plate. For plates more than 10 feet long, skip lines are added along the sides. A warning "STEEL PLATE" sign in combination with corner only pavement markings on the plates was the method selected by the study task group to improve the visibility of steel plates.

Full-text PDF of this report is available for free download at

<http://www.viriniadot.org/vtrc/main/online%5Freports/pdf/07-r16.pdf>

# Research Digest

---

## *Item 24*

### **Identification of Core Functions and Development of a Deployment Planning Tool for Safety Service Patrols in Virginia**

*VIRGINIA TRANSPORTATION RESEARCH COUNCIL*

*VTRC 07-R17 • 2006*

The purpose of this study was to identify and document the core functions of the Virginia Department of Transportation's (VDOT) Safety Service Patrol (SSP) programs and to develop a deployment planning tool that would help VDOT decision-makers when considering expanding SSP coverage and/or altering existing route coverage. The study involved a literature review of the functions, mission statements, objectives, and deployment criteria of other SSP programs across the United States that are commonly accepted as successful; documentation of the functions currently provided by VDOT's SSP programs and the benefit each provides; and the development of an SSP deployment planning tool. VDOT's SSP programs share core functions, but the urban and rural programs differ in the type of benefits they emphasize. Urban regions place greater emphasis on the benefits associated with reduced travel delays and number of secondary crashes, and rural regions place greater emphasis on the benefits associated with improved safety for motorists in distress and creation of goodwill for VDOT. The study recommends that VDOT's regional operations directors prioritize the core functions of their programs in relation to the direct, indirect, and incidental benefits each provides. Emphasis should be placed on those core functions that provide the most direct benefits. Indirect and incidental benefits are also of importance and should not be overlooked in the prioritization process. The planning tool developed in this study is a segment-based ranking scheme that can be applied to rural and urban freeway segments. Within the tool an incident prediction model was developed to predict incidents statistically using freeway segment average annual daily traffic (AADT), length, average daily percent of ADT served, and truck percentage. The study recommends that the SSP deployment planning tool be used by VDOT's regional operations directors as they consider deploying new patrols or altering existing ones. To do this, existing and potential SSP routes should be included in the evaluation. Each route must be divided into its constituent segments (traffic links), and each segment scored using the predicted number of incidents, level of service, planned projects, air quality, maximum access distance, maximum structure length, AADT, and daily truck volume. Routes should then be ranked based on their scores. Hypothetically, if three routes (X, Y, and Z) are under consideration for SSP deployment in an urban region and funding is made available for only one deployment, the planning tool will indicate the route that will provide the greatest return on investment. For example, if the annual costs of operating an SSP on a route are \$275,000 and if routes X, Y, and Z have benefit/cost ratios of 4.8, 4.3, and 3.1, respectively, the benefits to VDOT of choosing route X over route Y or Z are \$137,500 and \$467,500, respectively.

Full-text PDF of this report is available for free download at

<http://www.virginiadot.org/vtrc/main/online%5Freports/pdf/07-r17.pdf>

# Research Digest

---

## *Item 25*

### **Reflectivity of Pavement Markings: Analysis of Retroreflectivity Degradation Curves**

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION

WA-RD 592-1 • 2006

The intent of this project was to develop retroreflectivity degradation curves for roadway pavement markings. To accomplish this objective, this study utilized a vehicle-mounted Laserlux retroreflectometer to take measurements on approximately 80 test sections throughout Washington state. The resulting retroreflectivity values from roadways with similar average annual daily traffic (AADT) and environments displayed a significant amount of variability. Best-fit trendlines were extrapolated to determine when each category of paint would fall below a selected minimum threshold of 100 mcd/m<sup>2</sup>/lux and require repainting. Unfortunately, given the variability of the data observed to date, it may not be possible, even with the collection of more data, to create striping performance predictions that have a high level of statistical confidence. The data do not suggest conclusively that the existing WSDOT striping schedule should change. According to that schedule, long line painted markings should be painted at least once a year, and heavy wear, long line pavement markings should be painted at least twice a year.

Full-text PDF of this report is available for free download at

<http://depts.washington.edu/trac/bulkdisk/pdf/592.1.pdf>

## *Item 26*

### **AVL-Equipped Vehicles as Speed Probes (Final Phase)**

WASHINGTON STATE TRANSPORTATION CENTER

WA-RD 617.1 • 2006

The Washington State Department of Transportation (WSDOT) operates a central traffic management system (TMS) for both day-to-day surveillance and traveler information. Past efforts developed the ability to create real-time traffic speed information by using virtual sensors that are based on transit vehicle tracking data. In order for this new information source to be merged into the TMS, a number of questions, such as probe density in time and space, needed to be resolved. This report presents the solution developed at the University of Washington (UW). This solution provides real-time congestion information from Seattle area freeways and arterials—I-5, I-90, SR 520 and SR 99—to the WSDOT TMS using the Intelligent Transportation System (ITS) Backbone. This project harvests existing automatic vehicle location (AVL) data from within King County Metro Transit and transports the raw data to the UW, where a series of operations converts the data into roadway speed information. This roadway speed information is color coded on the basis of specific, localized conditions for the arterials and freeways to reflect traffic congestion. The resulting traffic data product is then provided to WSDOT as a data source for virtual sensors located in roadways where currently there are no inductance loops. In addition to creating the infrastructure for an AVL-equipped fleet to serve as probe vehicles, this project created several user interfaces for traveler information. One is “StoreView,” a Java application that displays the spatial and temporal average speeds of transit vehicles as color-coded bubbles on a map of the area’s major arterials and freeways. A second type of traveler information, analogous to TrafficTV and WSDOT’s pictographic traffic maps, is also available. This report documents both the technical issues addressed in creating a virtual sensor data stream from probe vehicle data and the creation of a set of real-time traveler information applications.

Full-text PDF of this report is available for free download at

<http://www.wsdot.wa.gov/research/reports/fullreports/617.1.pdf>

# Research Digest

---

*Item 27*

**Evaluation of the Influence of Tack Coat Construction Factors on the Bond Strength Between Pavement Layers**

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION

WA-RD 645.1 • 2006

This study investigated the influence of several factors on the adhesive bond provided by the tack coat at the interface between pavement layers. These factors included the surface treatment, curing time, residual application rate, and coring location. Three tests were performed for measuring the bond strength between an existing hot mix asphalt (HMA) and a new HMA overlay, namely the Florida DOT Shear Tester, the UTEP Pull Off Test, and the Torque Bond Test. Testing involved a CSS-1 type emulsion as the tack coat. The results from the three tests were statistically analyzed. Generally, milling provided a significantly better bond at the interface between the existing surface and the new overlay. Curing time had a minimal effect on the bond strength. The results indicated that the absence of tack coat did not significantly affect the bond strength at the interface for the milled sections, whereas it severely decreased the strength for the non-milled sections. The results also showed that increasing the residual rate of tack coat did not significantly change the bond strength at the interface. Lastly, the coring location was found to be an insignificant factor.

Full-text PDF of this report is available for free download at

<http://www.wsdot.wa.gov/research/reports/fullreports/645.1.pdf>

# Research Digest

---

## *Item 28*

### **Operational Remote Sensing Solutions for Estimating Total Impervious Surface Areas**

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION

WA-RD 653.1 • 2006

The Washington State Department of Transportation (WSDOT) commissioned this research, conducted by the Urban Ecology Research Laboratory (UERL) at the University of Washington, to assist in effectively designing and managing operational, maintenance, and improvement activities within the context of the many growth management and clean water regulations and ordinances in Washington State. The goals of this study were to 1) implement a classification scheme for mapping the percentage of total impervious surfaces due to different types of transportation infrastructure based on satellite imagery, 2) develop and assess a remote sensing methodology for detection of road impervious surface area (RISA) and the fraction of RISA compared to the total impervious surface area (TISA) and 3) make recommendations on the imagery best suited for identifying impervious surfaces related to transportation infrastructure. The results of this analysis have important implications regarding the use of remote sensing to determine the contribution of impervious surface from transportation infrastructure at regional scales. Higher resolution satellites, while more visually appealing, do not necessarily provide a net benefit in terms of accuracy that may justify their added expense. Our results indicate that, in most cases, Landsat performed as well if not better than the higher resolution SPOT imagery for determining regional scale roadway impervious surface area. The problem with using high resolution data for extracting road footprints at regional scales lies in the difficulty and cost of gathering a comprehensive set of imagery for the entire area of interest. Furthermore, extracting road footprints from high resolution imagery is a difficult proposition. Our findings recommend using digital imagery with other GIS data that can serve as a proxy for road footprints. Transportation rights-of-ways taken from vector parcel data were highly effective at limiting the area that could be considered as road. Using this in combination with Landsat impervious surface data proved to be an accurate and relatively simple way to estimate road impervious surface area. We recognize that not all areas are covered by the detailed parcel datasets used in this analysis. To fill these gaps, a simple predictive road impervious surface area model was developed using a combination of data developed and gathered for this project. Linear regression was used to build the model and road impervious surface area extracted from test sites was used as the independent, or predicted, variable. The predictors, or independent variables, used in the model were total impervious surface (as measured by Landsat or SPOT), urban area background, and total road length measured using readily available GIS transportation data. All three independent variables were significant with a 95% confidence interval and the model as a whole was significant at the 99% level. Full-text PDF of this report is available for free download at <http://www.wsdot.wa.gov/research/reports/fullreports/653.1.pdf>

# Research Digest

---

## *Item 29*

### **The Use of Weather Data to Predict Non-recurring Traffic Congestion**

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION

WA-RD 655.1 • 2006

This project demonstrates the quantitative relationship between weather patterns and surface traffic conditions. The aviation and maritime industries use weather measurements and predictions as a normal part of operations, and this can be extended to surface transportation. Data from two data mines on the University of Washington campus were combined to evaluate the quantitative relationship between freeway speed reduction and rain fall rate as measured by Doppler radar. The University of Washington's Atmospheric Science department maintains an archive of Nexrad radar data, and the Electrical Engineering department maintains a data mine of 20-second averaged inductance loop data. The radar data were converted into rainfall rate, and the speed data from the inductance loop speed traps were converted into a deviation from normal performance measure. The deviation from normal and the rainfall rate were used to construct an impulse response function that can be applied to radar measurements to predict traffic speed reduction. This research has the potential to accomplish (1) prediction of non-recurring traffic congestion and (2) prediction of conditions under which incidents or accidents can have a significant impact on the freeway system. This linkage of weather to traffic may be one of the only non-recurring congestion phenomena that can be accurately predicted. This project created algorithms and implementations to correlate weather with traffic congestion. Furthermore, it may provide a means for traffic management to determine where and when to proactively place resources to clear incidents.

Full-text PDF of this report is available for free download at

<http://depts.washington.edu/trac/bulkdisk/pdf/655.1.pdf>



