

TRANSPORTATION RESEARCH DIGEST

NOVEMBER-DECEMBER 2007

ARIZONA TRANSPORTATION INSTITUTE

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ARIZONA TRANSPORTATION INSTITUTE

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NOVEMBER-DECEMBER 2007

TO: TRANSPORTATION PROFESSIONALS, MANAGERS, & POLICY MAKERS

FROM: ARIZONA TRANSPORTATION INSTITUTE

The volume of information on transportation issues, policies, technologies, and related topics is huge. Not even the most well-read professional can keep up with everything that might be useful to know. The *Transportation Research Digest* series is designed to expedite the transmission of information by condensing and summarizing significant documents. Busy professionals or managers may quickly obtain the gist of new developments and determine whether they need to see the full document.

The *Transportation Research Digest* is not meant to present definitive resolutions of scientific or policy controversies, but contributions to the pursuit of knowledge and the debate of issues. The intent is to be comprehensive rather than conclusive on the multitude of issues and topics of concern to those working in the field of transportation. Readers are encouraged to obtain the original document summarized in the *Transportation Research Digest* and subject the content to their own judgment.

Transportation professionals who would like to recommend documents to be summarized or submit summaries to be considered for inclusion in this publication are invited to do so. To recommend a document please send a copy (or information indicating how a copy can be obtained) of the research report to be summarized. To be considered, the report must meet the following requirements: (1) it is transportation related, (2) it is no more than two years old, (3) there is enough information in the report to warrant a two page summary. To write a summary, insure that the document being summarized meets the above requirements. The summary should be submitted in an electronic format. This summary should be in the 500 to 800 word range and may include tables and/or simple graphics—all of which must fit within the *Transportation Research Digest's* two-page format. Submissions are subject to editing for clarity and length. We do not guarantee that all submissions will be published.

If you would like to obtain the full report upon which a *Transportation Research Digest* summary is based you have several options. Check your local university library. You may want to contact the publisher using the contact information appearing in the *Transportation Research Digest*. Some of the documents are free for the asking. Others can be purchased.

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Transportation Research Digests from December 1995 to November 2003 are available at <http://www.dot.state.az.us/ABOUT/atrc/Publications/DocRev/TRDtest.htm>

A “Topic” code in the Table of Contents will help readers more quickly identify items of interest. The topic codes are explained in the table below.

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ADM	Administration	PLAN	Planning
AIRP	Airports	PRIV	Privatization
AVIA	Aviation	RAIL	Railroads
BIKE	Bicycles	RDSO	Roadside
CON	Construction	ROW	Right-of-Way
ECON	Economics	SAFE	Safety
ENV	Environment	STR	Structures
FIN	Finance	TECH	Technology
INOV	Innovations	TOLL	Toll Roads
MAIN	Maintenance	TRAN	Transit
MISC	Miscellaneous	TRF	Traffic
MVD	Motor Vehicle Dept	TRK	Trucking
PAVE	Pavement	VEH	Vehicles

Requests or inquiries may be made via e-mail (jsemmens@cox.net).

Thank you.

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When Public Participation in Administration Leads to Trust: An Empirical Assessment of Managers' Perceptions by XiaoHu Wang, University of Central Florida and Montgomery Wan Wart, California State University at San Bernardino (*Public Administration Review*, Vol. 67 Issue 2 Page 188-366; <http://www.blackwell-synergy.com/toc/puar/67/2>) (March/April 2007)

Highlights

- Participation affects trust when the participation process eventually leads to the improvement of public services.
- Public trust increases when public officials demonstrate integrity, honesty, and moral leadership.
- Public trust increases when ethics are institutionalized in government through the process of participation.

This study has examined the argument that public participation enhances public trust. The results suggest that participation affects trust through two factors of administrative behavior. First, participation affects trust when it produces high-quality services that the public wants. Second, enhanced ethical behavior on the part of administration is another reason that participation leads to trust. Public trust increases when public officials demonstrate integrity, honesty, and moral leadership and when ethics are institutionalized in government through the process of participation.

The results also indicate that, although participation builds public consensus, consensus building alone does not lead to public trust. Consensus building is a process in which the public and government reach an agreement as to what needs to be done. Signing the agreement does not win public trust; fulfillment of the agreement does. A similar conclusion applies to the finding on accountability practices. Although participation enhances accountability of an organization,

public exposure to information does not necessarily lead to public trust. The administration needs to do more than reveal information to gain public trust. In addition, the improvement in managerial competence has little influence on public trust, which indicates that such improvement is considered an internal administrative issue that is not in the domain of the public's concern.

These results suggest an effective strategy for administrators who attempt to use public participation as a tool to improve their credibility among the public. First, the strategy should emphasize that participation efforts must ultimately be results oriented. The administration should demonstrate to the public that the participation process eventually leads to the improvement of public services. Also important to the administration is the realization that the process of consensus building and information exposure should be viewed by the public as a part of administrative effort to produce results desired by the public. Yet even successful consensus building and accountability alone do not gain public trust.

Second, the strategy should stress the improvement of administrative ethical behaviors. The public should strongly perceive the integrity of administrative behaviors during participation. Public trust is further enhanced when ethical competencies are institutionalized through training sessions, workshops, codes of ethics, and the like.

This research provides empirical evidence to support the theoretical argument

that the stakeholders who are involved in governments can develop a better sense of trust toward them. This is specifically achieved by linking participation to improvements in service competence and changes in administrative ethical behavior.

A limitation of this study is that it examines public participation and trust through the perceptions of administrative experts. Although the overall levels of trust in this study are consistent with other studies, the weight and importance of specific administrative behaviors may or may not vary with these findings when citizens' perceptions are compared to those of experts. Thus, the next

step would be to directly examine the public's perceptions. Additionally, this model can serve as part of a larger framework to evaluate governmental participation efforts that are designed to improve participation outcomes to foster not only improved administrative trust but also enhanced legitimacy, a well-informed public, improved decision making, and altered forms of power.

Finally, replication of this study might validate its results, but — more interestingly — provide important trend data that demonstrate the possible change of public participation, public trust, and other variables over time.

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Life-Cycle Economic Evaluation of Alternative Road Construction Methods on Low-Volume Roads by Ron Gerbrandt and Curtis Berthelot in *Transportation Research Record 1989* (Transportation Research Board, 500 Fifth Street, NW, Washington, DC 20001; (202) 334-3213; <http://gulliver.trb.org/bookstore>) (2007)

Highlights

- A model has been developed that can be used to evaluate economic considerations between conventional and non-conventional construction methods.

One of the primary goals of the economic evaluation framework is to allow agencies to consider economic feasibility associated with undertaking various types of technology for the construction of different road projects. The methodology used as part of the framework addresses three major objectives: (a) quantifying cost comparisons between existing and new technology methods, (b) quantifying risk associated with undertaking new technology methods, and (c) mitigating risk when projects are undertaken. Understanding these three major issues is critical in considering existing or new technologies.

The model that has been developed as part of this research initiative provides the methodology that can be used to evaluate economic considerations between conventional and non-conventional construction methods on a project-by-project basis. The model framework provides enhanced decision-making tools not only by evaluating initial construction costs but also by considering long-term life-cycle maintenance costs.

The model quantifies the risk associated with undertaking various types of technology. Risk is quantified by looking at the potential economic impacts associated with different

technical factors. The economic model considers individual β -coefficients on the basis of various technical considerations and issues. Each β -value is assigned a level of importance and is then aggregated to an overall β -value that is used to calculate the discount rate when future maintenance cash flow expenditures are calculated.

At this time, the risk analysis framework is limited by the fact there is little or no information in determining β -coefficient values for different road construction methods. Given the lack of information, initial values will be highly subjective and based on relative measures. In many cases, conventional technology has a history and certainty and is better understood than non-conventional PSI technology. For this reason it is expected that β -values associated with conventional technology will be more accurate and easier to predict. Non-conventional technology has higher uncertainty and is expected to have higher risk, resulting in higher β -values.

Quantifying risk allows managers to take mitigative measures when considering projects. The third component to the economic analysis was to research mitigative measures that could be undertaken to reduce risk associated with implementing new technology. In some cases, the risk in undertaking new technology is too high to justify the economic value. In other cases, undertaking projects allows managers to better understand and learn from implementing the technology. Currently in the model, the following technical factors are

recommended to evaluate and manage potential risks: soil properties, road geometries, environmental conditions, traffic considerations, and other (unique project characteristic risk considerations). Although input values for calculating β -values are not fully understood at this time, managers can decide on the economic risks they are willing to accept. Over time, through additional research and experience, verifying parameters and model inputs will allow managers to quantify risk better, which will lead to better-informed management decisions.

Findings and Recommendations

Today the Saskatchewan Department of Highways and Transportation (DHT) and other agencies are increasingly scrutinized by government officials and road users as they struggle to manage sustainable road networks. Additional pressures on the road system are causing increased road damage requiring structural improvements to address lower levels of service. In many parts of Saskatchewan, good-quality aggregate resources are becoming increasingly scarce, which results in the need to research and develop non-conventional treatments. Using non-conventional technology is a cost-effective method for constructing and rehabilitating roads under certain situations. A number of project factors-including grading requirements, surfacing material thicknesses, project location, aggregate availability, and other unique characteristics-need to be considered as part of the project evaluation process. Project economic evaluation should be based not only on short-term initial cost comparisons but also on a project life-cycle cost analysis. The analysis should include initial construction costs and anticipated future

maintenance expenditures. To undertake life-cycle cost analysis, future maintenance treatment schedules and road performance predictions are required. A better understanding of conventional and non-conventional technology allows road infrastructure managers to better assess the long-term costs associated with different technologies.

To address decision makers' concerns, risk assessment needs to be considered. Risk management is an important aspect of any new technology. Risk management measures have been incorporated into the life-cycle economic evaluation methodology to allow managers to assess risk systematically as part the project decision process.

It is important to evaluate each project on a case-by-case basis to determine the most cost-effective solution. As part of this ongoing research initiative, a financial model that allows DHT to evaluate individual project initial costs and life-cycle costs has been developed. At this time, additional knowledge and experience still need to be acquired and disseminated with regard to the long-term performance and risk parameters associated with further refining both conventional and non-conventional technology. Through better understanding, decision makers will be better positioned to make long-term, informed choices.

This economic evaluation methodology has universal applications for other jurisdictions and transportation agencies. The framework can be applied across different road construction methods and infrastructure asset management systems. The result is that decision makers are provided with better information to allow them to improve the long-term sustainability of their transportation system.

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Leviathan: The Growth of Local Government and the Erosion of Liberty in *Notes from FEE* by Clint Bolick (Foundation for Economic Education, 30 South Broadway, Irvington-on-Hudson, New York, 10533; 914-591-7230) (Feb 2007)

Highlights

- ❑ State and local governments spend \$1.06 trillion annually.
- ❑ Adjusted for inflation, local government spending quadrupled from \$638 per capita in 1961 to \$2,983 per capita today.
- ❑ Entry into businesses is often heavily regulated by state or local government.
- ❑ Often, the most vulnerable are the poor and the powerless.

The Framers of our Constitution had a vision: American government would be limited and decentralized. They cautioned us to keep a watchful eye on all levels of government. Indeed, James Madison warned us in the *Federalist Papers* that local government was especially prone to tyranny. He noted that "the smaller the society, the smaller the number of individuals composing a majority, and the more easily will they concert and execute their plans of oppression."

His concerns proved true. Today local government has grown so big and so unwieldy that it is impossible for us to know who our local governments really are. The image of the town hall where people gather in spirited public debate to argue the issues of the day simply does not exist. Ironically, both conservatives and libertarians who lament the expansion of federal government largely ignore the explosive growth of local government in recent years.

State and local governments spend \$1.06 trillion annually, which constitutes 11.5% of gross domestic product (GDP). In constant dollars this spending quadrupled from

\$638 per capita in 1961 to \$2,983 per capita today. While the Federal civilian workforce decreased between 1980 and 2000 from 2.9 million workers to 2.7 million, state and local employees increased from 13.3 million to 17.5 million. This means that almost one in five of all Americans is either directly employed by state or local government or completely dependent on someone who is. That makes for a very potent special interest.

A new local government entity is created every single day. This explosive growth is taking place primarily in the special districts or the regional authorities that have government-like powers. Among those powers are eminent domain, issuing bonds, regulating the use of property (zoning, etc.). Such entities have now grown more numerous than cities, towns, or school districts.

The result is a dizzying array of pervasive local governments that regulate every instance of our lives. For example, metropolitan Chicago is governed by 1,200 separate and overlapping governmental entities. You can't fight city hall if you can't even identify all of the people you need to fight.

The power of the local leviathan is especially destructive in two areas: economic liberty and private property rights. Economic liberty is the right to pursue an honest business or profession free from arbitrary government regulation. Most Americans think we have such a right. However, entry into professions or businesses is often heavily regulated by government. The most vulnerable here are those who lack the resources and educational

skills while trying to gain a toehold in the economy and earn their share of the American dream.

Leroy Jones and three of his fellow taxicab drivers at Yellow Cab decided to make the transition from being employees to becoming business owners. The four aspiring entrepreneurs formed their own taxicab company, Quick Pick Cabs, and discovered a market that was not being served: a low-income section of Denver. They got the paperwork together, including a petition demonstrating that people wanted their services. It seemed they had everything they needed: the know-how, the capital, the insurance, and the cars. They were missing only one little thing: a piece of paper called a certificate of public convenience and necessity from the Public Utilities Commission (PUC).

To obtain such a certificate, an applicant must surmount the almost impossible hurdle of demonstrating both that adequate service is not being provided and that the existing companies are unable to provide it--with no objective criteria of how to demonstrate such inadequacy. Quick Pick Cabs applied to the PUC for the certificate and got the same response as every applicant for a

taxicab license in Denver since World War II: application denied.

By this time Leroy Jones had been fired from his job at Yellow Cab for having the temerity to try to launch a competing company and was selling sodas at Mile High Stadium. He and the other three drivers experienced financial hardship.

CBS's "Eye on America " followed Leroy Jones for a day as he toiled selling sodas at a ballgame at Mile High Stadium in the hot sun. It made the point this man was not asking for a handout, he was merely asking for a share of the American dream that he wanted to earn. It is amazing that in modern America the right to receive a welfare check has much greater judicial protection than the right to earn an honest living.

Due to the negative publicity, the bureaucracy backed down and the state of Colorado deregulated entry into the taxicab market in Denver . Along the way Leroy Jones had an epiphany. "You know," he said, "this is much bigger than just me. This is a huge struggle that we're engaged in." And he and his friends renamed their company Freedom Cabs. Today Denver has a fleet of 75 cabs bearing the Freedom insignia.

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Guidelines for the Selection of Snow and Ice Control Materials to Mitigate Environmental Impacts, NCHRP Report 577 by Levelton Consultants Limited, Richmond, BC (Transportation Research Board, 500 Fifth Street, NW, Washington, DC 20001; (202) 334-3213; <http://gulliver.trb.org/bookstore>) (2007)

Highlights

- There is no commonly accepted guidance for determining which products are "environmentally friendly."
- The objective of this project was to develop such guidance.

Every year, considerable quantities of snow and ice control products are applied to highways; environmental and regulatory agencies have questioned the environmental effects of these products. Transportation agencies are asked to use "environmentally friendly" or less toxic alternatives wherever possible, but there is no commonly accepted guidance for determining which products meet these criteria. The traditional use of road salt has been prohibited in some locations, leaving highway agencies uncertain about how traffic safety can be maintained in winter conditions.

Studies of the most common chemical alternatives--sodium chloride (salt, NaCl), magnesium chloride (MgCl₂), calcium chloride (CaCl₂), calcium magnesium acetate (CMA), and potassium acetate (KA)--have focused on performance and cost under various weather conditions without evaluating their relative effects on the environment. Several new chemical preparations, including some that are proprietary formulations, have entered the market as snow and ice control chemicals for use by transportation agencies, but there is limited information about the environmental effects of these preparations.

Rational decision-making guidelines are needed to assist winter maintenance managers in selecting the most appropriate snow and ice control materials for the conditions that exist in their jurisdictions. A transportation agency must consider a range of factors when assessing snow and ice control materials for use, including performance, cost, potential for the material to impair the natural receiving environment, and potential for the material to impair infrastructure. Each agency will have unique objectives and conditions that influence the importance of each of these factors in the decision-making process. The overall objective of this project is to develop guidelines for selecting snow and ice control materials based on their properties and common site-specific conditions near roadways on which these products would be used.

When selecting a snow and ice control material, the factors affecting the decision processes can be numerous and complex. The framework provided here is relatively straightforward and addresses the most common and significant items. Decision categories include cost, performance, potential to impair the natural environment, and potential to impair infrastructure. These balance economic value related to cost and performance with potential consequences of use related to environmental and corrosion impacts. User input is a key element to the tool to ensure that maintenance area conditions are represented. The end product is a practical tool that generates a numerical evaluation that can be

used to compare snow and ice control materials.

Each agency will have unique objectives and priorities that will affect their selections for the decision categories and these will be expressed through percentage weighting of importance. Decision subcategories that support the natural environment and infrastructure decision categories are relatively straightforward and represent the most significant components contributing to the higher level decision category.

To quantify risks of impairment for environmental and infrastructure subcategories resulting from each snow and ice control material type, numerical rankings were developed. These were based on a material's potential to elicit an effect on a receptor, as developed from a comprehensive information review and analytical test results. These values were applied where sensitive receptors existed in the maintenance area as identified through user-completed receptor inventory worksheets for each decision subcategory.

When assessing relative cost and performance of snow and ice control materials, many factors are influential and considerable research continues to be done here. The Decision Tool uses the following approaches:

- Cost is based on the purchase price of the dry active ingredient. Active ingredients include the five primary snow and ice control chemicals: NaCl, MgCl₂, CaCl₂, CMA, and KA.

- Performance is based on melting potential derived from phase curve information and expected winter temperature in the maintenance region. Melting potential represents the chemical's ability to melt ice at a specified temperature.

These approaches may not be ideal; however, they provide a standardized and practical method that reasonably represents the dominant component for each decision category.

For each decision category, a weighted score is generated. These are summed for each material to produce a numerical product score that is used to compare snow and ice control material types objectively. Once a material type has been selected; various sources may exist. Considerable variation in certain attributes can exist among similar material types from different sources or between batches from the same source. A Purchase Specification containing concentration-based guidelines for key attributes will allow transportation agencies to screen out unsuitable products. The Purchase Specification is supported by a Quality Assurance Monitoring Program to assess received materials and by standard test methods to measure these attributes.

Product selection occurs after a review of the Purchase Specification and supplemental considerations that may include but are not limited to product availability (delivery times and quantities), quality testing results, and equipment availability.

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An Assessment of WSDOT's Hot Mix Asphalt Quality Control and Assurance Requirements by Kim A. Willoughby and Joe P. Mahoney, Washington State Transportation Center (TRAC) University of Washington, Box 354802, University District Building; 1107 NE 45th Street, Suite 535 Seattle, Washington 98105-4631 (Research Office, Washington State Department of Transportation, Transportation Building, MS 47372, Olympia, Washington 98504-7372) (Jan 2007)

Highlights

- ❑ Coarse-graded Superpave ¾-inch mixes require a higher level of density.
- ❑ Superpave gyratory compactors must be carefully checked for gyration angle.
- ❑ The CoreLok@ method for measurement of bulk specific gravity provides improved estimates of density when the sample air voids exceed 8%.
- ❑ Mix volumetric measures are an important aid to the mix design process.

The focus of this study was on the Washington State Department of Transportation (WSDOT) specification for hot mix asphalt (HMA) and was conducted, in part, to aid in the implementation of the Superpave mix design system. During the study, WSDOT tested the concept of using volumetric mix parameters as a partial basis for Contractor pay. Field results from these projects were compared to "traditional" pay factor projects to allow an initial assessment.

Literature Review

Typical specification bands (such as gyratory-compacted air voids (V_a) in Superpave gyratory compactors (SGCs) specimens) and test precision are uncomfortably close.

Volumetric mix properties can be partially characterized by tests such as asphalt content and aggregate gradation.

The SGC and its associated variability need to be considered with respect to mix volumetric measures.

Measurement of the bulk specific gravity can affect mix volumetric results. The CoreLok@ measurement system provides improved density results.

The same or similar volumetric properties and strength characteristics can be attained with very different gradations and asphalt contents based on a National Cooperative Highway Research Program (NCHRP) study. The implication is that volumetric mix properties are not "absolute" measures of mix performance.

In-place density (air voids) strongly impact pavement performance. The general rule-of-thumb is that a 1% increase in air voids over a base air void level of 7% tends to produce about a 10% loss in pavement life.

Permeabilities are strongly influenced by lift thickness and compaction requirements, especially coarse-graded Superpave mixtures. The recommended compaction requirement (as a percent of theoretical maximum density) is higher for coarse-graded ¾-inch Superpave mixes as compared to ½-inch mixes. The critical in-place air void levels are about 6% for ¾-inch mixes and 7% for ½-inch mixes. The mat thickness for improved compactability based on thickness to nominal maximum aggregate size (t/NMAS) should be: (1) fine-graded mixes, t/NMAS ratios ≥ 3.0 , and (2)

coarse-graded and stone matrix asphalt (SMA) mixes, t/NMAS ratios ≥ 4.0 .

Conclusions

Coarse-graded Superpave $\frac{3}{4}$ -inch mixes require a higher level of density than current WSDOT standards to keep mix permeability at low, acceptable levels. The work at NCAT showed that in-place air void levels higher than 5.5% had excessive mix permeability. Further, a thickness to NMAS ratio of 4 or greater is recommended by NCAT resulting in a minimum layer thickness of 3.0 inches. If a higher density standard and sufficient lift thickness are not possible, a second option is not to use $\frac{3}{4}$ -inch coarse-graded Superpave mixes as wearing courses.

SGCs must be carefully checked for gyration angle. Otherwise, mix density variability can result. WSDOT has been proactive in doing so.

The CoreLok@ method for measurement of bulk specific gravity provides improved estimates of density when the sample

air voids exceed 8%. WSDOT should consider its adaptation, WSDOT -specific results support this conclusion.

There are currently two approaches used by WSDOT for field quality assurance (QA) tests and calculation of contractor pay factors: (1) use of in-place density, asphalt content, and gradation (2) use of in-place density, asphaltic concrete (AC), voids in mineral aggregate (VMA), V_a , and selected measures of gradation (112 inch, 3/8 inch, No.4, No.8, and No. 200). WSDOT is in the process of assessing which of the two approaches it will use for Superpave projects. Based on NCHRP 409 (a laboratory study that showed a wide range of volumetric properties resulted in similar mix performance), a positive link between typical volumetric pay factors and enhanced performance is uncertain. Mix volumetric measures are an important aid to the mix design process and should be considered for use in making test section job mix formula (JMF) adjustments.

TRANSPORTATION RESEARCH DIGEST

ARIZONA TRANSPORTATION INSTITUTE

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NOVEMBER-DECEMBER 2007

Installation of Warm Mix Asphalt Projects in Virginia by Stacey D. Diefenderfer, Kevin K. McGhee, and Bridget M. Donaldson, Virginia Transportation Research Council, 530 Edgemont Road, Charlottesville, VA 22903 (Virginia Department of Transportation, 1401 E. Broad Street, Richmond, VA 23219) (Apr 2007)

Highlights

- Warm mix asphalt (WMA) saves energy and extends the period in which work can be done into colder weather.
- Tests were conducted on two materials: Sasobit and Evotherm.

Rising energy costs and increased environmental awareness have brought attention to the potential benefits of warm mix asphalt (WMA) in the United States. Warm asphalt is produced by incorporating additives into asphalt mixtures to allow production and placement of the mix when heated to temperatures well below the 300°F+ temperatures of conventional hot mix asphalt (HMA). Benefits such as reduced plant emissions, improved compaction in the field, extension of the paving season into colder weather, and reduced energy consumption at the plant may be realized with different applications. Currently, four technologies are available in the United States:

1. Sasobit, developed by Sasol International (Sasol Wax)
2. Aspha-min zeolite, developed by Eurovia Services GmbH
3. WAMfoam, developed by Shell International and Kolo Veidekke
4. Evotherm, developed by MeadWestvaco Asphalt Innovations.

However, only Sasobit and Evotherm were used during this study because of the availability of trial sections.

Sasobit is a synthetic long-chain Fischer-Tropsch wax produced from coal gasification. It is introduced to HMA by blending with the binder at the terminal or contractor's tank, adding it with the aggregate, or pneumatically blowing it into the plant through a modified fiber feed line. The recommended addition rate is 0.8% to 3% by mass of the binder. Sasobit lowers the viscosity of the binder such that working temperatures decrease by 32°F to 97°F. Sasobit has a congealing temperature of about 216°F and is completely soluble in binders at temperatures higher than 248°F. At temperatures below the melting point, it forms a crystalline network structure in the binder that is reported to provide added stability.

Evotherm is a non-proprietary technology that is based on chemistry that includes additives to improve coating and workability, adhesion promoters, and emulsification agents. The additives are delivered in an emulsion with a relatively high asphalt residue (approximately 70%) that is stored at 176°F. Water in the emulsion is liberated as steam when mixed with the hot aggregate.

The purpose of this study was to evaluate the installation of WMA to compile experiences with the various technologies and evaluate their effects on construction methods and performance.

Three trial sections were installed using warm mix technologies between August and November of 2006. Two used the Sasobit

technology, and the third employed the Evotherm technology.

This report discusses the material makeup of these technologies and documents the production and placement of the three trial sections. The results of this study and further studies can serve as a basis for VDOT decision making regarding the use of WMA technology.

Findings

The use of the Sasobit additive did not cause substantial changes in volumetric properties.

Average air void contents of the Sasobit WMA cores were slightly less than those of the control cores, although the difference was not statistically significant. The variability in the voids was slightly greater for the Sasobit cores. Estimated void contents from the uncorrected nuclear density measurements generally supported this finding, although differences were significant for one of the two trial sections.

Permeability was similar for the control and Sasobit sections in both trials.

The tensile strength ratio (TSR) test provided inconsistent results for Sasobit mixtures when compared to the control mixture. Plant-produced Sasobit specimens had lower indirect tensile strengths, although the TSR was less than for the control in Trial A and greater than for the control in Trial B. Reheating the Sasobit mixture from Trial 1 to produce TSR specimens significantly increased the indirect tensile strength of the mixture, although TSR values still failed the specification requirement.

The rutting resistance of the Sasobit WMA mixtures and the HMA control mixtures

was not statistically different when the asphalt pavement analyzer (APA) was used.

The asphalt content of the control mixture was lower than that of the Evotherm mixture; no other differences in volumetric properties were seen.

Air void contents of Evotherm cores were slightly higher than those of the control cores, although the difference was not statistically significant: The air void contents of the Evotherm cores did have greater variability. Estimated voids from the uncorrected nuclear density measurements also indicated slightly higher void contents and variability for the Evotherm section as compared to the control section; in addition, the difference in compaction was statistically significant as measured by the uncorrected density.

TSR values for the Evotherm specimens were lower than those for the control mixture. Storage of both specimen sets at ambient temperature resulted in a slight increase in the dry and conditioned strengths of the Evotherm mixture and a slight reduction in the dry and conditioned strengths of the control mixture; however, these changes were not significant. Storage resulted in a small increase in the TSR values for both specimen sets, although the TSR of the Evotherm specimens still did not comply with the specification.

Evotherm specimens exceeded the maximum allowable rutting depth when tested using the APA. Control specimens had acceptable rutting resistance.

Asphalt fume sampling conducted during the Evotherm WMA paving and control HMA paving for Trial C indicated that crew members were exposed to non-detectable levels or levels below the maximum recommended exposure levels of airborne asphalt fumes.

TRANSPORTATION RESEARCH DIGEST

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NOVEMBER-DECEMBER 2007

Test Methods for Characterizing Aggregate Shape, Texture, and Angularity, NCHRP Report 555 by E. Masad, T. Al-Rousan, J. Button, E. Tutumluer and D. Little (Transportation Research Board, 500 Fifth Street, NW, Washington, DC 20001; (202) 334-3213; <http://gulliver.trb.org/bookstore>) (2007)

Highlights

- Aggregate Imaging System (AIMS) was recommended for measuring the characteristics of coarse and fine aggregates.
- For measuring the coarse aggregate shape only, the Multiple Ratio Shape analysis method (MRA) was the most appropriate.

The literature review conducted in this project revealed that the characteristics of coarse and fine aggregates used in hot-mix asphalt and hydraulic cement concrete mixtures, and unbound base and subbase layers influence the performance of the pavement system in which they are used. Aggregate characteristics can be identified by three independent components: shape (or form), angularity, and texture. Methods currently used for measuring these characteristics have several limitations: they are laborious, subjective, lack direct relation with performance parameters, and have a limited ability to separate the influence of angularity from that of texture. A number of research studies have shown that aggregates, especially coarse aggregates that exhibit high texture, do not necessarily have high angularity. Consequently, it is important to develop methods that are capable of quantifying each of the aggregate characteristics rather than a manifestation of their interactions.

This study evaluated available test methods for measuring aggregate characteristics. The evaluation was conducted based on accuracy, repeatability,

reproducibility, cost, ease of use, ease of interpretation of the results, readiness of the test for implementation, portability, and applicability for the different aggregate sizes and types. Thirteen different coarse aggregate types and five different fine aggregate types were used in this evaluation.

The evaluation of imaging-based test methods considered both the characteristics of the image acquisition procedure and the accuracy of the image analysis methods. Evaluation of the accuracy of the image analysis methods was conducted in two steps. In the first step, all the analysis methods were used to quantify the characteristics of particle projections that geologists have used for visual evaluation of particles. This step helped to identify analysis methods that are capable of distinguishing between particles of distinct characteristics. These methods were further evaluated in step 2 through the analysis of images of the aggregates used in this study. This step identified the analysis methods that are able to accurately rank aggregates based on their characteristics. The analysis results revealed that some of the available analysis methods do not distinguish between angularity and shape and some analysis methods do not distinguish between texture and angularity.

Accuracy of the test methods was assessed through statistical analysis of the correlations between the results from these methods with measurements of shape using a digital caliper and visual rankings of surface

irregularity and texture by experienced individuals.

Analyses of repeatability and reproducibility results were conducted following the guidelines of the American Society of Testing and Materials (ASTM) standards E 177, C 802, and C 670. The Analytical Hierarchy Process (AHP) is a process of developing a numerical score to rank test methods based on how each of these methods meets certain criteria of desirable characteristics--was used to rank the test methods. The desirable characteristics of repeatability, reproducibility, accuracy, operational characteristics, and applicability for different sources of aggregates were considered in the evaluation.

The Aggregate Imaging System (AIMS) was recommended for measuring the characteristics of both coarse and fine aggregates. The system employs methods based on sound scientific concepts for the analysis of shape, angularity, and texture and provides the distribution of each of the characteristics in an aggregate sample. It has very good control of lighting and provides repeatable and reproducible results. The University of Illinois Aggregate Image Analyzer (UIAIA) can also be used for measuring the shape, angularity, and texture of coarse aggregates. For measuring the coarse aggregate shape only, the Multiple Ratio Shape analysis method (MRA) was the most appropriate and is much cheaper than all the other test methods. Similar to the imaging systems, the MRA provides the distribution of shape in an aggregate sample, but it cannot be

used for measuring angularity or texture. All these test methods can be used for routine analysis of aggregate characteristics as they require minimal training and provide an easy to use summary of the results.

The ability of X-ray computed tomography (CT)--a nondestructive technique to capture the three dimensions of materials--to provide detailed measurements of aggregate characteristics was assessed. The X-ray CT proved to be a powerful tool, but is premature for use in the routine measurements of aggregate characteristics. The image processing techniques used in separating the particles in X-ray CT require substantial manual manipulation of images, which could influence the measurements of angularity and texture.

A methodology for classification of aggregates based on their characteristics was developed in this project. The methodology unifies the methods/used to measure the characteristics of fine and coarse aggregates, and describes these characteristics by cumulative distribution functions rather than average values, thus better defining the effects of blending and crushing on aggregate characteristics. This methodology can be used to (1) explore the influence of different processes such as crushing and blending on aggregate shape, (2) conduct quality control by detecting changes in the distribution of any of the characteristics, (3) relate the distribution of different characteristics to performance, and (4) develop specifications based on the distribution of aggregate characteristics rather than average indices.

TRANSPORTATION RESEARCH DIGEST

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Exploratory Analysis of Children's Travel Patterns by Noreen C. McDonald in *Transportation Research Record 1977* (Transportation Research Board, 500 Fifth Street, NW, Washington, DC 20001; (202) 334-3213; <http://gulliver.trb.org/bookstore>) (2006)

Highlights

- ❑ 77% of trips are made in a private vehicle.
- ❑ 1% of trips are by public transit.
- ❑ 12% of trips are by walking.
- ❑ 2% of trips are by bike.
- ❑ Children of single parents make the most trips.
- ❑ Children from low-income or minority households travel less.

Commuting in America, a series of articles on the socioeconomics of urban travel, and numerous other papers and reports provide a fact base on American adult travel. From these, it is known that nearly 85% of daily local travel uses the private automobile, that there are more cars than licensed drivers, and that Americans make an average of four trips per day. But these statistics are not known for children. This is unfortunate because politicians and public health officials have begun to ask questions about how children travel. To make policy decisions about investments in Safe Routes to School programs and to investigate links between children's travel and obesity, a good understanding is needed of how youth are traveling.

This paper uses the 2001 National Household Travel Survey (NHTS) to address five questions: (a) How much are children traveling? (b) Why are children traveling? (c) Who are children traveling with? (d) How do the observed travel patterns vary with demographic characteristics such as age, race, sex; and income? and (e) What are the barriers to the analysis of children's travel? The picture

of children's travel that emerges is an essential underpinning to policy decisions and future analyses of children's travel demand.

The results show that children's travel resembles that of adults in many ways. For example, youth travel is dominated by the automobile, with nearly 75% of trips being made in a private vehicle. But in important ways, children's travel is different. Because of their youth, children often travel with others. However, the burden of transporting children is not distributed equally among parents; young children are more than five times as likely to travel with their mothers as with their fathers. Age also greatly affects how much children travel. Infants make half as many trips as 18-year-olds. Once teens reach driving age, they make many more trips, often driving themselves. Children from low-income, minority households without cars consistently travel less than their peers. These children show a deficit of recreation trips, particularly for sports and exercise. The differences are not large but they are suggestive, particularly given current concerns about obesity.

Conclusions

What this entire analysis reveals is that children's travel has moved well beyond simplistic images of children being carted back and forth to school on yellow school buses or walking around the neighborhood. Children today need to reach many destinations and must rely on autos and parents to do so. This automobility has two major implications. First, parents, particularly mothers, spend significant

amounts of time transporting children. Second, auto access is central to the travel patterns of driving-age teens. Many of them have primary access to a household vehicle, and they use it.

School, shopping, and socializing are the primary reasons children travel. One problem with current survey data for children is that it is impossible to determine whether the trip was taken for the child's benefit or if the child was simply going along with a parent. This difference is particularly important for shopping trips, many of which may prove to be grocery store trips rather than sneaker shopping trips. The finding that children of single parents make the most trips, after controlling for auto ownership, suggests that these babysitting or

go-along trips are an important part of children's travel patterns and need to be better understood.

The analysis consistently showed that children from low-income or minority households traveled less than their peers and that the foregone trips were often for social and recreation purposes. In particular, these students made fewer sports and exercise trips. As mentioned, this may simply reflect that middle- and upper-class children are more likely to be involved in organized sports and therefore the act is recorded on a survey. Nevertheless, the current concern with physical activity and obesity make children's travel an area for further analysis.

Mode Split by Trip Purpose

Mode	School	Shop	Socialize	Meals	Sports-Exercise	Total
Auto	54	90	73	93	57	77
School bus	30	0	1	0	1	7
Walk	13	8	20	5	27	12
Bike	1	1	4	0	12	2
Transit	2	1	1	1	0	1
Other	0	0	1	0	2	1
Total	100	100	100	100	100	100

NOTE: Columns may not total 100 because of rounding.

TRANSPORTATION RESEARCH DIGEST

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Preserving and Using Institutional Memory Through Knowledge Management Practices NCHRP Synthesis 365 by Maryanne Ward, Mount Vernon, Washington (Transportation Research Board, 500 Fifth Street, NW, Washington, DC 20001; (202) 334-3213; <http://gulliver.trb.org/bookstore>) (2007)

Highlights

- Neither strategic intentionality or conscious effort is strongly evident in most STAs.
- Printed matter, at least, is stored in reasonably convenient and accessible locations.

This TRB Synthesis Report documents practices regarding the preservation and use of institutional memory through knowledge management (KM) practices of transportation agencies. There are a number of important reasons for state transportation agencies (STAs) to better preserve and manage institutional memory, including:

- Facilitating and expediting training and succession management;
- Needing to build on past understandings and improve efficiency when providing the information and knowledge;
- Doing more with fewer resources;
- Answering requests from legal staff for information to support agency positions in litigation;
- Integrating historical perspectives and lessons learned into current transportation agency activities and decision making; and
- Striving to respond efficiently and accurately to requests for information.

Of the 38 transportation agencies returning questionnaires [34 U.S. state departments of transportation (DOTs), three Canadian provinces, and one Canadian city],

seven reported having a successful KM process robust enough to continue through staff and administration changes. Nineteen STAs in all reported having a KM-related program in existence at some organizational level and in varying states of development. Thirty-three STAs reported that they are making efforts to retain the knowledge of retiring employees.

Specifically, this synthesis documents STA practices, at a practical level, for preserving and enabling use of internally generated knowledge resources--that is, on those materials, knowledge, and resources in the unique possession of individual STAs at the program, policy, project, and project detail levels. It also contains an annotated literature survey, interviews, and other resources detailing practices from transportation and other types of organizations.

For this synthesis study, the following definitions of key terms apply throughout:

- Institutional memory-"the body of knowledge, formal as well as informal, that is essential to the continuous and effective functioning of the agency at all levels."
- Knowledge-"the combination of data and information, to which is added expert opinion, skills, and experience, to result in a valuable asset which can be used to aid decision finding stored KM resources for application to current work and decision making, the most common responses indicated that overall, it depends on which work unit

is handling the resource. Individual STAs reported a variety of finding tools, mixtures of databases and manual (hardcopy) indexes, databases, clearing-house-type websites, and knowledgeable individuals. A few states reported an intranet portal, which presumably offers a "one-stop-shopping" approach by means of some kind of unified display screen with links to various resources. Iowa and Minnesota reported on electronic document/records management systems. The Virginia DOT noted that an effort to create an enterprise-wide taxonomy is underway to allow searching of multiple repositories simultaneously. However, a clear strategy of providing a kind of "one-stop-shopping" approach conceived of from the point of view of the employee looking for and needing the resources rather than from the work unit that "owns" the resource was not apparent.

Once the resources are identified, however, most DOTs reported that physical resources, at least, are stored in reasonably convenient and accessible locations, and that decisions to move or destroy records are done carefully, probably the result of well-established records management programs. Seven DOTs reported a high priority to get KM resources available to the desktop, however; two have a "push" or proactive system. Therefore, perhaps one can conclude that hardcopy resources are more readily available than electronic ones.

Overall, the main conclusion from the questionnaire results is that institutional

memory practices exist at some level in at least 19 STAs; however, overall strategic intentionality or conscious effort are not strongly evident in most STAs on an agency-wide basis. Exceptions are documented in the case studies.

In general, the main conclusion is that institutional memory practices exist at some level in at least 19 STAs; however, overall strategic intentionality or well-implemented business processes are not present. As revealed in the literature search and interviews, KM practices are generally not as well defined or measurable as other business processes. In recent years, KM practices have been implemented as an underlying internal process to support organization's evolution into customer-oriented, team-based, highly flexible, global enterprises, where internal knowledge is viewed 'as' a major asset. There is not a set protocol or clear path for implementation such as may exist, for example, in the management of financial assets. Thus, it takes creativity and careful strategizing to implement KM practices that actually deliver benefits and are embedded in day-to-day operations. According to CEN Workshop Agreement 14924-1, efforts in many organizations have typically taken an IT approach initially; however, the Agreements were written specifically to help organizations align culturally and socially to take advantage of knowledge sharing within and beyond their organizational boundaries. This people-centric approach adds value to technology-focused initiatives. The goal is to put in place the cultural, human, environmental, and technical ecology necessary to take advantage of collective knowledge.

TRANSPORTATION RESEARCH DIGEST

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NOVEMBER-DECEMBER 2007

Strategies Are Available for Making Existing Road Infrastructure Perform Better (United States Government Accountability Office, 441 G Street NW, Room LM, Washington, D.C. 20548; JayEtta Z. Hecker at (202)512-2834 or heckerj@gao.gov; <http://www.gao.gov/new.items/d07920.pdf>) (July 2007)

GAO identified three strategies...

1. use the private sector to managing existing road infrastructure,
2. expand use of the user-pay concept for managing demand and generating revenue for transportation investments, and
3. develop a systematic performance-based management approach to increase the accountability of public expenditures and to link performance to investment decisions.

Three broad factors inhibit efficient use of roads and highways: design and operation factors; the revenue-raising structure; and a limited focus on selecting projects that produce the highest net social benefits in the current decision-making process. First, many roads were not designed and built to meet current traffic volumes, and operational changes—such as the timing of traffic signals—have not changed sufficiently to cope with the increased use. Second, the federal and state transportation revenue-raising structure, which collects the majority of revenues through motor fuel taxes and other user fees, does not provide incentives for drivers to take into account the external costs, such as increased travel time for other drivers, they impose in deciding when, where, and how to drive. For example, the tax rate on gasoline is the same regardless of whether drivers drive in congested or uncongested periods. Third, there is a limited focus in the current decision-making process on selecting projects that will produce the highest net social benefits. Decision makers also are limited in

their ability to identify and put in place infrastructure investments that would produce the highest estimated social benefits because the current decision-making process is compartmentalized by mode and is not driven by economic analysis.

Two categories of congestion mitigation techniques have been developed to improve the efficiency and better optimize the performance of the existing infrastructure. The first category includes techniques that enhance road capacity through better operations, such as incident response vehicles that quickly restore traffic flow after vehicle crashes, or the deployment of transportation technology, such as optimizing the timing of traffic signals to improve traffic flow. The second category includes techniques designed to better acknowledge the impact of using the road system during times of peak demand; these techniques influence drivers to make alternative choices, such as car pooling or shifting trips to less congested times. Studies and evaluations of projects indicate that these congestion mitigation techniques have the potential to provide benefits such as reduced congestion delays and improved traffic flows that maximize existing capacity. These studies and evaluations also indicate such techniques are most effective when tailored to the particular situation and used in combination.

At locations GAO reviewed, officials chose varying congestion mitigation techniques, but tended to implement them with a similar three-pronged approach: (1) changing planning and related processes to give them

higher priority, (2) developing creative mechanisms to fund them, and (3) collaborating with multiple stakeholders to put them in place. Officials said the success of these techniques depends on coordination among many partners. While officials said the techniques produced benefits, these officials also called attention to various challenges that tended to preclude wider use. These challenges ranged from resolving jurisdictional authority to identifying sufficient funding to allow implementation on a broader scale. As a result, they said, the approach they used to implement these techniques could provide only marginal improvement to the efficiency of the road network.

Various strategies exist for increasing the efficient use of infrastructure. GAO grouped the strategies by the level of government best suited to consider and implement them, given their current authorities, roles, and responsibilities. In some cases, all levels of government would need to be involved in implementing the strategy; in other cases, the federal government or a state government would be most appropriate to implement the strategy. GAO identified three strategies that cut across all levels of government, including (1) considering how the private sector can be used in managing existing road infrastructure, (2) expanding use of the user-pay concept for managing demand and generating revenue for transportation investments, and (3) developing a systematic performance-based management approach to

increase the accountability of public expenditures and to link performance to investment decisions. GAO also identified strategies that would be most appropriate for state and local governments to consider, including applying congestion mitigation techniques on a regional basis and fully integrating transportation and land-use planning. For example, traffic signal timing is one technique that can provide significant benefits to drivers by providing for the smooth flow of traffic along streets and highways. To fully enhance mobility, jurisdictions need to coordinate the timing along an entire corridor, which often crosses multiple jurisdictions. Finally, GAO identified strategies that the federal government could consider to help increase the efficient use of infrastructure. These strategies include (1) linking funding more directly to performance, (2) increasing the flexibility provided to state and local governments to promote innovative solutions, and (3) focusing on projects (or transportation corridors) of national interest. For example, the federal government could also use incentives to link funding to particular outcomes, such as encouraging state and local governments to increase the efficient use and performance of existing infrastructure. According to transportation research and transportation officials and experts we interviewed, the strategies are not mutually exclusive and ideally would be implemented in a comprehensive manner.

TRANSPORTATION RESEARCH DIGEST

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NOVEMBER-DECEMBER 2007

Update on Status of Proposed TransDominion Express (TDX) Passenger Rail Service by John S. Miller, Barclay F. Thorn, and Jason S. Beaton, Virginia Transportation Research Council, 530 Edgemont Road, Charlottesville, VA 22903 (Virginia Department of Transportation, 1401 E. Broad Street, Richmond, VA 23219) (Apr 2007)

Highlights

- The estimated annual operating subsidies required range from \$9 million to \$23 million.
- The envisioned rail passenger service would provide annual benefits of less than \$2 million.

Five studies of TransDominion Express (TDX) service have been conducted during the past 10 years:

1. Virginia Department of Rail and Public Transportation (DRPT) at the request of the General Assembly (1996)
2. Frederic R. Harris, Inc., at the request of DRPT in response to funding made available for such a study by the General Assembly in 1996 (1998)
3. National Passenger Railroad Corporation (Amtrak) at the request of DRPT (2000)
4. The Woodside Consulting Group, Inc. (2002)
5. DRPT (2005).

The estimated annual operating subsidies varied in these studies from \$9 million to \$23 million depending on the type of service presumed and the ridership level. Capital costs were estimated in the greatest detail in the 2002 Woodside Consulting study and those capital costs were generally used in the 2005 DRPT study.

The greatest variation in the studies, however, concerned the annual ridership

estimates: they ranged from slightly more than 26,000 in the 2000 Amtrak study (National Railroad Passenger Corporation, 2000) to slightly more than 500,000 in the 1996 DRPT study. The differences are attributable to (1) the difference in service levels each study suggested would be provided; (2) the sensitivity of ridership to the varying service levels; and (3) assumptions regarding the impact of freight movement on passenger travel schedules.

The purpose of this report is to update the TDX study in accordance with the requirements of the enabling legislation.

Costs and Benefits Assessment

Although it does not indicate whether or not the proposed passenger rail service should move forward, this report provides an action plan that is recommended for use should some entity (the Commonwealth, a private provider, or some combination thereof) decide to implement TDX. There are potential costs and potential benefits of using the action plan.

Step 1 of the action plan is to decide whether pilot service should be offered. A midrange estimate of the capital cost of one form of this pilot service--that suggested by Norfolk Southern in 2005 (DRPT, 2005)--was estimated to be \$21.5 million in 2010 dollars. As a starting point, if this service were offered for 2 years and the operating cost was \$19 million (in 2010 dollars) for that period of time, the cost of the 2-year pilot project would be about \$60 million.

The benefits from this pilot project would be threefold.

1. Assuming 36,000 passengers used the service annually, one benefit would be service provided for 72,000 passenger trips over the 2-year period.
2. Assuming an average trip length of 127 miles, that each rail mile eliminated one automobile mile, and that each automobile mile exerts an unpaid social cost of about \$0.30 per mile, then over a 2-year period, TDX would provide social benefits of \$2.74 million.
3. A 2-year pilot study should provide information about the feasibility of TDX service: it might well be the case that actual ridership levels would be much higher than those forecast here (in which case TDX might be a strong candidate for a public subsidy) or it might be the case that ridership levels would be much lower than those forecast here (in which case there are probably other transportation services that would yield a greater return on this investment).

TRANSPORTATION RESEARCH DIGEST

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Evaluation of Best Practices in Traffic Operations and Safety: Phase I: Flashing LED Stop Sign and Optical Speed Bars by E. D. Arnold, Jr., and K. E. Lantz, Jr., Virginia Transportation Research Council, 530 Edgemont Road, Charlottesville, VA 22903 (Virginia Department of Transportation, 1401 E. Broad Street, Richmond, VA 23219) (Jun 2007)

Highlights

- A flashing LED stop sign is effective in reducing the speeds of vehicles approaching an intersection, particularly when visibility of the sign is an issue; however, the speed reductions are likely to be small.
- Optical speed bars that extend across the travel lane are more effective in reducing speeds than those that just extend a short distance from the centerline or edge line.

The purpose of the study was to evaluate through before and after studies a flashing LED stop sign and optical speed bars. The measures of effectiveness used in evaluating the flashing LED stop sign were the average speed of vehicles approaching the stop sign and stop sign compliance. For the optical speed bars, the average speed of vehicles was used as the measure of effectiveness. The research effort did not include a crash analysis as time was not available to obtain the recommended minimum of 3 years of crash data after installation of a countermeasure.

The flashing LED stop sign was installed and evaluated at one site in Virginia, and the optical speed bars were installed and evaluated at two sites in Virginia.

Conclusions

- A flashing LED stop sign is effective in reducing the speeds of vehicles approaching an intersection, particularly when visibility of the sign is an issue; however, the speed reductions are likely

to be small. Speed reductions are greater during dusk and nighttime hours. Accordingly, these devices should be considered as a potential safety countermeasure when addressing accident problems at stop sign controlled intersections.

- Optical speed bars are effective in reducing the speeds of vehicles approaching a hazardous roadway section, a reduced speed zone, or other roadway/travel change area. The reductions in speeds may be small.
- Optical speed bars that extend across the travel lane are more effective in reducing speeds than those that just extend a short distance from the centerline or edge line.
- If thermoplastic tape is used for installation of the optical speed bars, motorists traversing the bars experience a slight bumping effect, similar to that with rumble strips but less pronounced and not as noisy. This experience likely enhances the effectiveness of the bars in reducing speeds.

Recommendations

- VDOT's Traffic Engineering Division and regional traffic engineers should consider the use of a flashing LED stop sign as a safety countermeasure at intersections controlled by a stop sign where the number of crashes is higher than expected. Field testing found

statistically significant speed decreases of vehicles approaching such a sign, which suggest drivers are more aware of the stop sign and thus more prone to stop. The speed decreases may be small, however: in the range of 1 to 3 mph. Speed decreases tended to be greater during the night than during the day. These facts, along with the costs of installing the sign and other site-specific conditions of the problem location, should be considered when comparing the use of a flashing LED stop sign with the use of alternative countermeasures; i.e., a flashing LED stop sign is one of many tools in a traffic engineer's toolbox that maybe applicable at a site given its specific conditions.

- VDOT's Traffic Engineering Division and regional traffic engineers should consider the use of optical speed bars as a safety countermeasure to be placed just in advance of a hazardous area, a reduced speed zone, or another roadway/travel .change area where the number of crashes is higher than expected or where excessive speeding occurs. Field testing found statistically significant .speed decreases of vehicles

at the downstream terminus of a set of such bars, which suggest drivers are more aware of the upcoming hazard or speed zone and thus more prone to be traveling at a recommended safe speed. The speed decreases may be small, however: in the range of 1 to 3 mph, especially with bars that are 18 inches long and extend from both edges of the travel lane. Speed decreases are higher when the bars extend across the travel lane, and this configuration should be considered first. If laid out with thermoplastic tape (and not just paint), the bars extending across the lane also produce a bumping sensation, similar to but less than that of transverse rumble strips but without the noise. These facts, along with the costs of installing the sign and other site-specific -conditions of the problem location, should be considered when deciding the layout of the bars and when evaluating optical speed bars with alternative countermeasures; i.e., optical speed bars are one of many tools in a traffic engineer's toolbox that may be applicable at a site given its specific conditions.

TRANSPORTATION RESEARCH DIGEST

ARIZONA TRANSPORTATION INSTITUTE

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NOVEMBER-DECEMBER 2007

Improving Motor Vehicle Crash Reporting on Nine South Dakota Indian Reservations by Polly Quick, Linda Bailey (South Dakota Department of Transportation, Office of Research, 700 East Broadway Avenue, Pierre, SD 57501-2586) (May 2007)

Highlights

- ❑ Crashes on tribal lands have been underreported by approximately 64%.
- ❑ Crash reports were often not filled out properly or in a timely manner.
- ❑ Most tribes are dissatisfied with their internal data processing.

The research team collected a total of 737 crash reports, though most were not in a form that could be input to the South Dakota Accident Record System (SDARS) for 2005. Nevertheless, as an estimate, this data collection showed that crashes on tribal lands had been underreported by approximately 64%.

In discussions with tribal law enforcement officers and others, it was clear that each tribe is in a unique situation in regard to crash reporting. However, some common themes emerged. Problems fell into two phases of the crash reporting process: the collection phase, and the data processing phase. In the collection phase, the team's research found that full crash reports, with all the details about crash causation and circumstances, were often not filled out properly or in a timely manner.

In the data processing phase, the team found that most tribes were dissatisfied with their internal data processing. Software problems, hardware problems, and general lack of procedures for keeping accurate crash records were found. In the data processing phase, the final transfer of crash reports to the South Dakota Department of Public Safety is key to a complete data set at the state level. One or two tribal councils were reported to be

explicitly opposed to data sharing with the state, but this was not the central barrier to reporting at most tribes.

The team discussed these issues and options for improving the crash reporting at a meeting of tribal law enforcement officials and others in Aberdeen in September 2006. Three major ideas emerged from this meeting. The first was training for law enforcement officers on the crash forms and crash reporting process for South Dakota. The second concerned software solutions for internal tribal data processing and making the crash report form easier to complete. Thirdly, the political issues involved in crash reporting represent a serious barrier to improvement, and are tied primarily to the overall relationship between tribes and the State of South Dakota.

In order to explore the ideas of the Aberdeen meeting, the interim report suggested two pilot projects, which took the form of subcommittees of the technical panel. The first pilot project focused on training for law enforcement officers on tribal lands, and resulted in a description of the appropriate training for tribal or BIA law enforcement officers on crash reporting:

Training in the proper completion of the accident report form will be provided by the State of South Dakota. This training will be provided in two formats, one being on-site and the other as a train the trainer program depending on the needs of the tribal authority. The training will be at no cost to the tribe and will be approximately three hours in length. The Department of Public Safety will be

responsible for the delivery of the report curriculum.

The second pilot project created a draft memorandum of agreement (MOA) on crash reporting between a tribe and the State of South Dakota. The draft MOA, as developed by SDDOT, is an agreement to exchange crash data between the tribe and the state to improve highway safety. The goal of the agreement as currently drafted is to support engineering solutions to hazardous areas of the roadway, and the agreement specifies that the crash data submitted will be used to address roadway hazards. The draft MOA is a five-year document that would commit the tribal council to sharing data, while the state would agree to provide training and technical assistance to law enforcement agencies submitting data.

For tribes interested in improving their crash reporting, the general principles are: (1) officers should fill out reports as soon as a crash has occurred; (2) supervisors should check the forms for completeness; and (3) the tribe should both maintain an internal file of all crash reports and send copies to both BIA and SDDPS.

Three different pathways to better reporting are described in detail in the report, based on best practices among tribes in South Dakota, tribes in other areas of the U.S., and other states' experiences.

The first pathway is a short-term solution, using paper filing and basic data tracking methods. Law enforcement officers fill out a crash report on site, using a paper form.

The tribal or BIA law enforcement office keeps a copy of the crash report form, keeps a tally or a list of all crashes in a central ledger, and sends a copy of the report form to the SDDPS and the BIA. Several tribes are already using some permutation of this process, sometimes listing crashes in a spreadsheet to keep count and to be able to perform basic analysis. SDDPS can also provide reports to tribes based on the crash reports sent in.

The second and third options involve computerized solutions. Tribes have the option of purchasing and using an off-the-shelf software package for tracking crashes, such as the Cisco, Global, New World, and CRIS software that tribes already use in South Dakota. A key to using this software is to budget for technical support, because several law enforcement agents said that although they had software, it was not always working properly. Alternatively, tribes can choose to use the Traffic and Criminal Software (TraCS) package, a software tool for motor vehicle crash reporting that will soon be available from the SDDPS. One of the main advantages to TraCS over other software is that staff at SDDPS, the Highway Patrol, and others will be trained on the software, and SDDPS will be able to provide technical assistance directly to tribes that use the software. Tribes may need to check the compatibility between TraCS and other software systems they are using for computer-aided dispatch, citations, and other parts of the criminal justice system.

TRANSPORTATION RESEARCH DIGEST

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NOVEMBER-DECEMBER 2007

Knowledge Sharing Should Help States Prepare for Increase in Older Driver Population (United States Government Accountability Office, 441 G Street NW, Room LM, Washington, D.C. 20548; Katherine Siggerud at (202) 512-6570 or siggerudk@gao.gov; <http://www.gao.gov/new.items/d07413.pdf>) (Apr 2007)

Highlights

- ❑ all states reported implementing advance traffic control warning signage on approaches to intersections.
- ❑ 24 states reported including about half, most, almost all, or all of FHWA's practices in their state design guides.
- ❑ 12 states reported they had trained about half, most, almost all, or all of their technical staff.
- ❑ 38 states reported they had held sessions on older driver issues with local governments.

To make roads safer for older drivers, the Federal Highway Administration (FHWA) has recommended practices—such as using larger letters on signs, placing advance street name signs before intersections, and improving intersection layouts—for the design and operation of roadways that make them easier for older drivers to navigate. FHWA is also continuing research to demonstrate the effectiveness of these practices. While these practices are designed to address older drivers' needs, their implementation can make roads safer for all drivers. States have, to varying degrees, incorporated FHWA's older driver safety practices into their design standards, implemented the practices in roadway operation and maintenance activities, trained technical staff in applying the practices, and coordinated with local agencies to promote the use of the practices.

FHWA also provides federal highway funding that states may use to implement

projects that address older driver safety. While older driver safety projects are eligible for federal highway funding, state Departments of Transportation (DOTs) generally place a higher priority on and commit more of their limited resources to other projects—such as railway/highway intersection safety projects, roadside hazard elimination or mitigation projects, road intersection safety projects, and roadway departure projects—that more broadly affect all drivers. Although older driver safety is not the primary focus of these projects, the projects may incorporate FHWA's recommended practices to improve older driver safety.

More than half of the states have implemented assessment practices to support licensing requirements for older drivers that are more stringent than requirements for younger drivers. These requirements generally involve more frequent renewals (16 states), mandatory vision screening (10 states), in-person renewals (5 states), and mandatory road tests (2 states) for older drivers. In addition, all states accept physician reports and third-party referrals of concerns about drivers, while 36 states use medical advisory boards to assist licensing agencies in assessing driver fitness. However, assessment of driver fitness in all states is not comprehensive because cognitive and physical functions are generally not evaluated to the same extent as visual functions. Furthermore, the effectiveness of assessment practices used by states is largely unknown. For example, research indicates that in-person license

renewal is associated with lower accident rates for older drivers—particularly for those aged 85 and older—but vision screening, road tests, and more frequent license renewal cycles are not always associated with lower older driver fatality rates. Because there is insufficient evidence on the validity and reliability of driver fitness assessments, states may have difficulty discerning which assessments to implement. Recognizing the need for better assessment tools, the National Highway Traffic Safety Administration (NHTSA) is developing more comprehensive practices to assess driver fitness and intends to provide technical assistance to states in implementing these practices.

A key initiative implemented in five of the six states we visited was their use of coordination groups to assemble a broad range of stakeholders—including public agencies, academic institutions, medical professionals, and partner nongovernmental organizations—to develop strategies and implement efforts to improve older driver safety. Specific efforts under way in the states we visited were generally in areas of strategic planning, education and awareness, licensing and driver fitness assessment, engineering, and data analysis. Following are examples:

Florida promotes education and public awareness through the Florida GrandDriver® Program that reaches out to older drivers by providing Web-based information related to driver safety courses and alternative transportation; provides training to medical, social service, and transportation professionals on older driver issues; sponsors safety talks at senior centers; and holds events to help older

drivers determine if they need to make adjustments to better fit in their cars.

Michigan conducted a demonstration program, funded jointly by state, county, and local government agencies, along with the American Automobile Association (AAA) of Michigan, that made low-cost improvements at over 300 high-risk, signal-controlled intersections in the Detroit area; an evaluation of 30 of these intersections indicated that the injury rate for older drivers was reduced by more than twice as much as for drivers aged 25 to 64 years.

However, according to officials we spoke with in these six states, knowledge sharing among states on older driver safety practices is limited, and the general consensus of these officials is that states could benefit from knowledge of other states' initiatives to address older driver safety issues. According to these officials, sharing this information could help them make decisions about whether to implement new practices and identifying the research basis for practices could assist them in assessing the benefits to be derived from implementing a particular practice. To facilitate this transfer of knowledge between stakeholders in all states, we are recommending that the Secretary of Transportation implement a mechanism that would allow states to share information on leading practices for enhancing the safety of older drivers. This mechanism could also include information on other initiatives and guidance, such as FHWA's research on the effectiveness of road design practices and NHTSA's research on more effective driver assessment practices.

TRANSPORTATION RESEARCH DIGEST

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NOVEMBER-DECEMBER 2007

Rational Shear Provisions for AASHTO LRFD Specifications by Arghadeep Laskar, Jun Wang, Thomas T. C. Hsu, and Y. L. Mo, Department of Civil & Environmental Engineering Cullen College of Engineering, University of Houston, Houston, TX 77204-4003 (Texas Department of Transportation, Research and Technology Implementation Office P.O. Box 5080, Austin, Texas 78763-5080; 979.845.1734; <http://tti.tamu.edu>) (Jan 2007)

Highlights

- Prestress causes a 15% increase of concrete compressive strength under sequential loading.
- An analytical model is developed to calculate the ultimate shear capacity of the prestressed concrete beams.
- A new design equation is developed using the results of the beam tests performed in this research.

The purpose of this research was to study the behavior of prestressed concrete elements and beams under shear and to finally develop a simplified equation for the shear design of prestressed concrete girders. The following conclusions are made from this research:

The Softened Membrane Model for Prestressed Concrete (SMM-PC) is presented in this research as an analytical model to predict shear behavior of prestressed concrete elements. The SMM-PC is an extension of the SMM developed at the University of Houston. This new model is applicable to reinforced and prestressed concrete, with any ratio of longitudinal steel to transverse steel, and in any orientation of steel reinforcement with respect to the applied principal stresses. Although this model was verified for application to concrete of normal strength (42 megapascals (Mpa)) in this research project, future research is likely to prove that it is also applicable to high-strength concrete up to 100 MPa.

To implement the new model SMM-PC, new constitutive laws are established for prestressed concrete under sequential and proportional loading. The constitutive laws of concrete in tension include the decompression load stage.

Prestress causes a 15% increase of concrete compressive strength under sequential loading. In the case of proportional loading, a prestress factor in softening concrete (W_p) is proposed for incorporation into the softening coefficient of prestressed concrete. W_p is expressed in terms of the deviation angle β , and takes care of the effect of prestress on concrete compressive strength.

The constitutive laws of prestressing strands embedded in concrete are obtained. Compared to bare prestressing strands, the smeared (average) stress-strain relationships of prestressing strands has a lower ultimate strength, a lower elastic limit, and a knee region of smaller curvature.

A post-tensioning system was developed for seven-wire strands to simulate the bond condition of pre-tensioning strands. A system of self-compacting concrete grout (SCCG) in flexible conduits was developed to create the same crack patterns in post-tensioned concrete as those in pre-tensioned concrete.

The shear behavior of prestressed concrete beams was critically examined by full-scale tests on five Texas Department of Transportation (TXDOT) Type-A beams with web shear or flexural shear failure.

Using the constitutive laws developed in this research, an analytical model is developed to calculate the ultimate shear capacity of the prestressed concrete beams. Using this model, ultimate capacities of beams can be calculated corresponding to given angles of failure planes.

A new design equation is developed using the results of the beam tests performed in

this research as well as test results from other tests available in literature. Four design examples are shown to illustrate the use of the developed design equation for prestressed girders.

The new design equation is extended to include non-prestressed girders, and a design example for the same is also prepared.

TRANSPORTATION RESEARCH DIGEST

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NOVEMBER-DECEMBER 2007

Survey of Cathodic Protection Systems on Virginia Bridges by Stephen R. Sharp and Michael C. Brown, Virginia Transportation Research Council, 530 Edgemont Road, Charlottesville, VA 22903 (Virginia Department of Transportation, 1401 E. Broad Street, Richmond, VA 23219) (Jun 2007)

Highlights

- If sufficient cathodic current is supplied to the steel reinforcement, the corrosion rate of the steel will decrease to a negligible value.
- Up to 10,000 m² of reinforced concrete surface can be protected by a CP system using less power than it takes to run a single 100-watt light bulb.

The Virginia Department of Transportation (VDOT) has employed cathodic protection (CP) systems to preserve reinforced concrete structures that have deteriorated, primarily because of chloride-induced corrosion. These systems function by supplying the reinforcing steel with a cathodic current (electrons are forced into the steel) using either an impressed current CP (ICCP) system or a galvanic anode CP (GACP) system. These systems are sometimes referred to as "active" and "passive" systems, respectively. GACP is sometimes referred to as sacrificial anode CP.

In these systems, if sufficient cathodic current is supplied to the steel reinforcement, the corrosion rate of the steel will decrease to a negligible value. The difference between ICCP and GACP is the source of the cathodic current. The benefit of the ICCP system is that it is adjustable, such that if sufficient current is not being supplied, the current can usually be increased by simply adjusting the rectifier output. Its life is often limited by the life of the anode or electronic components within the system. The disadvantage of an ICCP system is that periodic monitoring and routine maintenance by the bridge owner are vital if it

is to provide optimal protection for a significant period of time.

A GACP system provides a nearly maintenance-free option. However, the current output of the system is limited because it depends on the naturally occurring difference in voltage between the sacrificial anode and the steel. Moreover, the life of the system is limited by the mass of the anode, which is consumed over time and will not be completely converted into protective current.

Up to 10,000 m² of reinforced concrete surface can be protected by a CP system using less power than it takes to run a single 100-watt light bulb. Although CP systems can theoretically be an efficient means of combating corrosion in reinforced concrete structures, the reported practical success of CP when applied to reinforced concrete structures indicates mixed results.

Conclusions

Research on some GACP systems (e.g., GACP structural jackets and thermally sprayed GACP systems) has demonstrated favorable results. This technology has not yet been commonly deployed in the field in Virginia structures. The literature review in this study indicated that GACP systems enhance the service life of reinforced concrete structures or components and require less monitoring and maintenance than do their ICCP counterparts.

A CP system installed in VDOT's Hampton Roads District in a non-research application was not successful. The researchers suspect this was because the relatively large

system constituted the first CP treatment of a structure in Virginia that was not part of a research study and thus was not deployed under the tightly controlled conditions of a research study. As CP systems in non-research applications become common, and they are thus treated as an integral part of the structure with the concurrent ordinary maintenance, greater successes will likely accrue.

To rehabilitate a three-span, 150-ft-long structure carrying two lanes of traffic, a latex-modified overlay can be applied for approximately \$10.25 per square foot (using VDOT project costs from 2006). Such an overlay could be expected to extend the life of the deck by about 18.5 years. The deck could be further protected with an ICCP system at \$13 per square foot (not including the cost of repairs and overlay) for approximately \$70,000 additional cost. The ICCP system would be expected to extend the life benefit of the overlay to 35 years if properly maintained. By contrast, if the ICCP system is not installed, rehabilitation after approximately 18 years would cost approximately \$110,000 in 2007 dollars. By nearly doubling the life of the deck repairs and overlay, the ICCP system can prevent the occurrence of another such rehabilitation in the future. Even with routine monitoring of the ICCP system, at the cost difference of approximately \$40,000 over the same 18-year period, the CP system can

provide substantial savings. The direct costs of the two approaches, with or without a CP system, are similar over the life of the deck. However, this simple analysis does not take into consideration the user costs associated with the closing of a structure for rehabilitative repair. By preserving the structure and extending the life of the initial overlay with a CP system, a future rehabilitation can be deferred or prevented and fewer intermediate repairs will be necessary. This can have significant implications for users of a structure, particularly on congested urban or arterial routes.

The substructure of such a bridge with two four-pier bents might receive an Al-Zn-In alloy thermal spray GACP system. The cost of this application would be on the order of \$12 per square foot, for a total of approximately \$24,000 in addition to the cost of any necessary repairs. The GACP system is expected to last 15 years on average, depending on the severity of exposure. Substructure repairs cost on the order of \$75 per square foot. A GACP system would break even in cost if it could prevent the need for repairs on approximately 16% of a substructure surface over the life of the structure. Further, this sort of system does not require a significant investment in monitoring or maintenance, thereby reducing long-term costs.

TRANSPORTATION RESEARCH DIGEST

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NOVEMBER-DECEMBER 2007

Nanotechnology Synthesis Study by Richard Liu, Zhibin Zhang, Rui Zhong, Xuemin Chen and Jing Li, Department of Electrical and Computer Engineering, University of Houston, 4800 Calhoun Rd., Houston, TX 77204-4005 (Texas Department of Transportation, Research and Technology Implementation Office P.O. Box 5080, Austin, Texas 78763-5080; 979.845.1734) (Apr 2007)

Highlights

- At the current stage, nano materials and smart materials are still in the lab stages.
- Practical applications will come 5 to 10 years from now.

Growing with the development of semiconductor fabrication industry, microelectrical mechanical systems (MEMS; also called nanotechnology) technology has begun to impact highway pavement construction materials and the pavement infrastructure condition monitoring sensor network. This project investigated the potential nanotechnology applications in highway pavements mainly in two different categories: smart materials for pavement construction and sensors for transportation and pavement infrastructure condition monitoring. The smart materials are applicable to the pavement construction materials including concrete, asphalt, aggregates, and pavement marking materials, and the sensors, including temperature sensor, strain sensor, pressure sensor, accelerometer, and moisture sensor, now form a reliable, accurate, low-cost network and are suitable for transportation and pavement infrastructure condition monitoring.

Radio frequency (RF) MEMS technology is an advanced and innovative MEMS sensor technology which transmits MEMS sensor data wirelessly at a high speed securely, instead of using a traditional wired communication system. Ultra-low-cost RF MEMS sensors can be placed in the pavements,

bridges, and even inside concrete and asphalt in large quantities to form a local RF MEMS sensor network for different pavement infrastructure monitoring purposes. Smart materials and applications of RF MEMS sensor networks are also investigated in this report. Nano materials are very attractive to the Texas Department of Transportation (TxDOT). Though nano materials are still in the research and development (R&D) stages and are not cost effective for implementation at this time, nano-based sensors are maturing and can be used in TxDOT for monitoring and other applications.

Conclusions

Based on the investigations performed in this project, there are many aspects of nanotechnologies that can be applied to transportation systems. However, the successful nanotechnology application may need 5 or 10 years to be commercialized. Two categories of nano-products have great potential to transportation: 1) nanotechnology-based materials and 2) nanotechnology-based sensors. Smart materials are materials with sensors and actuators built in. Nano-based sensors are also called MEMS. In transportation applications, sometimes we prefer bigger sensors and actuators to small-scale ones. Therefore, many emerging sensors, even though they are not nano-based sensors, are useful, such as microwave and fiber-optic WIM sensors. At the current stage, nano materials and smart materials are still in the lab stages. Practical applications will come 5 to 10

years from now. Possible applications of nanosensors include the following:

1. *Stop sign monitoring sensor network:* a MEMS accelerometer and a magnetometer collects the rotation and tilt information of stop sign. And it is very useful in maintaining the safety of transportation. Details are discussed in the demo application.

2. *RF tags:* RF tags are mostly used for replacing bar codes for inventory purposes. The costs of RF tags are getting very low. Passive RF tags are in the sub-dollar range in quantities. The distance to which an RF tag can send signals is about a few feet to 100 ft. Passive RF tags have a sensing range of only a few feet. Active RF tags have a longer distance, up to about 100 ft, depending on the operating frequencies. TxDOT can use RF tags for pavement on-site monitoring, traffic sign position locations, monitoring to prevent signs from being moved, and materials inventory.

3. *MEMS-based sensors:* Examples of such sensors include MEMS-based accelerometers, which can be used in a profiler

to replace costly coil-type accelerometers. Due to the low-cost nature of the MEMS accelerometer (\$10 each in small quantities, in contrast to \$800 for coil-type accelerometers), several MEMS accelerometers can be stacked for lower measurement noise, to extend a lower speed limit to the profiler. The current profiler has a low speed limit of 20 miles per hour, which is sometimes a problem.

4. *Innovative sensors and actuators that are not based on nanotechnologies:* There are emerging sensors and actuators that use advanced technologies, but not based on nanotechnologies. And that may have great application potentials to TxDOT, such as fiber-optic sensors and microwave WIM sensors.

In a few years, the sensors and actuators using nano and other technologies will have a lower cost and be in production. TxDOT is in a good position for applying these materials and sensors in Texas highways in the future to reduce maintenance costs, increase pavement lifespan, reduce accidents, and increase construction efficiency.

TRANSPORTATION RESEARCH DIGEST

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NOVEMBER-DECEMBER 2007

The Role of Tolls in Financing 21st Century Highways by Peter Samuel (Reason Foundation, 3415 S. Sepulveda Blvd., Suite 400, Los Angeles, CA 90034; 310/391-2245; <http://www.reason.org/ps359.pdf>) (May 2007)

Highlights

- ❑ The “gas tax-and-grant” system does not generate enough revenue to properly maintain the existing highway system.
- ❑ A promising option is the long-term toll concession agreement, used extensively in Europe and Australia.
- ❑ This option can deliver a substantially larger investment of resources for a given toll project than the conventional state or local government toll authority.

Traffic congestion in America is bad and getting worse. Our road system is not being maintained and expanded commensurate with our growth, despite being the most important means of moving goods and people from here to there. Because of a lack of proper investment in road capacity, congestion costs Americans at least \$168 billion each year. Worse, buried in those costs is the reality that congestion is clogging the arteries of our cities. If we don't solve the problem our cities will begin to die as centers of economic productivity, as centers of culture, and as pleasant places to live.

Federal and state highway budgets are determined by government grants and funded by taxes on gasoline. This “gas tax-and-grant” system, which was developed between the 1920s and the 1950s, is running on fumes. It does not generate enough revenue to properly maintain the existing highway system, let alone expand and modernize it for our growing population and dynamic economy.

As more and more fuel-efficient vehicles have allowed us to reduce gasoline

consumption per mile driven, the revenues from gas taxes drop and the need for pavement construction and maintenance continues to grow. The tax-and-grant system does a poor job of targeting investment to where road capacity is truly most needed and where it would yield the greatest returns, resulting in an inefficient use of scarce capital. It is also unfair, as the discretionary grant element in the system indulges politically well-connected constituencies at the expense of others with less political clout.

The tax-and-grant system has largely become a public works program used by politicians to bring home the “pork.” Alone, it is not able to solve the nation's growing congestion problem, and it has no chance of producing the high-performance roadways needed in the 21st century. The American public has lost confidence in this outdated system, which funds “bridges to nowhere” while trucks with valuable cargoes sit in congestion amid frustrated commuters, delivery van drivers, and shoppers on deteriorating urban expressways.

Fortunately, there is a better way. The first key to reform is to begin to break free of the stifling pay-as-you-go doctrine embedded in the tax-and-grant system. Rather than make marginal improvements to the system as the funds become available, a better public policy would finance new highways and bridges, so that they can get built promptly today and then be paid for by their users over the useful life of these projects. This is the principle of toll finance that is being rediscovered in this

country, as technical revolutions in toll collection technology have swept away the limitations of stopping at tollbooths.

The second key is to break free of the limitations of traditional government toll road agencies, which are subject to political influences that are often not in the best interest of highway users or the public at large. Also since government toll agencies bring little or no private equity capital and rely almost entirely on borrowing, they are unable to manage risks such as construction delays, cost overruns, and shortfalls in projected usage, thus unduly limiting the range of projects that can be financed with tolls. Toll authorities tend to be granted monopoly powers in a region and therefore experience no competitive pressure to improve performance. They are also geographically constrained to the boundaries of their jurisdiction, when many needed projects cross these boundaries, including state lines.

Alternate financial mechanisms promoted as innovative in the 1990s—such as shadow tolls (payments from the government to private road builders/operators based on the number of vehicles using the road), borrowing against future grants, and the creation of non-profit corporations to operate highways—have demonstrated that they offer little improvement over the traditional government toll agency model.

A more promising model is the long-term toll concession agreement, used extensively in Europe and Australia, and only recently introduced to the United States. In

exchange for a long-term, franchise-type agreement (called a lease and concession agreement), a competitively selected private firm or consortium designs, finances, builds, operates, and maintains a tolled project for a long period (anywhere from 35 to 99 years). Because the private concessionaire is willing to invest its own money on a long-term basis, it is willing and able to manage risks that public toll authorities are ill-equipped to handle. Also, by being able to pool risks and deploy expertise across multiple jurisdictions and countries, the private concessionaire can operate more efficiently. The evidence from innovative jurisdictions that have introduced long-term toll concession agreements through public-private partnerships, such as Chicago, Indiana, Texas, and Virginia, suggests that this model can deliver a substantially larger investment of resources for a given toll project than the conventional state or local government toll authority model. Private concessions operating within broad performance guidelines are also better suited for the management of “value-priced” electronic tolling for congestion relief.

Tolls can only answer part of the funding needs for our transportation system over the next 25 years. Toll finance is not the answer for all future highway projects, nor are long-term concessions the only model that can deliver such projects. But the successes of such models are so striking that they should rapidly become an important part of our transportation system.

TRANSPORTATION RESEARCH DIGEST

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A Return on Investment Study of the Hampton Roads Safety Service Patrol Program by Lance E. Dougald, Virginia Transportation Research Council, 530 Edgemont Road, Charlottesville, VA 22903 (Virginia Department of Transportation, 1401 E. Broad Street, Richmond, VA 23219) (Jun 2007)

Highlights

- Savings generated by the program are nearly 5 times the expenditure it takes to run it.
- Weekend operations had benefits smaller than the costs.
- The average clearance times for VSP assists (with no SSP support) and SSP assists were 49 and 10 min, respectively.

Safety Service Patrol (SSP) programs are widely used to help mitigate the effects of nonrecurring congestion on our nation's highways and have become an increasingly vital element of incident management programs. SSPs are typically deployed in areas that have high traffic volumes (e.g., urban freeways). They are charged with clearing obstructions such as debris and disabled vehicles from roadways and assisting state police with traffic control at crash scenes.

In recent years, some state departments of transportation have initiated studies that attempt to quantify the benefits associated with their SSP programs. Benefits are typically quantified by measuring reductions in motorist delay, fuel consumption, emissions, and secondary accidents. The underlying means used to obtain such benefits are determining incident durations with and without SSP operations. Obtaining incident duration data prior to SSP program implementation has often proven difficult because of the lack of available data. Therefore, many studies either make an assumption of incident duration reductions with SSP or attempt to analyze incident duration

reductions using current SSP and state police computer-aided-dispatch (CAD) data.

A recent study by the Virginia Transportation Research Council (VTRC) that evaluated the benefits of the Northern Virginia (NOVA) SSP estimated a 17% reduction in overall incident durations with SSP operations. Evaluation showed that the benefits outweighed the costs associated with SSP operations by a ratio of 6:1. As a result of this study and in support of the Virginia Department of Transportation's (VDOT) return on investment (ROI) initiatives, staff from VDOT's Operations Planning Division requested that a similar study be conducted with regard to the Hampton Roads SSP.

Conclusions

The Hampton Roads SSP generates a positive return on VDOT's investment. The estimated dollar benefit of the Hampton Roads SSP (measured in terms of savings in delay and fuel consumption) was approximately \$11.1 million from July 1, 2005, through June 30, 2006. VDOT's investment, in terms of supplying patrollers and patrol vehicles to the routes, was approximately \$2.35 million for the same period. Thus, the savings generated by the program are nearly 5 times the expenditure it takes to run it. In other words, the benefit to cost (B/C) ratio of the program is nearly 5:1.

Incidents occurring at locations with low volume to capacity (V/C) ratios will have less of an impact on motorists (in terms of delay); this appears to be the case for the routes

that have an associated low B/C ratio. Of the 21 evaluations performed, 9 revealed a B/C ratio of less than 1; all were Saturday and Sunday evaluations. A contributing factor to the low B/C ratio is low route-wide V/C ratios. High V/C ratios indicate that traffic volumes are near (or above) the facility's capacity and thus even minor incidents occurring at locations with high V/C ratios (such as shoulder disablements) have a greater chance of creating delay to motorists.

During the summer months when there is a large number of vacationers traveling on I-264, the V/C ratios will likely increase and thus the B/C ratios will likely increase. Because this study evaluated the benefits of the Hampton Roads SSP during a one-year period, seasonal variations in traffic volumes and incidents were attenuated. For example, Route 20/2I had a high number of Saturday and Sunday incidents during the evaluation year yet was associated with low B/C ratios, primarily because of low V/C ratios.

By integrating databases and establishing consistent protocols for incident "start" and "end" times, a comprehensive incident duration reduction analysis can be performed in the Hampton Roads region that would reflect more accurate incident duration reductions. Based on clearance time data obtained from the VSP CAD and the ADMS databases for all accident, breakdown, and

debris incidents within the boundaries of SSP-covered routes, the average clearance times for VSP assists (with no SSP support) and SSP assists were 49 and 10 min, respectively. These clearance time values indicate an incident duration reduction of approximately 79% with SSP support. This percentage, however, can be misleading because VSP personnel typically respond to more major incidents that require more time to clear. Further, because of limitations in VSP CAD details (e.g., absence of information on the number of lanes blocked), irregularities present in both databases with incident "start" and "end" times, and the fact that the databases are not integrated, a comprehensive incident duration reduction analysis that compares clearance times for like incidents could not be performed. The NOVA SSP study found a 17% incident duration reduction with SSP support. This finding was obtained via a time-consuming incident matching and comprehensive statistical analysis of clearance times with and without SSP for similar incident severity types. Such an analysis was not performed for the Hampton Roads SSP because of the inconsistencies in data entry protocols and the absence of VSP CAD incident detail. If such an analysis could be performed, incident duration reduction values might be closer to those of the NOVA SSP study.

TRANSPORTATION RESEARCH DIGEST

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Effectiveness of Commercial Motor Vehicle Driver Training Curricula and Delivery Methods, CTBS Synthesis 13 by John F. Brock, John McFann, Robert E. Inderbitzen, & Gene Bergoffen (Transportation Research Board, 500 Fifth Street, NW, Washington, DC 20001; (202) 334-3213; <http://gulliver.trb.org/bookstore>) (2007)

Highlights

- The level of driving proficiency and knowledge required to earn a commercial drivers license (CDL) is widely regarded in industry as well below the level required to be a safe and reliable driver.
- Carriers and transit agencies report that they are sure that training reduces accidents; however, little data support that view.

This synthesis summarizes the state of vehicle operator training in the trucking, motorcoach, and transit industries. It captures in detail the experiences of those training programs that are using some combination of simulators and computer-based instruction (CBI). The synthesis also identifies current measures of training effectiveness in the commercial vehicle operator school and carrier communities. It describes training effectiveness measures being used in the military and industry and describes some potential training effectiveness measurement models for commercial vehicle operator training programs.

Conclusions

Content. There is general agreement across the industry about the core content of commercial driving curricula. However, the content has evolved through an informal consensus based on the 1984 FHWA Model Curriculum, which listed what was believed to be the necessary content at the time. There are no national standards on content, although when one examines various curricula, little

content difference can be found. The industry could use a systematic development of a modern commercial driver training curriculum.

Instructional Methods. The favorite method for training commercial drivers is a combination of classroom lectures and supervised driving. Most of the research findings on adult learning and instructional technology from the last 30 years have not been incorporated into many commercial driving training enterprises. In those cases where advanced technologies are being applied, early data indicate that well-designed CBI, including simulation, can improve student performance and also realize efficiencies in the instructional process. Distance learning shows great promise for post-licensing training.

Train the Trainer. It is natural that older, experienced drivers are selected to be instructors, no matter if the training is administered by a school, carrier, bus company, or transit agency. But there is no evidence that a person who is a job expert is necessarily a good teacher. There are two sets of skills a good driver training instructor must possess beyond driving competence. One set involves classroom skills (presentation fundamentals, using classroom equipment, listening to students). These skills are well recognized and are a part of good train-the-trainer programs. The second set involves BTW skills (observational fundamentals, explaining activities in understandable and behavioral terms, cool head, ability to anticipate risky situations). Since there are no standards for

commercial vehicle driver training instructors, this most important role in the training process is extremely variable.

Lack of Systematic Training Design. The commercial vehicle industries have reached an informal consensus on the subject of commercial driver training. However, it has been more than 20 years since a formal curriculum design for commercial drivers was systematically developed. In those 20 years, the CDL program has become law, new technologies and regulations for truck and bus operations have had a major impact on the drivers, and the collected knowledge about what effects a commercial driver's performance (e.g., fatigue, distraction, age) has grown exponentially.

Lack of Standards for Measuring the Effectiveness of Driver Training Programs. Currently, the only generally acceptable standard for measuring the effectiveness of commercial driver training is the number of graduates who can pass their CDL tests. In both the survey and in personal conversations,

schools reported that they also track the number of graduates that are hired by carriers. Carriers, motorcoach operations, and transit agencies report that they are sure that training reduces accidents; however, little or no data support that view. Standards purporting to measure training effectiveness tend to measure processes (classroom hours, time spent behind the wheel) rather than specific performance outcomes.

Commercial Vehicle Operator Abilities. There has been a spate of recent research on the capabilities and limitations of adolescent drivers. However, a similar scientific approach to commercial drivers is lacking. If commercial vehicle operator trainers understood more about the learning styles, cognitive strategies, and past educational experiences, training could be tailored to the relevant needs of the individual student. A set of diagnostic tests that could funnel students into unique optimum learning opportunities would be a major jump in improving commercial driver training.