# *TRANSPORTATION RESEARCH DIGEST*

*OCTOBER 2009*

ARIZONA TRANSPORTATION INSTITUTE

***e-mail jsemmens@cox.net***

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# *TRANSPORTATION RESEARCH DIGEST*

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***e-mail*** jsemmens@cox.net

*OCTOBER 2009*

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.

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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.

| Code | Topic | Code | Topic |
|---|---|---|---|
| ADM | Administration | PLAN | Planning |
| AIRP | Airports | PRIV | Privatization |
| AVIA | Aviation | RAIL | Railroads |
| BIKE | Bicycles | RDSD | 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 |

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***e-mail*** jsemmens@cox.net

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***Highway Drainage at Superelevation Transitions*** by Randall J. Charbeneau, Jaehak Jeong, Michael E. Barrett, Center for Transportation Research, University of Texas at Austin, 3208 Red River, Suite 200, Austin, TX 78705-2650 (Texas Department of Transportation, Research and Technology Implementation Office, P.O. Box 5080, Austin, TX 78763-5080; http://www.utexas.edu/research/ctr/pdf_reports/0_4875_1.pdf) (Mar 2008)

**Highlights**

- The primary features that influence pavement drainage and ponding of stormwater runoff near superelevation transitions are the combined effects of the change from negative to positive lateral grade for the outside lanes of a curve near the transition and the longitudinal slope.

The research objectives focused on four major questions: 1) whether literature characterization of sheet flow mechanics provides appropriate models for application to highway drainage; 2) whether kinematic or diffusion wave models are applicable for simulation of highway runoff near superelevation transitions; 3) how the pattern of pavement drainage at superelevation transitions is influenced by longitudinal grade; and 4) whether design guidance can be developed to minimize stormwater ponding through control of longitudinal grade at superelevation transitions.

The physical modeling program has shown that conventional models from fluid mechanics can be used to describe sheet flow behavior on rough surfaces with a primary variable that is directly related to surface roughness. Significantly, the much simpler Manning equation provides a model that is equally capable of representing the experimental data. Estimated magnitudes of roughness height determined using the logarithmic boundary layer model and Manning's equation are very similar and correspond directly to the material characteristics that were used to create the three different experiment surfaces. The effective flow depth should be measured from near the top of the roughness element height, and this effective flow depth corresponds to the depth that is significant in determining hydroplaning potential. While there is large uncertainty in predictions for small flow rates, the lack of Reynolds number dependence on the primary flow parameter is different than found in other recent highway-related research studies and greatly simplifies model development and application. Finally, for sheet flow over rough surfaces, the effect of rainfall at intensity of approximately 100 mm/hr does not have a consistent effect on flow behavior. Apparently, the chaotic effects of raindrops do not significantly affect flow behavior beyond that caused by the surface roughness.

Both kinematic and diffusion wave numerical simulation models have been developed as part of this research program. For regular (flat) surfaces, these models give equivalent results. However, with irregular roadway sections such as found near superelevation transitions, the kinematic wave model formulation cannot be used because transverse (between adjacent flow paths) head gradients can become significant. In contrast, the diffusion wave model formulation is capable of addressing all flow conditions that would be expected. Diffusion wave model

formulation is much simpler than full dynamic wave models, and solution methods are much easier to develop and apply.

The primary features that influence pavement drainage and ponding of stormwater runoff near superelevation transitions are the combined effects of the change from negative to positive lateral grade for the outside lanes of a curve near the transition and the longitudinal slope. For a roadway without curbs under normal crown conditions, the greatest ponding depth occurs near the roadway edge and increases with roadway width, rainfall intensity, surface roughness, and longitudinal slope. There is approximately a 40% increase in maximum flow depth at the roadway edge as the longitudinal slope increases from zero to 6% under normal crown conditions. The situation is quite different for superelevation transition sections. The magnitude of the maximum flow depth increases compared to normal crown conditions and the location of maximum depth changes with longitudinal slope. For transitions entering a superelevated section with positive longitudinal grade (down slope) the location of maximum depth is near the outside edge of pavement for slopes up to 0.4%. For longitudinal slope values between about 0.4% and 3%, the location of maximum ponding depth is located near the roadway centerline, but on the outside lanes. For longitudinal slope values greater than about 3%, the location of maximum flow depth is located on the inside edge of pavement at a distance downstream from the zero cross slope (ZCS) station. For a Type-II configuration, which corresponds to a roadway exiting a superelevated section with positive slope, the location of maximum flow depth is always located near the outside edge of pavement at a distance downstream of the ZCS station that increases with longitudinal grade. For both Type-I and Type-II configurations, the magnitude of the maximum flow depth changes very little with longitudinal grade.

Development of design guidance to minimize ponding depth as a function of longitudinal grade is difficult. The primary difficulty is that the maximum ponding depth on the roadway surface is not very sensitive to longitudinal grade. What is possibly more significant is the observation that the location of maximum ponding depth is sensitive to longitudinal grade. Other issues that are possibly important for vehicle safety include lateral variation in ponding depth, which may cause torque on the vehicle due to differential drag on tires, and the longitudinal rate-of-change in ponding depth, which could serve to initiate hydroplaning.

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***e-mail*** jsemmens@cox.net


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***Prediction Model for Concrete Behavior*** by Kevin J. Folliard, Maria Juenger, Anton Schindler, Kyle Riding, Jonathan Poole, Loukas F. Kallivokas, Samuel Slatnick, Jared Whigham, J.L. Meadows, Center for Transportation Research, University of Texas at Austin, 3208 Red River, Suite 200, Austin, TX 78705-2650 (Texas Department of Transportation, Research and Technology Implementation Office, P.O. Box 5080, Austin, TX 78763-5080; http://www.utexas.edu/research/ctr/pdf_reports/0_4563_1.pdf) (May 2008)

**Highlights**

- Significant savings can be expected at several different stages of projects for which the ConcreteWorks model is used.
- The savings in avoiding repairing or replacing bridges will be significant.

ConcreteWorks provides engineers, contractors, and inspectors with a user-friendly tool for quantifying concrete material behavior, particularly the heat generation and cracking risk of mass concrete members in transportation structures. In order to develop the software, significant research was performed to quantify early-age concrete behavior. A heat of hydration model was developed in which a non-linear regression analysis was used to produce equations for the activation energy of cementitious systems, as well as models to quantify the heat of hydration development. Different models were developed for cement compositions determined by the Rietveld and Bogue methods. These models account for mixture proportions, cement and SCM chemistry, and chemical admixture dosages.

To complete the temperature prediction model, the effects of geometry, formwork type, and environmental conditions needed to be quantified as well. An analysis of the heat conduction in the concrete, the heat generation from the hydration process, and the heat exchanged at the boundary of the structural element was carried out. Once the model was completed, the results were compared with field site data to validate its effectiveness.

Next, early-age concrete property development was modeled using results from rigid cracking frame results and splitting tensile, elastic modulus, and compression testing. A nonlinear multivariate model for predicting creep was developed based on concrete constituent material properties and mixture proportions from Rietveld or Bogue data. Failure criteria to calculate the probability of concrete cracking based on the concrete tensile strength-to-splitting tensile strength ratio were also developed.

ConcreteWorks allows the user to input the member dimensions, environmental conditions, and formwork properties, as well as time and location. The program predicts the temperature development in the member and assesses the cracking potential.

**Economic Benefits**

A thorough analysis on the economic benefits of using ConcreteWorks has not been carried out. However, significant savings can be expected at several different stages of projects for which ConcreteWorks is used. In the design stage, the engineer can run ConcreteWorks with mixes containing different kinds of local aggregates in order to create an efficient mix design while minimizing cost.

In the construction stage, contractors can use ConcreteWorks instead of more complex and expensive analysis to develop a thermal stress control plan. Furthermore, ConcreteWorks can be used to assess when formwork may be removed. Removing formwork earlier will result in speedier construction and thus reduced overall costs.

Most importantly, the savings in avoiding repairing or replacing bridges will be significant. Repairing or replacing bridges that are not functionally obsolete is very costly. The most critical time for assuring a long service life for a concrete structure is before and during construction. Proper use of ConcreteWorks during the design and construction stages will result in these unexpected problems being avoided. Also, with the chloride ingress model structures can be designed for greater durability, so that future maintenance and replacement costs can be reduced.

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***e-mail*** jsemmens@cox.net

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***A Cost Evaluation of Cross-Border Truck Emissions Testing Using Heavy Duty Remote Sensing Equipment*** by Vi Brown, Prophecy Consulting Group, LLC, 2005 S. Henkel Circle, Mesa, AZ 85202-6564 (Arizona Department of Transportation, 206 S. 17th Avenue, Phoenix, Arizona 85007; http://www.azdot.gov/TPD/ATRC/publications/project_reports/PDF/AZ637.pdf; Ph. 602-712-3138) (Jun 2008)

**Highlights**
- Remote sensing is still an emerging technology.
- The cost to implement remote sensing for heavy duty vehicles at Arizona's LPOEs ranges up to $2 million.

Emissions measurement systems and programs for light-duty vehicles are well defined in the literature and demonstrated within the Arizona, nationally and globally. Most of these systems rely on an inspection and maintenance (I&M) program that is tied to a vehicle registration program. In the U.S., most states use the SAE J1667 snap-acceleration test to measure gaseous pollutants and opacity. A cup-like device is used to capture emissions from the vehicle's exhaust prior to screening by equipment.

Unlike I&M programs, remote sensing is the measurement or acquisition of information about an object by a recording device that is not in contact with the object. A remote sensing device (RSD) can be designed to estimate emissions from heavy duty vehicles. As an example, the heavy duty remote sensing (HDRS) technology used for the Nogales, AZ border study utilized both ultraviolet and infrared light beams to instantaneously measure HC, CO, NOX, and PM2.5 from heavy duty truck exhaust. Although HDRS emissions measurement is not used on a large scale, the technology has been around for about 15 years and its efficiency continues to improve.

HDRS is still an emerging technology although significant advances have been made over the last 10 years. HDRS technology has performed well as an emissions screening tool, but has not been used as a primary emissions program. Identifying deployment and set-up strategies for varying truck traffic continues to be a challenge. One such challenge is the varying height and location of the exhaust muffler on many heavy duty diesel trucks.

The review of the literature identified numerous vendors of emissions measuring equipment in the market place. However, when the criteria is narrowed to vendors providing remote sensing equipment, especially instruments designed to measure emissions from heavy duty diesel engines, the field is narrowed to a handful of suppliers.

Three alternatives were developed for a HDRS emissions measurement system data plan:

1. Basic: this is a bare-bones monitoring system that includes HDRS emissions measurement equipment with data collection and communication.
2. Intermediate: this system builds on the basic system by including particulate monitoring equipment and an aethalometer to measure diesel particulates.
3. Fully-integrated: this system is the most robust of the alternatives and provides for a stationary monitoring system (proposed in the basic and intermediate

set-up) as well as a portable monitoring unit.

Cost data were developed for each alternative and includes figures for capital equipment installation and five years of operation and maintenance (O&M) expenses. The present worth costs for each data plan utilizing contract labor ranged from $1,320,828 to $2,177,467. If employees of the Arizona Department of Transportation (ADOT) or the Arizona Department of Environmental Quality (ADEQ) are used, the present worth costs range between $1,140,349.00 and $1,923,247.

While it is obvious that the use of employees is less expensive than contract labor, the agency could find it difficult to attract highly skilled employees for a proposed HDRS emissions measurement program at the Arizona-Mexico border.

ADOT has not stated that it will install an HDRS emissions monitoring station at an Arizona land port of entry (LPOE). However, traffic has increased at the border for all vehicle types: privately owned vehicles (POVs), buses, and large trucks. The increase in border crossings over the years along with the need for more secure border stations has prompted the federal General Service Administration (GSA) to approve a modernization and renovation construction project for the Nogales-Mariposa LPOE. Bids are being solicited for the construction project, estimated at $100 to $150 million. Construction is expected to begin in 2009.

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***e-mail*** jsemmens@cox.net


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***Getting What You Paid For -- Paying For What You Get: Proposals for the Next Transportation Reauthorization*** by Randal O'Toole (Cato Institute, 1000 Massachusetts Avenue, N.W., Washington D.C. 20001-5403; http://www.cato.org/pub_display.php?pub_id=10538; ph 202- 842-0200) (September 15, 2009)

**Legislation Should…**

- Encourage states to focus on user fees rather than taxes to pay for transportation improvements.
- Promote the cost-efficient use of transportation resources.

When Congress passed the Federal Aid Highway Act of 1956, it gave the Bureau of Public Roads a clear mission: oversee construction of a safe, high-speed Interstate Highway System. As that system neared completion in the 1980s, the mission of the Department of Transportation became increasingly murky. Now the department is supposed to reduce congestion; attract people out of their automobiles; clean the air; promote economic development; improve livability; create a sense of community: and accomplish a variety of other often conflicting goals — most of which are not easily quantifiable.

As the mission became muddied, each surface transportation reauthorization since 1982 has included an increasing number of earmarks, divided revenues among more and more different funds, and added lengthy rules for how those funds may be spent. Each earmark, apportionment, and rule has made transportation spending incrementally less efficient.

This increasing politicization of something that began life as a fairly efficient program is the predictable result of government involvement in what is essentially a private economic activity. The inevitability of such decline is a good argument for abolishing the U.S. Department of Transportation and devolving federal transportation programs to the states.

Short of that, Congress should make every effort to return to a system where people get what they pay for — that is, transportation user fees are dedicated to systems that benefit the people who paid those fees — and people pay for what they get — that is, people pay the full cost of the facilities they use.

As a second-best solution to abolishing the Department of Transportation, this paper offers eight proposals essential for the 2009 reauthorization to achieve these goals. These proposals include

1. Apportion funds to states based on population, land area, and user fees
2. Require that short-term plans be efficient or cost efficient
3. Create a citizen-enforcement process that will ensure efficiency and cost efficiency
4. Eliminate long-range transportation planning
5. Allow unlimited use of road tolls
6. Eliminate clean-air mandates
7. Avoid earmarks
8. Remove employee protective arrangements from transit law

**Conclusion**

America's surface transportation network would be extraordinarily improved if

only transportation users were able to get what they pay for and asked to pay for what they get. Getting what you pay for ensures that scarce transportation dollars are not spent on facilities that people really do not need. Paying for what you get ensures that the facilities we build are the ones that people will really use.

Achieving these twin goals means making several major changes in the next reauthorization of federal surface transportation programs. One important change is to encourage states to focus on user fees rather than taxes to pay for transportation improvements. A second important change should be to promote the cost-efficient use of transportation resources.

Finally, Congress should ensure that these changes are properly implemented by directing the Department of Transportation to create a citizens' enforcement process. Making these changes will save taxpayers billions of dollars and lead to a tremendous increase in national wealth and productivity.

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***e-mail*** jsemmens@cox.net



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***Identification of Compliance Testing Method for Curing Effectiveness*** by Seongcheol Choi, Moon Won, Center for Transportation Research, University of Texas at Austin, 3208 Red River, Suite 200, Austin, TX 78705-2650 (Texas Department of Transportation, Research and Technology Implementation Office, P.O. Box 5080, Austin, TX 78763-5080; http://www.utexas.edu/research/ctr/pdf_reports/0_5106_2.pdf) (Jun 2008)

**Highlights**

- The purpose of this research was to identify simple testing procedures that can be implemented to verify the compliance with specification requirements on curing.

Curing has substantial effects on the long-term performance of Portland cement concrete (PCC) pavement. TxDOT requires two applications of curing compounds, with a maximum 180 sf/gal per each application. However, no compliance testing is conducted for curing and, from a practical standpoint, compliance with specification requirements are rarely verified. The purpose of this research was to identify simple testing procedures that can be implemented to verify the compliance with specification requirements on curing. To this end, various test methods that appear to have potential for compliance testing for curing were evaluated in the field. A factorial experiment was set up for field testing, and the test methods evaluated in the field. Varying rate of curing compound applications as well as application time was included as variables in the factorial experiment. Advantages and limitations of each method were identified. Based on the findings in this research, the following conclusions are made.

1. Because the probe of the Windsor probe system is relatively small, the penetration depth is significantly affected by whether it hits coarse aggregate or mortar. The variations in penetration depth due to whether it hits coarse aggregate or mortar could be more than those affected by curing effectiveness. Additionally, substantial error could occur if the probe doesn't penetrate perpendicularly to the surface of the concrete pavement.
2. Surface temperature may detect the difference in the loss of evaporation heat which is caused by varying degrees of curing effectiveness. However, surface temperature also varies depending on weather conditions during construction. It may not be feasible to evaluate the curing effectiveness solely based on surface temperature.
3. The test on initial surface absorption is not simple and easy to implement due to the difficulty in sealing the interface between the instrument and concrete surface.
4. Reflectance has a potential for the field compliance testing to identify the application rate of the curing compound. However, it requires further advancements in this technique to make this approach feasible in the field.
5. The technology for the measurement of internal relative humidity of early age concrete is still under progress and various types of humidity sensors have been tried. In order to obtain the accurate RH in the fresh concrete, there are still a lot of improvements to be made. It is considered that, at this point in time, measurement of

RH may not be a practical field compliance testing method for curing effectiveness.

6. Dielectric constant of concrete constantly changes in fresh concrete as water evaporates from the concrete. The accuracy of dielectric constant measurement techniques currently available is not accurate enough to be included in the specifications as compliance testing.

Based on the findings above, it is concluded that the methods evaluated in this research study are neither practical nor accurate enough to be included in TxDOT specifications as a compliance testing. Based on the research effort in this study, the following potential implementation is recommended.

**Potential Implementation**

One practical issue in the curing operation is to ensure that sufficient amounts of curing compounds are applied uniformly. Currently, there is no good compliance testing available that enables TxDOT to accurately estimate the application rate of the curing compound and its uniformity. It is difficult to keep track of how much curing compound is applied. The rate of the curing compound application and its uniformity primarily depend on cart speed, pump pressure, and nozzle spacing. Retrofit of a curing machine with hardware for speed and pressure measurements may improve the current curing operation and eventually the curing effectiveness in concrete pavement.

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***Will Obama's "Livability" Program Bring Britain's "Hobbit Homes" to America?*** by Ronald D. Utt (Heritage Foundation, 214 Massachusetts Avenue NE | Washington DC 20002-4999; ph 202.546.4400; http://www.insideronline.org/summary.cfm?id=10977) (September 1, 2009)

**Highlights**
- "Smart Growth" programs in the UK made housing scarce, tiny and expensive.
- Similar results can be expected if "smart growth" is imposed in American cities.

Shortly after taking office President Obama announced his intention to develop federal policies to induce states and local communities to embrace "smart growth" land use strategies that would deter growth, crowd development, and discourage automobile use.

Dubbed the "Livable Communities Program," several of the President's cabinet departments have proposed a series of early initiatives to implement the plan and establish long-term strategies. As part of this effort, the Administration provided funding support to the transit industry's *Moving Cooler* study, which argued that their greenhouse gas reduction proposals "may result in higher housing prices, and some people might need to live in smaller homes or smaller lots than they would prefer."

As the evidence from other countries reveal, the creation of a federal land use policy will likely lead to a decline in housing quality, including house size. To prevent this outcome, Congress should ensure that land use policy remains exclusively the responsibility of state and local government.

Residents of the United Kingdom have indeed experienced a dramatic shrinkage in the size of their homes as a result of restrictive land use and housing regulations enacted in 1947 to discourage suburbanization and preserve the rustic countryside.

Recent studies reveal that these regulations have led to shortages of land available for housing, and this in turn has caused the U.K. to have the smallest and most expensive housing in the developed world. London Mayor Boris Johnson refers to these tiny units as "hobbit homes," and he promises to change the situation.

As earlier reports by The Heritage Foundation have pointed out, the smart growth strategies President Obama proposes for the U.S. have led to high home prices in states and communities where elements of such programs have been imposed. And the ensuing affordability problems there have contributed to the mortgage default and foreclosure epidemic that has battered the nation's financial markets for the past two years.

Whereas some communities in the U.S. did not impose smart growth regulations until the early 1970s, the U.K.'s experience with strict land regulation dates to the *Town and Country Planning Act of 1947*, which confined residential development within existing urban areas. By freezing the supply of land for new housing, a growing population was forced to compete for what little was available, and house prices soared as a consequence.

According to the 2009 *Demographia* housing cost study, which covers the United States, Ireland, New Zealand, the United Kingdom, and Australia, not a single British urban area managed to make it into the "affordable" or "moderately unaffordable" categories. Of the 16 U.K. urban areas covered in the report, six were rated "seriously

unaffordable" in 2007, and 10 were rated "severely unaffordable," meaning that all homes in these areas cost more than four times a household's annual income. Those rated "affordable" sell at or below two times average annual income.

On top of these high costs, the British are also forced to get by with less housing, and a series of new reports show just how severe the decline has been. According to one report compiled and published by *The Times* and the BBC, new housing built in Britain is now among the smallest in the developed world. This reflects a notable retrenchment from past international comparisons, when the Japanese were at the bottom of the list. As the chart reveals, new British homes are a little more than a third as big as new U.S. homes.

Although the Obama Administration has yet to produce many details of its forthcoming housing and land development strategies, the Secretaries of HUD, EPA, and Transportation have generally described their goals as encouraging denser housing arrangements to deter automobile use, accommodate the transit industry, save land and energy, and clean up the environment.

And under Transportation Secretary Ray LaHood, the government has also provided financial and political support to organizations that favor using the federal government to force Americans to change the way they live and travel, most notably the *Moving Cooler* report funded by the transit industry and environmental groups.

Congress, too, has joined the effort, and the recent House version of the highway reauthorization bill includes livability provisions to encourage communities to adopt smart growth strategies.

Both the President and the bipartisan leadership of the House Transportation and Infrastructure Committee have committed themselves to an unprecedented expansion of the federal government into new areas of responsibility to limit how American's travel and how they live.

Currently, these are responsibilities of states and local governments. Some states and many communities have used their land use authority to impose counterproductive and exclusionary housing policy, but most have not. This gives all Americans the opportunity to escape oppressive regulation by voting with their feet. Members of Congress should reject any effort by the President or the congressional leadership to force all Americans into these misguided policies.

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***e-mail*** jsemmens@cox.net

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***Bus Operator Types and Driver Factors in Fatal Bus Crashes: Results from the Buses Involved in Fatal Accidents Survey*** by Daniel Blower, Paul E. Green, Anne Matteson, Transportation Research Institute, 2901 Baxter Road, University of Michigan, Ann Arbor, Michigan 48109-2150 (Federal Motor Carrier Safety Administration, U.S. DOT, 1200 New Jersey Ave SE, Washington, D.C. 20590; http://www.umtri.umich.edu/content/MotorCarrierTypeinFatalBusCrashes_final.pdf) (Jun 2008)

**Highlights**
- School bus drivers had the best driving records. Charter bus drivers had the worst.

Passenger carrier type has a significant effect on virtually all aspects of the experience of buses in fatal traffic accidents. Suggestive differences were found, in this and previous studies, between the four primary carrier types defined here—school, transit, scheduled intercity, and charter/tour—in virtually every dimension examined. These differences are reflected in the time of the crashes, the area and roads on which the crashes occurred, and who in the crash is at greatest risk of fatal injury.

The passenger carrier types also differ in the percentages at which drivers involved in fatal accidents are coded with a driving error in the crash. The driver errors here are specifically identified on the original police report or other crash investigation. While not a comprehensive determination of contribution to the crash, they can be regarded as the judgment of the investigators as to the driver's role in precipitating the crash. In this way, they reflect on the safety performance of the different bus operator types.

In terms of previous driver record and driver errors in the crash, significant differences were found among the passenger carrier types examined. Some of these differences were great enough to be statistically significant, even given the limited data available. School bus drivers had the best driving records and were coded with relatively few driving errors in the crash, compared with the other bus carrier types. Both intercity and charter/tour bus drivers had much higher percentages than school bus drivers on most of the measures. Statistical significance could not be established for intercity drivers because of the number of cases available, but the differences for charter bus drivers were both large and statistically significant. Fully 44% of charter bus drivers had a conviction, suspension, or crash in the three years prior to the crash, compared with only about 30% of school bus drivers. And 31.0% of charter bus drivers were coded with a driving error in the current crash, compared with 24.1% of school bus drivers. This difference was statistically significant at the 0.05 level.

The bus operations types identified here differ in a number of respects, any of which are arguably related to safety and tend to influence the likelihood of driver error. Transit and school buses operate typically on predictable, regular schedules, and usually in urban areas on low speed roads. Scheduled intercity buses of course are scheduled, but have longer hauls and travel more on roads that may have lower traffic density but higher speeds. Charter/tour buses may also have long hauls, but less predictable schedules. School buses have a higher proportion of female drivers, while the collection of "other" buses may include very

inexperienced drivers whose main occupation is something other than driving. A wide variety of factors were considered, including age, sex, trip type (local or over-the-road), type of driver compensation, and hours driving, in addition to driver record and bus operations type.

A logistic regression model was used to estimate the effect of the different factors on the probability of bus driver error in the crash. This technique accounts for the separate effects of the different factors. A stepwise procedure was used, in which all the factors were included in the model initially; then nonsignificant parameters were eliminated until a good fit was achieved with significant parameters.

In the final model, driver record captured as violations and crashes within the previous three years, and bus operation types were the only factors with statistically significant parameters. Even though trip type, compensation, and even driver sex (i.e., the high proportion of female school bus drivers) are related to passenger bus operation types, none significantly contributed to the fit of the model—the ability of the model to predict driver error—and so were dropped. Prior driver record, captured as previous violations and previous crashes, both increase the probability that a driver will be coded with an error in the crash. Put another way, drivers with a record of driving violations, or who have been involved in a crash, are more likely to have contributed to the current crash than other drivers.

The type of bus operations is also a significant predictor of coded driver error in the current crash. Both transit and school bus drivers are the least likely to have contributed to the crash. Intercity operations are associated with an increase in the odds by 1.9 times, with a 95% confidence interval from 1.1 to 3.2 times. Both charter and the "other" bus operations were associated with significantly higher odds of driver error. The odds ratio for charter/tour bus operations was 1.7 (range of 1.2 to 2.4), while for "other" buses it was 2.6 (1.9 to 3.6).

The differences uncovered in this analysis have implications for safety improvements and validate the approach taken in the survey. Motor carrier type plays a major role in fatal bus crash involvements and, even at the level undertaken in this study, point to quite different safety interventions, depending on the operation type. Pedestrian/bicyclist crashes are of course a problem for school buses and improved driver vision around the bus remains an issue. The high proportion of rear-end crashes in which the bus is struck suggests that conspicuity and awareness that the bus is stopped may need to be addressed. Driver vision around the bus is clearly a major issue for transit bus drivers, in light of the very high proportion of pedestrian/bicyclist collisions. Driver issues are more of a focus for intercity, charter/tour bus, and the diverse "other" bus operations, although the small sample size for intercity involvements make conclusions tentative. Finally, there are safety differences associated with the operations themselves, beyond the type of drivers employed.

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***e-mail*** jsemmens@cox.net

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***Cost/Benefit Analysis of Electronic License Plates*** by Andrew Eberline (Arizona Department of Transportation, 206 S. 17th Avenue, Phoenix, Arizona 85007; Ph. 602-712-3138; http://www.azdot.gov/TPD/ATRC/publications/project_reports/PDF/AZ637.pdf) (Jun 2008)

**Highlights**

- Possible benefits that these technologies could offer are: the ability to better enforce registration laws, the ability to better enforce insurance laws, the ability to implement tolls, the ability to acquire more accurate traffic count data, and the ability to aid law enforcement by screening for vehicles associated with crimes.

Electronic technology such as automatic license plate recognition systems (ALPR) and electronic vehicle registration systems (EVR) have increasingly been used by departments of transportation (DOTs), tolling authorities, and law enforcement to find innovative ways to achieve their unique objectives. This project was commissioned to see if these advanced electronic systems might be beneficial to the Arizona Department of Transportation (AzDOT).

ALPR technology utilizes cameras and alphanumerical recognition software to read license plates as they pass. This technology has been used by Transport for London in implementing their congestion charge. As vehicles enter the charging zone they pass by ALPR cameras that read the license plates. The London congestion charge is a flat fee that road users entering the charging zone must pay daily. No matter how many times the camera systems recognize a particular vehicle each day, each vehicle is only charged once per day. Those that need to pay the congestion charge can do so either online, by text message, by phone, or via collection machines set up within the charging zone. If road users enter the charging area but do not pay the charge, they are subject to fines by mail. Vehicles of residents that reside in the charging zone receive a 90% discount on the charge, while taxis, ambulances, and the disabled are exempt from the congestion charge.

ALPR technology has also been used for law enforcement purposes by police in Arizona, in other states in the United States, and in other countries. As a police cruiser equipped with ALPR drives around, the mounted ALPR cameras are constantly reading license plates and then checking the license plate numbers against both the NCIC database (National Crime Information Center) and the ACIC database (Arizona Crime Information Center). These databases contain information about persons wanted by police. If it turns out that the vehicle is listed in the database the computer inside the police car will alert the officer. The $25,000 - $50,000 ALPR systems in squad cars have proven to be effective, and thus the Arizona Department of Public Safety, Phoenix police, Mesa police, Chandler police, Tempe police, and Tucson police all have purchased ALPR systems for squad cars.

EVR technology utilizes radio frequency identification (RFID). RFID tags and RFID readers are the two main components of RFID technology. RFID tags emit a radio frequency that can be read by an RFID reader. RFID technology has become very prevalent as a means of payment for tolls in the United States, giving easy access to HOT (High Occupancy Toll) lanes. Perhaps E-ZPass is the

most well known RFID application in the United States. E-ZPass is a voluntary program that allows toll users to set up a pre-paid account to pay tolls. When an E-ZPass user uses a toll that accepts EZPass they enter a special lane. The reader identifies the vehicle and corresponding E-ZPass account, and then the toll user is electronically charged and is allowed to pass. All of this is done without interacting with a human or having to exchange money. For HOT lanes in California on Interstate 15 and State Route 91 the corresponding RFID payment tags can be read at the speed of regular freeway traffic. If a vehicle does not have an RFID tag for the toll lane, the license plate's picture is taken and the driver receives a ticket by mail.

**Conclusion**

ALPR technology was recommended as the technology of choice to accomplish the previously stated goals for AzDOT in the present. ALPR was chosen for the following reasons:

a) ALPR's Previous Applications – ALPR has been used successfully in London for the congestion charge.

b) The Low Cost of an ALPR Trial vs the High Up-Front Cost of EVR – With ALPR a trial run can be conducted at a low cost. EVR's high up-front cost makes such a trial not possible.

c) ALPR's Ability to Read Virtually Any State's License Plate – ALPR technology can assist Arizona in recovering lost revenue due to Arizona residents using out-of-state plates. EVR would not be able to read out-of-state plates unless the state that issued the plate also required an RFID device be placed in the vehicle. Currently no states utilize EVR technology as a means of enforcing vehicle registration.

d) The Possibility that EVR Technology Will Require ALPR Technology – It's possible that EVR technology would require a camera system similar to ALPR in order to be effective. This is because it is conceivable that an Arizona resident could tamper with a required RFID tag and disable it.

e) The Potentially Lower Degree of Public Opposition to ALPR – ALPR might be perceived by the public as less intrusive. Thus there might be less overall opposition to ALPR vs EVR.

Both ALPR technology and EVR technology are rapidly progressing in effectiveness and affordability. A change in the technology's effectiveness, the technology's affordability, or U.S. policy regarding an RFID standard could change the variables that generated the recommendation for ALPR technology. This report is simply suggesting that, based on the information available today, it appears that ALPR technology should be further researched and implemented.

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***e-mail*** jsemmens@cox.net



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***Addressing Women's Fear of Victimization in Transportation Settings*** by Anastasia Loukaitou-Sideris & Camille Fink (University of California Transportation Center, 2614 Dwight Way, 2nd Floor, Berkeley, CA 94720-1782; http://www.uctc.net/papers/875.pdf) (2008)

**Highlights**

- No special effort is made by most transit agencies to offer special safety or security programs for women.
- There is a serious mismatch between the existing safety and security practices of transit operators and the needs and desires of women passengers.

At the turn of the twentieth century, the Hudson and Manhattan Railroad, which ran between New York and Jersey City, briefly instituted women-only cars on its system. This consideration of the specific anxieties and needs of women passengers was short-lived. A hundred years later, such special attention to women travelers is all but missing from the practices of U.S. transit agencies, despite the fact that empirical studies show women are typically more fearful of transportation settings than are men. While women, like all passengers, are expected to benefit from the increased attention given to the security of transportation systems post-9/11, no special effort is made by most transit agencies to offer special safety or security programs for women. Simply, the concept of providing services and security tailored to the needs of women passengers is not yet espoused by U.S. transit operators, despite the fact that most of them admit that women do have some specific and different needs than men. Interestingly, a significant number of agencies rightly provide special services to other subgroups of vulnerable customers but are worried that they may be accused of "reverse discrimination" if they develop specific security strategies for women.

Additionally, there is a serious mismatch between the existing safety and security practices of transit operators and the needs and desires of women passengers as identified by focus groups, safety audits, and empirical studies. For example, the concentration of security measures on the more enclosed and easily controllable parts of the transportation system (buses, trains, and station platforms) and the relative neglect of the more open and public parts (bus stops and parking lots) does not serve women's needs well. Women passengers are typically more fearful of waiting at desolate bus stops or walking through parking lots devoid of human activity than of being seated among other passengers on the bus or train. Similarly, the practice of privileging technological over human security measures—which is widely followed by transit agencies—goes contrary to women's wishes. Women passengers certainly feel safer being watched by a police officer than by the lenses of CCTV cameras.

There seem to be important reasons why the response of U.S. transit operators to the particular safety and security needs of women is less than satisfactory and why there seems to be a mismatch between research findings and policy. For one, there are only limited financial resources available to public transit operators. Transit managers have struggled to balance the costs and uncertain benefits of increased transit security against the costs and certain benefits of attracting

passengers. There is no doubt that transit agencies do not have the resources to install a police officer at every transit stop of their system. Security strategies generally favored by transit operators, such as the installation of cameras, are decidedly less expensive than instigating police patrols or employing security personnel on transit vehicles and stops.

The over reliance on technological responses to crime is also influenced by the aggressive marketing of "antiterrorist" technologies and security hardware by the security industry, post 9/11, as well as the example of British and Japanese cities that have extensively retrofitted their stations with security cameras and CCTV technology.

Transit operators are facing a risk-management dilemma, as courts are not inclined to find against them when passengers are accosted while traveling to and from bus stops and stations. On the other hand, if a transit agency institutes an on-street security program, then fails to provide accurate security measures and an incident occurs, the agency may be found liable by the court.

It is likely that the gender mix of management in public-transit agencies is overrepresented by male planners, who may not be as knowledgeable about or responsive to the particular needs of their female transit customers. In a survey (which was sent to the general managers of transit agencies), 76% of the respondents were male.

The past decade has witnessed an increase in scholarly activity on issues relating to women's safety, travel patterns, and health. Nevertheless, there is a general ambiguity among transit operators regarding the security needs and the appropriate security measures for female passengers and an almost complete lack of implemented programs in the United States. This finding points to a major gap between research and practice. A number of combined initiatives may help close this gap. For example, the initiation of researcher–practitioner dialogues in professional and academic conferences would help make research on women's issues in transportation more accessible to transit professionals. The compilation, publication, and dissemination of best practices from the American Public Transportation Association and/or the Transit Cooperative Research Program would allow operators to access information about the lessons learned from successful programs in other countries. The creation of certain pilot programs supported through targeted and competitive funding from the Federal Transit Administration would also go a long way toward implementing programs "on the ground" and measuring their impact and success. Finally, the incorporation of women's voices in planning and policy making around transportation issues, through regular safety audits and targeted surveys of women passengers, would help diminish the current ambiguity regarding gender-appropriate security measures.

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***e-mail*** jsemmens@cox.net



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***Field Testing of Cantilevered Traffic Signal Structures under Truck-Induced Gust Loads*** by Matthew N. Albert, Lance Manuel, Karl H. Frank, Sharon L. Wood, Center for Transportation Research, University of Texas at Austin, 3208 Red River, Suite 200, Austin, TX 78705-2650 (Texas Department of Transportation, Research and Technology Implementation Office, P.O. Box 5080, Austin, TX 78763-5080; http://www.utexas.edu/research/ctr/pdf_reports/0_4586_2.pdf) (Jun 2008)

**Highlights**

- The natural wind produced greater strain amplitude cycles on the mast arm than any of the trucks.
- Truck-induced gusts are not a critical design loading consideration for cantilevered traffic signal structures.

The research documented here was based upon a study of the effects of truck-induced gusts on cantilevered traffic signal structures in the field. Initially, an extensive literature review was completed through which valuable knowledge of cantilevered traffic signal structures was obtained. This provided a useful starting point for the design of a field testing setup. It was decided to complete short-term monitoring of the structures by measuring strain data in both the in-plane and out-of-plane directions. When a truck would pass beneath the mast arm, the time was recorded, as were the speed of the truck and the traveling lane; additionally, a picture of the truck was taken. The method employed offered a rather simple and inexpensive way to obtain strain data as well as other pertinent information about the trucks. The only disadvantage was that the field testing was time-consuming since there was typically idle time between truck events. Long-term monitoring was also completed by recording rainflow cycle counts data using MicroSAFE devices.

Structures at two sites were instrumented as part of this study. One field test site was located on RM 620 at Home Depot Blvd in Bee Cave, Texas; the other was located on US 290 at SH 95 in Elgin, Texas. Structures at both sites consisted of 40-foot mast arms; however, the site on RM 620 at Home Depot Blvd was a single mast arm, while the site on US 290 at SH 95 was a dual mast arm assembly. Over 400 truck events (trucks not slowed down or stopped by the traffic signal) were observed at the two sites. Of these 400 truck events, only eighteen trucks caused any significant or appreciable movement in the mast arm. Sixteen of these trucks only influenced the out-of-plane direction and two trucks influenced the mast arm in both the in-plane and out-of-plane directions. Thus, for this study, trucks were more likely to move the mast arm in the out-of-plane direction than in the in-plane direction. This contradicts the AASHTO design provisions which suggest that only truck-induced gusts in the vertical direction need to be considered.

Even though trucks potentially pose a greater problem in the out-of-plane direction than in the in-plane direction, the natural wind produced even greater response in both directions during the field tests. The natural wind produced greater strain amplitude cycles on the mast arm than any of the trucks. For this reason, the natural wind loads are concluded to be more critical than truck-induced gust loads for cantilevered traffic signal structures. Natural wind gusts can affect all cantilevered traffic signal structures whereas truck-induced

gusts can only potentially affect a limited number of structures.

**Recommendations**

Based upon results from the field test studies carried out, it has been determined that truck-induced gusts are not a critical design loading consideration for cantilevered traffic signal structures. As previously discussed, natural wind has a far greater influence on the overall behavior of cantilevered traffic signal structures. Therefore, it is believed that if engineers design cantilevered traffic signal structures correctly for natural wind, then any possible influence of truck-induced gusts will automatically be accounted for. It is important to point out that this study did not include the effects of truck-induced gusts on cantilevered highway signs (VMS or regular) structures, so these conclusions should only be applied to cantilevered traffic signal structures. Also, this study was limited to only two cantilevered traffic signal structures in Texas, where there is a minimum clearance of 18 ft (5.5 m) above the roadway to the lowest point on the mast arm or attachments. It is believed that the most extreme truck-induced gust for each structure was observed and recorded, but the most extreme natural wind gust likely did not occur during the field testing. For this reason, the natural wind has the potential to be an even larger controlling factor in the design of cantilevered traffic signal structures than what was initially believed. This study did not check the validity of the AASHTO design equations for natural wind gusts on cantilevered traffic signal structures, but on the basis of back-calculated strains associated with the AASHTO-specified equivalent static pressure ranges for design against truck-induced gusts, it was found that the design pressure ranges are extremely conservative compared to the measured strains in the field for the two structures.