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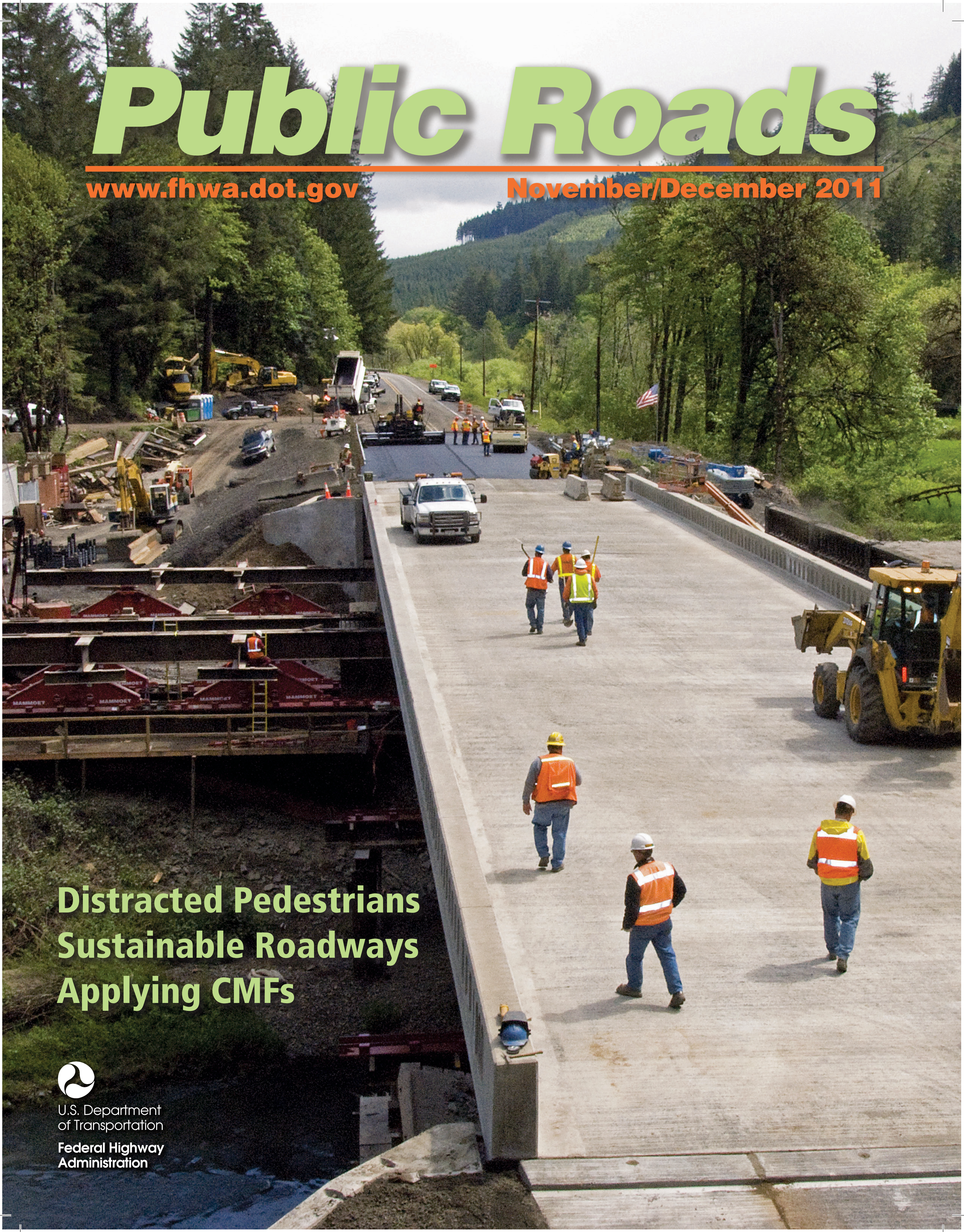

Distracted Pedestrians
Sustainable Roadways
Applying CMFs

U.S. Department of Transportation
Federal Highway Administration

Public Roads

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—featuring developments in Federal highway policies, programs, and research and technology—

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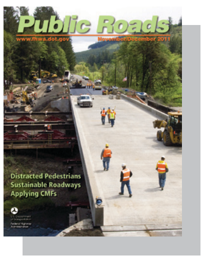

Front cover—Applying the Federal Highway Administration's new decisionmaking tool will enable bridge owners to select elements of accelerated bridge construction as appropriate for building projects similar to this one in Oregon. Here, workers are completing the bridge approaches. Using ABC techniques enabled the Oregon Department of Transportation (ODOT) to build the replacement adjacent to the existing structure, saving taxpayers $0.5 million. For more information, see "To ABC or Not?" on page 8 in this issue of PUBLIC ROADS. *Photo: Gary Weber, ODOT.*

Back cover—Shown here are an asphalt-stabilized, open-graded pavement base (left) and the open-graded edge aggregate (right) that drains it. FHWA researchers shot this photo at a project to relocate a two-lane highway in northern Virginia. FHWA, in cooperation with the Virginia Department of Transportation and a local crushed stone producer, installed two instrumented research sections to compare the normal asphalt pavement, which includes the drainage layer, with an inverted pavement section incorporating a granular base compacted to a high density, over a stiff, cement-treated aggregate base layer overlaid with an asphalt surface. *Photo: Richard Meininger, FHWA.*

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Guest Editorial

A Home for Highway Statistics

Have you ever wondered how much travel occurs on the Nation's highways? And how many gallons of gasoline are consumed annually for highway travel, and the amount of revenue the tax on those gallons contributes to the Highway Trust Fund? Information on these topics and so much more is available in the Federal Highway Administration's (FHWA) annual publication *Highway Statistics*. Before the end of this year, FHWA's Office of Highway Policy Information will produce the 66th edition of *Highway Statistics*, making it one of the longest running, continuously published agency documents.

Highway Statistics serves as a comprehensive portal for data and information on many areas the agency is involved with. The highway community can query and analyze the publication's data and information through a wide range of supporting databases and analytical tools. One example is the production of the apportionment factors for the annual Highway Trust Fund. Without a doubt, the apportionment factors are one of FHWA's most important data products. The programs apportioned by these factors total more than $28 billion annually.

Other examples of publications produced by FHWA's Office of Highway Policy Information are the monthly reports *Traffic Volume Trends* and *Monthly Motor Fuel Reported by States*; both are widely used throughout the transportation community. These reports serve as the barometers on national travel demand and revenue collection. For more on *Highway Statistics* and other data products from FHWA, see the article "What's in the Numbers?" on page 32 in this issue of PUBLIC ROADS.

In addition to *Highway Statistics*, FHWA's Office of Highway Policy Information strives to produce other high-quality, timely information products that educate and inform elected and appointed officials, public policymakers, academia, and the public. The office's data findings serve as the foundation for many FHWA projects and programs. Throughout the year, staff works with States and the FHWA division offices to ensure that data are submitted on time and meet FHWA's requirements for quality and completeness.

Over the years, the data products produced by FHWA have evolved to meet the needs of its customers. A few years ago, the office added a number of multiyear tables and charts to better illustrate how various highway attributes have changed over time. In 2011, the office redesigned its Web site to make it easier for visitors to find information (www.fhwa.dot.gov/policyinformation). A new feature is a section called "State Statistical Abstracts," which pulls together data on population, land area, mileage, fuel use, drivers, vehicles, and travel and summarizes them for each State. The Office of Highway Policy Information continues to work on new ways to make data even more timely and informative. In the future, expect to see additional briefs and white papers on a wide variety of topics.

Oh, and in case you were wondering: In 2009, Americans logged more than 2.9 trillion vehicle miles travelled, enough for 6,182 trips to the moon and back. That same year, Americans consumed 168 billion gallons of diesel and gasoline on highway travel, enough to fill more than 254,500 Olympic swimming pools. This onhighway fuel accounted for almost $26.9 billion in Highway Trust Fund revenue.

What questions do you have about the Nation's highways? *Highway Statistics* is a great place to look for answers.

David Winter
Director, Office of Highway Policy Information
Federal Highway Administration

Researchers at UNC Charlotte report on their study of the interaction between inattentive drivers and pedestrians at campus crosswalks.

When Distracted Road Users *Cross Paths*

by Ryan Brumfield and Srinivas S. Pulugurtha

(Above) Researchers at UNC Charlotte recently studied how pedestrian and driver distraction affect yielding behaviors at crosswalks on campus. *Photo: Ryan Brumfield, FHWA.*

It can happen to even the most attentive drivers. You're driving along and suddenly you realize you have no recollection of the last few seconds, or even minutes. Maybe you were fiddling with the radio or simply spacing out. Many motorists admit to periodically sacrificing their concentration to attend to something else, whether eating, putting on makeup, rubbernecking, daydreaming, or, increasingly, talking on cell phones or texting.

Psychologists refer to this looked-but-did-not-see phenomenon as inattentional blindness. An article, "Did you see the unicycling clown? Inattentional blindness while walking and talking on a cell phone," published in the July 2010 issue of the journal *Applied Cognitive Psychology* reports on a 2009 study conducted by researchers at Western Washington University that demonstrated the legitimacy of this theory for pedestrians as well. The researchers discovered that pedestrians on the college campus were less likely to notice an unusual activity—in this case, a clown riding a unicycle—if they were distracted by a cell phone. Even if they looked right at the clown, they failed to see the unicycle or the rider because their attention was focused on the phone conversation.

The same thing can happen to drivers when distracted. The nondriving task gets stored in the driver's memory, while the events relevant to driving may go unnoticed or are omitted from memory storage. According to the university researchers, "when driving a car while talking on a cell phone, people may be unaware of what they are missing until it is too late."

According to data from the National Highway Traffic Safety Administration (NHTSA), in 2009 nearly 5,500 people were killed and 450,000 injured in crashes that were reported to have involved distractions. The problem has received widespread media coverage in recent years, as U.S. Transportation Secretary Ray LaHood has taken to the airwaves and the Internet at www.distraction.gov to raise awareness of the dangers of inattentive driving. "Distracted driving is a serious, life-threatening epidemic that steals loved ones from us and puts responsible drivers in danger every time they hit the road," says LaHood.

A recent study, "Effect of Road User Distractions on Pedestrian Safety at Mid-Block Crosswalks on a College Campus," conducted by researchers at the University of North Carolina at Charlotte (UNC Charlotte) looked at the role of distraction—both among drivers and pedestrians—in yielding behaviors at crosswalks on the college campus. The results point to even greater dangers when motorists *and* pedestrians lose their focus in the roadway environment.

Pedestrians Are Vulnerable

Unexpected events such as a pedestrian crossing the street can catch a distracted driver unaware, leaving little time to react and take evasive action. Inattentive pedestrians exhibit a similar lack of awareness to respond to sudden conflicts or unexpected obstacles. Take, for example, the teenage girl in New York City who, in July 2009, fell into an open manhole while texting and walking on a sidewalk in Staten Island. Fortunately, she survived without serious injury. However, pedestrians exhibiting this level of obliviousness while crossing a street put themselves at the mercy of drivers who themselves may or may not be paying attention, as was the case in Salem, OR, earlier this year when a teen who was texting while driving struck and killed a pedestrian.

"Ultimately, crosswalk safety often depends on the attention level of road users when they interact with one another," says Beth Alicandri, director of the Office of Safety Programs at the Federal Highway Administration (FHWA). "Without sufficient concentration, drivers and pedestrians are ill-prepared to react to conflicts in the road environment."

UNC Charlotte Study

When drivers experience inattentional blindness and fail to notice certain details of their commutes, what mistakes could they be making without even realizing it? Maybe they unknowingly run red lights or pull out in front of other cars. Maybe they drift over the centerline or forget to use their turn signals. Maybe they drive slowly in the passing lane. Or, as a recent study from UNC Charlotte suggests, they might fail to yield to pedestrians at crosswalks.

Researchers at UNC Charlotte observed the behaviors of drivers and pedestrians at seven midblock crosswalks on the university campus. The intent was to investigate the yielding patterns of road users to determine if distracted drivers and pedestrians behave differently than their attentive counterparts. The researchers hypothesized that distracted drivers and pedestrians are unaware of their surroundings and therefore unlikely to notice and stop for other road users.

Each of the observed locations had crosswalk striping, although not highly visible in some cases. Several of the study sites included advance signage notifying drivers of the crossing area. The campus-wide speed limit at UNC Charlotte is 20 miles per hour (32 kilometers per hour).

For each location, researchers observed and recorded driver and pedestrian yielding behaviors, along with information regarding road user distractions. The researchers separated distractions into three categories: talking on a cell phone, texting, or other. The "other" category included distractions such as eating, listening to a portable music player, putting on makeup, reaching for something, talking to a passenger, or anything else that had an obvious effect on road user attention.

The researchers collected data only for road users who had an opportunity to yield. That is, data on drivers and pedestrians who passed through without interacting with another road user were not recorded. In cases where multiple pedestrians crossed at the same time, the researchers only collected data for the first pedestrian in the group.

The researchers also noted vehicle-pedestrian conflicts during the data collection. They recorded six types of

Ryan Brumfield, FHWA

With one hand on the wheel and the other on the phone, this driver's eyes are not on the road, which means that she is ill-prepared to react to an unexpected event, such as a pedestrian crossing the road.

Sample Data Collection Sheet

Date:			Start Time:		Location:		
			End Time:				
No.	Conflict Type	Vehicle Yield (Y/N)	Pedestrian Yield (Y/N)	Driver Distracted (Y/N)	Type of Driver Distraction	Pedestrian Distracted (Y/N)	Type of Pedestrian Distraction

Distraction Type

1. Talking on Cell Phone
2. Texting While Driving or Walking
3. Other

Conflict Type

1. Vehicle braking suddenly or swerving to avoid hitting a pedestrian.
2. Pedestrian having to jump forward or back to avoid being struck by a vehicle.
3. Pedestrian entering the crosswalk and stepping back because the vehicle does not yield.
4. Oncoming vehicle changed lanes so that vehicle could go without reducing speed.
5. Pedestrian trapped on a crosswalk because the oncoming vehicle did not yield.
6. Vehicle ran close to a pedestrian walking on a crosswalk.

Source: UNC Charlotte.

conflicts, each describing a situation when either the pedestrian or vehicle had to change paths or speed of travel abruptly to avoid collision with the other road user. For example, the most commonly noted conflict was a pedestrian entering the crosswalk and then stepping back because the vehicle did not yield. Upon completion of data collection, the researchers compiled and analyzed the results for statistical significance.

Study Findings

The results of the UNC Charlotte study show that overall about 64 percent of drivers yielded to pedestrians, and about 20 percent of pedestrian-vehicle interactions resulted in conflicts. One location experienced driver yield percentages as high as 76 percent, while another location had yield percentages as low as 46 percent. Likewise, the chance of conflict varied from 11 percent to 29 percent, depending on the location. These variations may be attributable to differences in crosswalk visibility, signage, and, of course, driver and pedestrian behavior.

Although results varied by location, on average, about 18 percent of drivers and 29 percent of pedestrians were noticeably distracted as they traversed the crosswalks. Approximately 9 percent of drivers (50 percent of distracted drivers) were talking on a cell phone, and 3 percent of drivers (15 percent of distracted drivers) were texting. About 16 percent of pedestrians (54 percent of distracted pedestrians) were talking on a cell phone and 7 percent (23 percent of distracted pedestrians) were texting.

When compared to attentive drivers (drivers not partaking in a nondriving task), distracted drivers were about 15 times less likely to yield to pedestrians (77 percent compared to 5 percent) and about 4 times more likely to be involved in conflicts with pedestrians (51 percent compared to

Ryan Brumfield, FHWA

Shown here is a typical crosswalk on the campus of UNC Charlotte. This pedestrian happens to be texting while crossing the road.

Driver Yield Percentages and Chance of Conflict By Location

Location	Number of Samples	Percent of Drivers Yielding	Rate of Conflict (%)
East Deck	28	61	11
Duke Centennial Hall	42	62	14
North of Student Union	72	76	22
South of Student Union	28	46	29
Auxiliary Services	54	72	28
Parking Services	41	59	17
Greenhouse	60	57	17
Overall	**325**	**64**	**20**

Source: UNC Charlotte.

13 percent). These results provide strong evidence that distracted drivers have poor yielding behavior compared to seemingly attentive drivers.

In contrast to the findings regarding distracted drivers, the data show that the chance of conflict was essentially the same for distracted and attentive pedestrians (21 percent versus 17 percent). Although this result implies that pedestrians can maintain safe crossing behavior while inattentive, in reality, the conflict potential is constant because drivers yield at a much higher rate when distracted pedestrians are present. In fact, results show that drivers were about 40 percent more

Prevalence of Distraction Among Drivers and Pedestrians

Location	Number of Samples	Percent of Drivers			Percent of Pedestrians		
		Distracted[1]	Talking on Cell Phone	Texting	Distracted[1]	Talking on Cell Phone	Texting
East Deck	28	32.1	7.1	0.0	39.3	3.6	7.1
Duke Centennial Hall	42	14.3	14.3	0.0	21.4	16.7	2.4
North of Student Union	72	20.8	11.1	5.6	48.6	26.4	15.3
South of Student Union	28	17.9	3.6	14.3	17.9	14.3	0.0
Auxiliary Services	54	14.8	1.9	0.0	16.7	5.6	1.9
Parking Services	41	9.8	7.3	0.0	26.8	14.6	12.2
Greenhouse	60	20.0	13.3	1.7	25.0	18.3	3.3
Overall	**325**	**18.2**	**8.9**	**2.8**	**29.2**	**15.7**	**6.8**

[1] Percent distracted includes percent talking on a cell phone and percent texting.

Source: UNC Charlotte.

Chance of Conflict and Percent Yield Based on Road User Behavior

Driver Behavior	Number Observed	Percent of Sample	Percent Involved in Conflicts	Percent Yield
Attentive	266	81.9	13.2	77.1
Noticeably Distracted[1]	59	18.2	50.9	5.1
Talking on Cell Phone	29	8.9	48.3	6.9
Texting	9	2.8	66.7	0.0

Pedestrian Behavior	Number Observed	Percent of Sample	Percent Involved in Conflicts	Percent of Drivers Yielding
Attentive	230	70.8	21.3	57.4
Noticeably Distracted[1]	95	29.2	16.8	80.0
Talking on Cell Phone	51	15.7	19.6	78.4
Texting	22	6.8	9.1	81.8

[1] Noticeably distracted includes talking on a cell phone and texting.

Source: UNC Charlotte.

Srinivas S. Pulugurtha, UNC Charlotte

These UNC Charlotte students are returning to their cars after attending class at Duke Centennial Hall. This raised crosswalk is one of seven sites where researchers collected data during the study.

likely to yield to distracted pedestrians than to those who were attentive. The researchers observed distracted pedestrians making aggressive crossing maneuvers, failing to make eye contact with approaching drivers, and darting in front of traffic. These behaviors support the notion that distracted pedestrians are more careless, obliging drivers to stop abruptly to avoid conflicts.

Although the study findings did not show a direct correlation between road user distraction and crash risk, the researchers believe that yielding behavior at a particular crosswalk is an indicator of the relative safety at that location. The greater the driver yield rate, the lower the chance of conflict with a pedestrian and, thus, the lower the crash risk. As the results from this analysis imply, if a high percentage of road users—motorists and pedestrians—are distracted, conflict potential will tend to be greater and, therefore, crash risks will be higher.

Countermeasures To Increase Yield Rates

In tandem with the efforts of NHTSA and other organizations to curb distracted driving, highway agencies can use infrastructure solutions to make the road environment less complex so drivers with limited attention are still able to process critical information. For example, crosswalk treatments that stand out, such as high-visibility lighting, striping, and signing, may increase the likelihood that distracted drivers will notice pedestrians and safely yield to them.

"We hope that countermeasures that can grab the attention of drivers, especially those who are distracted, can lead to better yielding behavior and decreased likelihood of pedestrian-vehicle conflicts," says Tamara Redmon, manager of FHWA's Pedestrian Safety Program. "Treatments that improve crosswalk visibility and make pedestrians more conspicuous may offer safety benefits."

FHWA has verified the safety effectiveness of numerous countermeasures for use at midblock crosswalks. For instance, in areas where crossings occur at nondesignated midblock

www.pedbikeimages.org, Mike Cynecki

Pedestrian hybrid beacons, such as this one in Phoenix, AZ, provide a break in traffic to allow pedestrians to cross safely. The device is activated when pedestrians engage a nearby pushbutton.

locations, simple striping and signing can make drivers aware of the presence of a pedestrian crossing zone. Installation of transverse markings, bar pair markings, or continental markings can alert drivers of possible pedestrian activity. Proper signage can help drivers recognize crossing areas and reinforce State laws that require yielding to pedestrians. In all cases, it is important that traffic control devices be in compliance with the national standards outlined in the *Manual on Uniform Traffic Control Devices* (MUTCD) so road users from all areas of the country can instantaneously recognize and comply with their messages.

When pedestrians must cross multiple lanes of travel, median refuge islands provide safe places for them to stand while waiting for a gap in the traffic stream. In areas where visibility is poor, installing overhead street lighting or in-pavement warning lights can help drivers recognize potential conflicts. For corridors with heavy pedestrian activity, agencies might consider installing midblock stop signs, traffic signals, or pedestrian hybrid beacons to create breaks in traffic for pedestrians to cross safely. Other proven midblock treatments include dynamic lighting (increased illumination of a crosswalk when a pedestrian is present), Danish offset islands (median refuge islands with offset entry and exit points), automated pedestrian detection, flashing beacons, in-pavement text, pedestrian countdown timers at signalized crossing areas, and advance stop lines near crosswalks.

Selected Pedestrian Safety Resources

- The *Pedestrian Safety Guide and Countermeasure Selection System* (FHWA-SA-04-003) provides countermeasure recommendations based on user input regarding a specific problem location and the desired objectives to be achieved by specific treatments.
- The "Pedestrian and Bicyclist Crash Analysis Tool" is a software product that assists in analyzing State and local data on crashes involving pedestrians and bicyclists. The tool is available for download at www.walkinginfo.org/facts/pbcat/index.cfm.
- The *Pedestrian Safety Guide for Transit Agencies* (FHWA-SA-07-017) is a resource for use in addressing common safety problems that arise near transit stations and bus stops.
- *A Resident's Guide for Creating Safe and Walkable Communities* (FHWA-SA-07-016) presents information and guidance to help community leaders understand and address local pedestrian safety problems.

Concluding Thoughts

Of course, safety problems differ by location, and highway agencies need to determine the most effective and appropriate solutions on a case-by-case basis. The FHWA Office of Safety and its partners have developed numerous online tools, publications, and guidance materials to help practitioners assess pedestrian safety problems and choose suitable treatments to reduce the likelihood and severity of crashes. (See "Selected Pedestrian Safety Resources" on this page.)

Distracted drivers and pedestrians, whether on a highway, at an intersection, or in a crosswalk, pose a threat to themselves and others. As shown in this study, distraction reduces the likelihood that a driver will yield to pedestrians in a crosswalk. Due to this increased failure to yield, it is likely that crash risk is higher for pedestrian-vehicle interactions involving a distracted driver. Further, when the observed pedestrians were distracted, they tended to cross the road in an aggressive manner, oblivious to approaching vehicles, which also had a negative effect on crosswalk safety. Ultimately, a safe roadway environment depends on all road users paying attention to where they are going and being aware of other users who might be sharing the road.

www.pedbikeimages.org, Dan Burden

This sign reminds motorists that State law requires yielding to pedestrians in crosswalks.

Ryan Brumfield is a civil engineer in FHWA's Arkansas Division Office. He is currently a participant in the agency's Professional Development Program, a 2-year training program for new employees. He recently graduated from UNC Charlotte with a master's degree in civil engineering.

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A new decision tool for Accelerated Bridge Construction is helping project planners assess the applicability and effectiveness of this technique at specific locations.

To ABC or Not?

by Toni L. Doolen, Benjamin Tang, Amirali Saeedi, and Samin Emami

(Above) Using ABC techniques enabled the Oregon Department of Transportation (ODOT) to build the replacement Elk Creek Tunnel bridges adjacent to the existing structure near the tunnel entrance and then move the new bridges into position over a weekend, saving taxpayers $0.5 million. *Photo: Gary Weber, ODOT Photographer.*

According to the Texas Transportation Institute, congestion in U.S. urban areas causes motorists to waste an estimated 4.8 billion hours in traffic and 3.9 billion gallons of gas annually. The economic impact was $115 billion in 2009 and is increasing every year. Although bridge and highway construction and maintenance projects are needed to increase capacity and maintain performance, these projects can add to the congestion problem. According to the Federal Highway Administration's (FHWA), 2010 National Bridge Inventory, 156,289 publicly owned bridges are structurally deficient or functionally obsolete—25.9 percent of all U.S. bridges. Whether those bridges are rehabilitated or new ones are built, the construction itself can exacerbate congestion and result in additional costs to users, sometimes can be associated with safety issues, and often limits road access.

Responding to the public's demand for a "get in, get out, and stay out" approach to bridge construction, the American Association of

State Highway and Transportation Officials (AASHTO) and FHWA encourage the use of various Accelerated Bridge Construction (ABC) strategies, including prefabricated bridge elements and systems, state-of-the-art equipment, new material technologies, and innovative contracting methods. Where applicable, these strategies can help reduce onsite construction time, minimize traffic and environmental impacts, improve work zone safety, and deliver longer lasting and more durable bridges.

Bridge owners and engineers need to determine early in the planning phases of a construction project whether elements of ABC are appropriate and effective for a specific bridge replacement or rehabilitation project. New technologies and accelerated construction techniques, however, can introduce risk and uncertainties into a project. Existing cost analysis tools often require significant training and typically address only limited aspects of a project. In addition, cost data often are not readily available in the early phases of a project, making traditional engineering economic analyses difficult to apply reliably.

In December 2009, the Oregon Department of Transportation (ODOT) initiated a pooled fund study, TPF 5(221), with the charge of developing a tool that could assist decisionmakers in identifying whether ABC should be applied to a specific project. To define the study's objectives, ODOT convened a 15-member technical advisory committee. The committee members included a principal investigator from Oregon State University and participants from FHWA and eight States with substantial experience in bridge replacement and rehabilitation. Many had direct experience in the use of ABC in their own States. To support the project, the researchers conducted a comprehensive review of ABC techniques and decisionmaking approaches. Ultimately, the researchers created an easy-to-use analysis tool that bridge owners can turn to in the early planning stages to determine whether to deploy ABC on individual projects.

ABC Approaches And Benefits

ABC approaches include the application of technical innovations and management techniques. Technical innovations include rapid embankment construction, specialized structural placement methods, and prefabricated bridge elements and systems, such as superstructure systems (composite units, truss spans), substructure systems (abutments, caps/columns, piers), and totally prefabricated bridges. Examples of management practices used as part of ABC include staged construction, A+B contracting (otherwise known as cost-plus-time), incentive/disincentive contracting, and lane rentals in which contractors must include the cost to the public as well as construction costs.

"To reduce congestion and improve safety, many communities, industry, and Federal organizations would like to see ABC tools and techniques become standard practice," says FHWA Associate Administrator for Infrastructure King W. Gee. "September 11 and subsequent threats to the U.S. transportation system also have highlighted the need to develop emergency response plans to react quickly to consequences of extreme events. This need also has been cited as an important reason for bringing ABC tools and techniques to more replacement and rehabilitation projects."

ABC Projects

Federal organizations have supported several initiatives to foster the development, implementation, and promotion of ABC by departments of transportation (DOTs). Because of the success of ABC projects to date, FHWA has provided resources to further advance ABC's deployment nationwide.

Addressing the challenge of reducing congestion through accelerated reconstruction of obsolete and deficient bridges, States and localities have undertaken successful ABC projects. These projects provide valuable insight for decisionmakers who are considering ABC for the first time or who have had limited exposure to the variety of ABC tools and techniques. A summary of 54 completed ABC projects using various types of prefabricated bridge elements and systems is available on FHWA's "Accelerated Bridge Construction" Web site at www.fhwa.dot.gov/bridge/prefab/all.cfm.

The Need for ABC Decisionmaking Tools

The U.S. Department of Transportation's (USDOT) strategic plan for 2006–2011 identified use of decisionmaking tools as a key strategy to reduce congestion and deliver longer lasting, high-performance infrastructure. Use of decisionmaking tools in the early stages of planning provides a way to help decisionmakers assess alternatives with greater confidence and prevent investment in more costly alternatives. In addition, data-driven decisionmaking tools are consistent with cost-saving recommendations from the U.S. Government Accountability Office.

The decision to use ABC must be made on a project-by-project basis as each bridge location is unique, and factors constraining each project are different. Toward this end, FHWA developed a qualitative decisionmaking framework to determine whether prefabricated bridge elements should be considered for a given project (see www.fhwa.dot.gov/bridge/prefab/framework.cfm). This framework includes three formats: a flowchart,

Examples of Benefits and Barriers to the Application of ABC Tools and Techniques

Benefits of ABC	Barriers to the Use of ABC
• Deliver projects earlier to traveling public • Reduce impact of onsite construction on surrounding community • Increase safety in construction work zones • Decrease user costs	• Traffic detour issues • Technical issues related to seismic design, structural durability, and reliability • Poor communication and coordination among stakeholders • Lack of technology for rapid bridge construction and replacement technologies after extreme events • Need for development in design methodologies, contracting approaches, and material supply chain management

Source: TPF 5(221) pooled fund study.

UDOT

Starting around 2006, the Utah Department of Transportation (UDOT) began erecting dozens of interstate bridges over weekends by implementing ABC as its standard practice. In 2008, UDOT bundled projects together and created this staging area, which local residents nicknamed the "bridge farm."

a matrix, and a list of categorical considerations. The formats may be used independently or in combination. For example, to use the framework, decisionmakers respond to questions about a project's specific characteristics. The questions relate to the appropriateness of rapid, onsite construction; safety and environmental issues; standardization and construction site issues; the costs of traffic management and contracting; owner costs; and service life. The framework provides a starting point for evaluating prefabricated bridge elements and systems for a given project but does not help decisionmakers evaluate the broader scope of ABC strategies nor estimate the economic impact of selecting various elements of ABC over traditional methods.

A Decisionmaking Tool for ABC

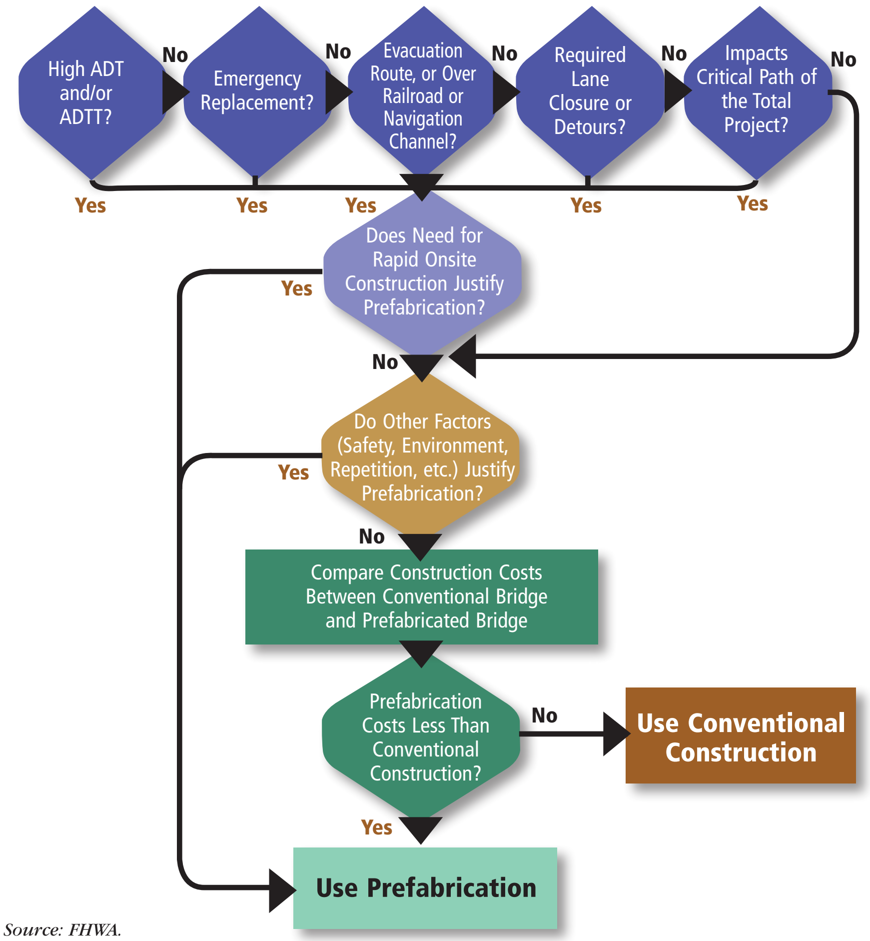
Users of the FHWA decision framework recognized that decisionmaking for bridge construction involves both quantitative and qualitative criteria. Pooled fund study 5(221) was established to develop a complete set of evaluation criteria. Many of the relevant criteria are difficult to measure, estimate, or evaluate. The pooled fund's technical advisory committee determined that a multicriteria decisionmaking approach was necessary to guide the development of a decisionmaking tool. That is, multiple criteria would have to be considered simultaneously.

Key assumptions to guide the tool's development were identified. First, the tool had to be usable by transportation specialists and decisionmakers who have a thorough understanding of the technical and nontechnical issues associated with a particular project, but who may not be familiar with multicriteria decisionmaking methods. Second, the tool had to be user-friendly and accommodate a range of construction situations. Third, to ensure that the decision rationale could be readily communicated to a broad base of stakeholders, the tool's methods of calculation and decision criteria had to be transparent.

After a comprehensive review of decisionmaking tools, the technical advisory committee identified the Analytic Hierarchy Process (AHP) as the best technique for this project. This process prioritizes multiple criteria, integrates both quantitative and qualitative criteria, and provides a summary ranking of alternatives, based on the multiple criteria. Despite the long-time use of this process in other domains, particularly manufacturing, AHP has not been widely used in civil and structural engineering applications. As a result, many transportation personnel may be unfamiliar with AHP.

The method uses a multilevel hierarchical structure of criteria, subcriteria, and alternatives. The pertinent data used for an AHP analysis are generated by performing pairwise comparisons between criteria, subcriteria, and alternatives.

ABC Qualitative Decisionmaking Framework



Source: FHWA.

These pairwise comparisons are made using both a numerical and qualitative scale. The results are used to obtain importance weights for decision criteria and to identify the extent to which various alternatives meet these decision criteria. The committee found AHP attractive due to the rigor of its method, which is mathematically based, and the fact that the required comparisons can be made based either on available data or the user's knowledge, familiarity, and experience with the alternatives being evaluated.

The simplest AHP form consists of three levels: the overall goal of the decision, the criteria by which alternatives will be evaluated, and the available alternatives. A hierarchical structure of decision criteria helps the user decompose the decision into comparisons between each set of criteria. The criteria and, if applicable, subcriteria, are organized in gradual stages from more general criteria, in the upper levels of the hierarchy, to more specific criteria, in the lower levels. A decisionmaker can insert or eliminate levels and elements as necessary. Sometimes, the user can drop a less important criterion from further consideration, if the prioritization shows a relatively small impact on the overall objective.

The first step in using AHP is to develop a hierarchy of criteria. In the second step, the user carries out pairwise comparisons. These comparisons are used to create a set of matrices, which then are evaluated mathematically to produce a recommendation. All pairwise comparisons are performed qualitatively using a predefined set of values or quantitatively using estimated values for the criteria being considered. The predefined set of values, called the Fundamental Scale, represent the importance or weight of one criterion over another or the extent to which a particular alternative meets a particular criterion.

Developing AHP for ABC Decisionmaking

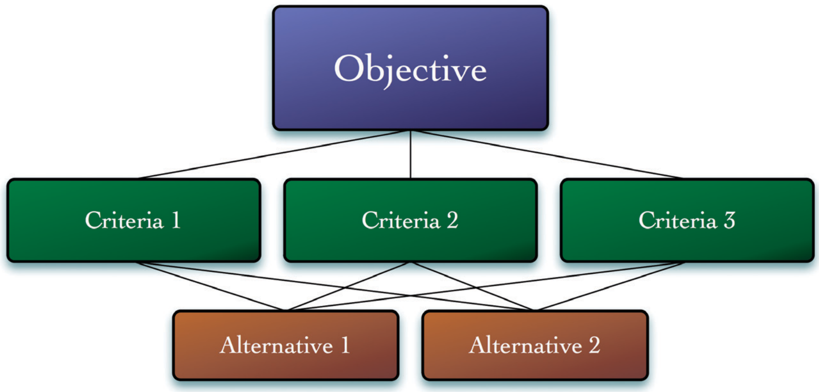
For this project, the technical advisory committee developed a hierarchy of criteria relevant to decisions about determining the best construction methods to apply to bridge replacement and rehabilitation projects. The committee refined the criteria over several months and tested them using previously completed and in-process bridge projects. The final hierarchy consists of two levels. The highest level consists of five criteria, each of which is further specified by two to nine subcriteria.

Definitions for all criteria and subcriteria were based on the members' experiences and expertise. A definition list helps users understand the decision hierarchy and to provide consistency between users who are completing the pairwise comparisons.

To check the completeness and robustness of the criteria, committee members conducted validations of the process using actual project cases. Considering the nature of the decision problems in a typical ABC project, these cases were used to confirm the suitability of the AHP approach in making decisions about whether various elements of ABC should be applied to a particular project. In addition to comparing each criterion and subcriterion in terms of its importance to a particular project, the technical experts also identified at least two different construction alternatives being considered for a particular project. They evaluated each alternative relative to all criteria and subcriteria. After that, they collected data for the cases by conducting interviews with DOT experts. Applications of AHP to two of these projects—Copano Bay Bridge in Texas and Keg Creek Bridge in Iowa—validated existing decisions about the best construction alternatives to apply to a specific project.

(Continued on page 13)

The Simplest Three-Level AHP Hierarchy



Source: TPF 5(221) pooled fund study.

The Fundamental Scale Used For Pairwise Comparisons in AHP

Value	Definition	Explanation
1	Equal importance	Two criteria contribute equally to the objective.
3	Moderate importance	Experience and judgment slightly favor one criterion over another.
5	Strong importance	Experience and judgment strongly favor one criterion over another.
7	Very strong importance	One criterion is favored very strongly over another; its dominance is demonstrated in practice.
9	Extreme importance	The evidence favoring one criterion over another is of the highest possible order of affirmation.

Scale values of 2, 4, 6, and 8 can be used to express intermediate values. Scale values such as 1.1, 1.2, 1.3, etc. also can be used for criteria that are very close in importance.

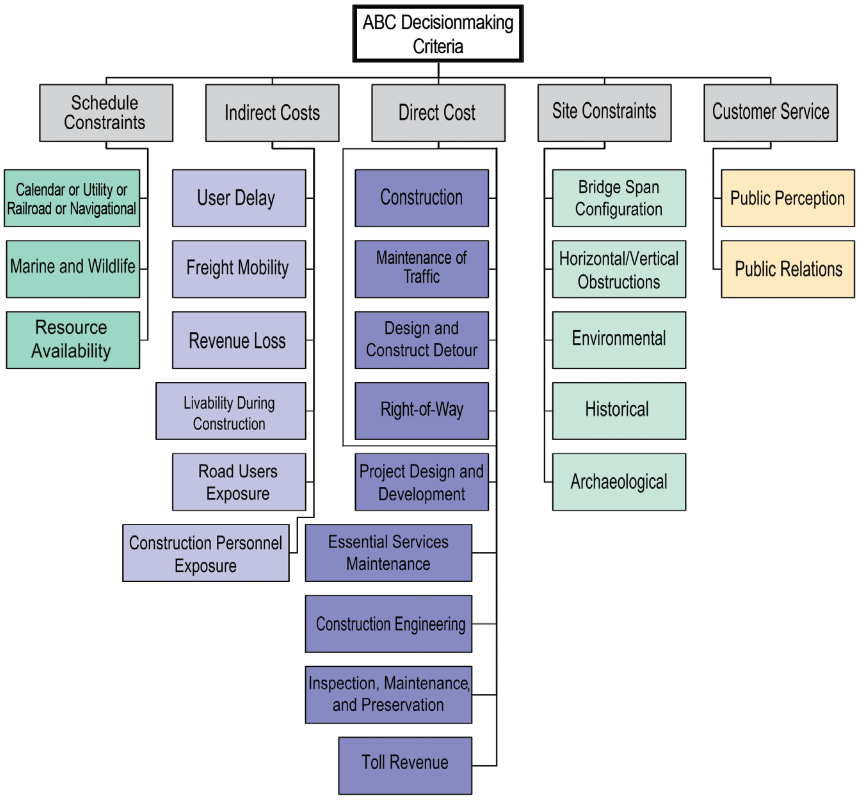
Source: Adapted from Triantaphyllou, E. and Mann, S.H. (1995). Using the Analytic Hierarchy Process for Decision Making in Engineering.

Definitions for All Criteria Included in the ABC Decisionmaking Hierarchy

Criteria	Subcriteria	Subcriteria Definition
Direct Costs	Construction	This factor captures the estimated costs associated with the construction of the permanent structure(s) and roadway. Included are the premiums associated with new technologies or innovative construction methods. Premiums might result from factors such as contractor availability, materials availability, and contractor risk. They might include incentive/bonus payments for early completion and other innovative contracting methods.
	Maintenance of Traffic	This factor captures the maintenance of traffic costs at the project site. Maintenance of traffic costs might affect preference due to its impact on total costs. This factor includes all costs associated with the maintenance of detours before, during, and after construction. Examples include installation of traffic control devices; maintenance of detours during construction, including flagging; shifting of traffic control devices during staged construction; and restoration associated with the temporary detours upon completion of construction.
	Design and Construct Detours	This factor captures the costs to design and construct temporary structures and roadways to accommodate traffic through the project site.
	Right-of-Way	This factor captures the cost to procure rights-of-way and includes either permanent or temporary procurements/easements.
	Project Design and Development	This factor captures the costs associated with the design of permanent bridge(s) and costs related to project development based on the construction method.
	Maintenance of Essential Services	This factor captures the costs associated with the need to provide essential services that may be affected by the construction selected. Examples of this factor include alternate routes or modes of transportation to provide defense, evacuation, and emergency access to hospitals, schools, fire stations, and law enforcement. This criterion is for situations where measures need to be implemented beyond those already considered in the "Maintenance of Traffic" and "Design and Construct Detours" criteria.
	Construction Engineering	This factor captures the costs associated with the owner's contract administration of the project.
	Inspection, Maintenance, and Preservation	This factor captures the life-cycle costs associated with the inspection, maintenance, and preservation of individual bridge elements.
	Toll Revenue	This factor captures the loss of revenue due to the closure of a toll facility.
Indirect Costs	User Delay	This factor captures costs of user delay at a project site due to reduced speeds and/or offsite detour routes.
	Freight Mobility	This factor captures costs of freight delay at a project site due to reduced speeds and/or offsite detour routes.
	Revenue Loss	This factor captures lost revenues due to limited access to local businesses resulting from limited or more difficult access stemming from the construction activity.
	Livability During Construction	This factor captures the impact on the communities resulting from construction activities. Examples include noise, air quality, and limited access.
	Road Users Exposure	This factor captures the safety risks associated with user exposure to the construction zone.
	Construction Personnel Exposure	This factor captures the safety risks associated with worker exposure at the construction zone.
Schedule Constraints	Calendar, Utility, Railroad, or Navigational	This factor captures the constraints placed on the project that might affect the timing of construction as a result of weather windows, significant or special events, railroad tracks, or navigational channels.
	Marine and Wildlife	This factor captures the constraints placed on the project by resource agencies to comply with marine or wildlife regulations. Examples include in-water work windows, migratory windows, and nesting requirements.
	Resource Availability	This factor captures resource constraints associated with the availability of staff to design and oversee construction. For example, a State may be required to outsource a project, which may result in additional time requirements.
Site Constraints	Bridge Span Configurations	This factor captures constraints related to bridge span configurations. This element may affect owner preference regarding bridge layout, structure type, or aesthetics.
	Horizontal/Vertical Obstructions	This factor captures physical constraints that may affect construction alternatives. Examples include bridges next to fixed objects such as tunnels, right-of-way limitations, sharp curves or steep grades, or urban area structures that constrain methods and/or bridge locations.
	Environmental	This factor captures the constraints placed on the project by resource agencies to minimize construction impacts on natural resources, including marine, wildlife, and flora.
	Historical	This factor captures historical constraints existing on a project site.
	Archaeological Constraints	This factor captures archaeological constraints existing on a project site.
Customer Service	Public Perception	This factor captures both the public's opinion regarding the construction progress and its overall level of satisfaction.
	Public Relations	This factor captures the costs associated with the communication and management of public relations before and during construction.

Source: TPF 5(221) pooled fund study.

Hierarchy of ABC Decisionmaking Criteria



Source: TPF 5(221) pooled fund study.

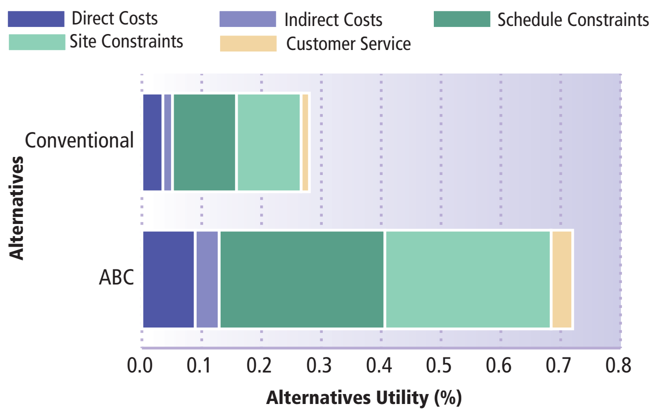
Using ABC Software for Analysis of a Texas Bridge

The Copano Bay Bridge will replace an existing causeway on State Highway 35 at the mouth of Copano Bay. The bridge connects the cities of Rockport/Fulton and Lamar on the Gulf Intracoastal Waterway. Copano Bay is home to oyster colonies and migratory birds, attracting birdwatchers year-round. Two peninsulas frame the bay opening, limiting right-of-way and dictating phased construction.

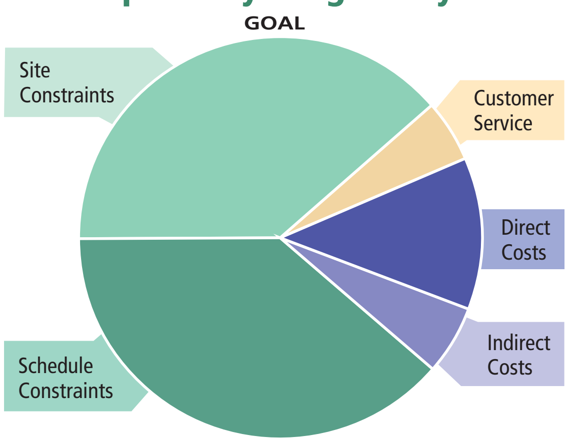
The bridge is 11,010 feet (3,356 meters) long, with a 129-foot (39-meter)-wide and 75-foot (23-meter)-tall navigation channel. The existing structure suffered severe corrosion damage from marine exposure requiring extensive repairs to many substructure elements. Providing corrosion protection, in the form of high-performance concrete, stainless reinforcing steel, and cylinder pile foundations, was of high importance. The superstructure consists of 100-foot (31-meter), 120-foot (37-meter), and 150-foot (46-meter)-long prestressed concrete girders. A majority of the piers consist of cast-in-place caps on trestle piles, with the tallest piers around the navigation channel being cast-in-place bent caps on cast-in-place columns and waterline pile caps. The bridge owner, the Texas Department of Transportation (TxDOT), allowed the contractors to propose precast bent caps as an alternate construction method to reduce the duration of construction activities over open water.

Experts from TxDOT provided the data for the AHP analysis. The analysis compared two construction alternatives: precast caps and cast-in-place. The utility value—degree of benefit or preference—for precast caps was 0.72, whereas the degree of benefit or preference for the cast-in-place alternative was 0.28. The results for the criteria weights indicate that site constraints and schedule constraints had the greatest impact on the selection of precast

Overall Utility Values for the Copano Bay Bridge



Criteria Weights for Copano Bay Bridge Analysis



Researchers used the AHP to compare ABC with conventional construction for a project to replace the Copano Bay Bridge in Texas. As shown in this bar graph (left), the AHP revealed that the ABC alternative offered significant benefits. The pie chart (right) indicates that site and schedule constraints were the most important drivers of this result. *Source: TPF 5(221) pooled fund study.*

caps as the best construction alternative. Based on the results of the AHP analysis and the importance weightings for each criterion in the ABC model, the analysis validated TxDOT's decision that precast caps are the alternative that best satisfies the project's objectives.

Using ABC Software for Analysis of an Iowa Bridge

The Keg Creek Bridge carries U.S. 6 over Keg Creek in Pottawattamie County, Iowa. The existing 180-foot (55-meter) by 28-foot (8.5-meter) continuous concrete girder bridge was constructed in 1953 and currently is classified as structurally deficient with a sufficiency rating of 33. The Iowa Department of Transportation's proposed bridge replacement aims to increase the structural capacity of the bridge, improve roadway conditions, and enhance safety by providing a wider roadway. The replacement structure will be a three-span steel/precast modular bridge with precast bridge approaches.

Iowa DOT provided the data for the AHP analysis. The analysis compared two construction alternatives: ABC modular bridge (all components prefabricated offsite) and a traditional bridge (conventional). Both alternatives are on the same alignment and use the same offsite detour. The utility values for the modular and conventional alternatives were 0.68 and 0.32, respectively. The results for the criteria weights indicate that direct costs and customer service had the greatest impact on the selection of the modular bridge as the best construction alternative. Based on the results of the AHP analysis, the ABC modular bridge alternative best satisfied the project's objectives.

ABC Decisionmaking Software

In parallel with testing and validating the approach, the AHP software was developed using Microsoft Visual Studio®.NET as a stand-alone application. The software can run on a variety of Windows operating systems, including Microsoft® Windows XP, Vista, and Windows® 7.0. Two alternatives may be compared in an analysis.

The initial interface manages the hierarchy of criteria. When first opening the software, the committee's default hierarchy loads. The user can add or eliminate criteria and subcriteria using the functionality provided in the criteria tab. In this tab, the user also can load, save, and/or modify previously developed hierarchies.

The second tab provides the interface needed for the user to complete the pairwise comparisons of criteria, subcriteria, and alternatives. The user can save an analysis at any time and later return to that specific position, without losing data.

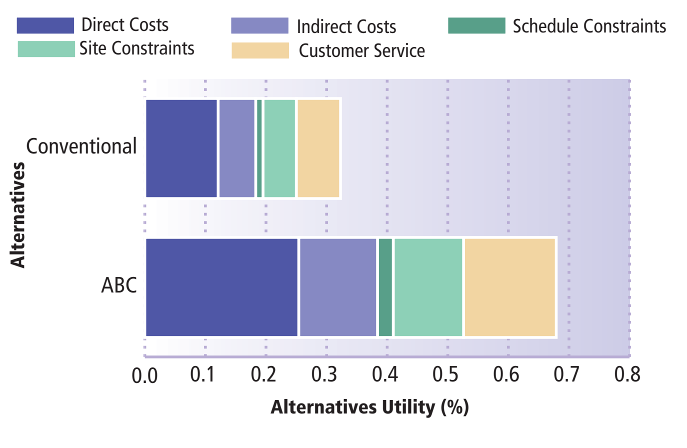
After completing all pairwise comparisons, the user goes to the third tab to review the results. For each criterion in the hierarchy, the software generates a set of two plots: a bar chart indicating the overall utility level for each alternative and a pie chart showing the importance weights for each criterion. The software also provides the option of completing an additional cost-weighted analysis in which decisionmakers can evaluate the impact of the direct cost criterion apart from all other criteria. The cost-weighted analysis may be used only after the user has eliminated all cost criteria from the decision hierarchy.

What Next?

In the early stages of a construction project, decisionmakers have the difficult task of assessing whether elements of ABC are achievable and effective for a specific bridge location. These decisions are even more difficult as multiple criteria and diverse (sometimes opposing) perspectives need to be considered. The use of appropriate decisionmaking tools in these early stages can help promote dialog and ultimately foster effective solutions.

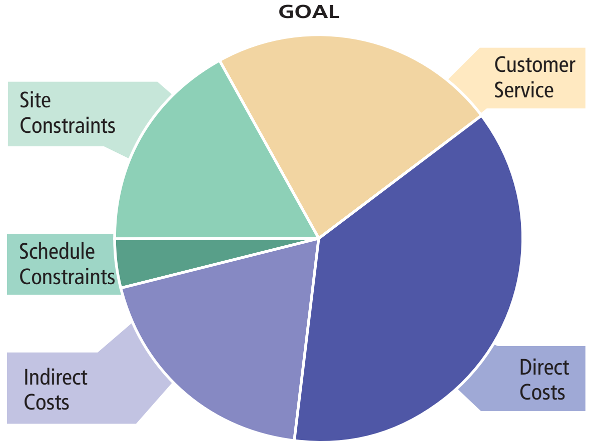
Applications of the AHP software tool have provided evidence that it can help decisionmakers identify and communicate the rationale behind a decision to select a particular construction method.

Overall Utility Values for the Keg Creek Bridge



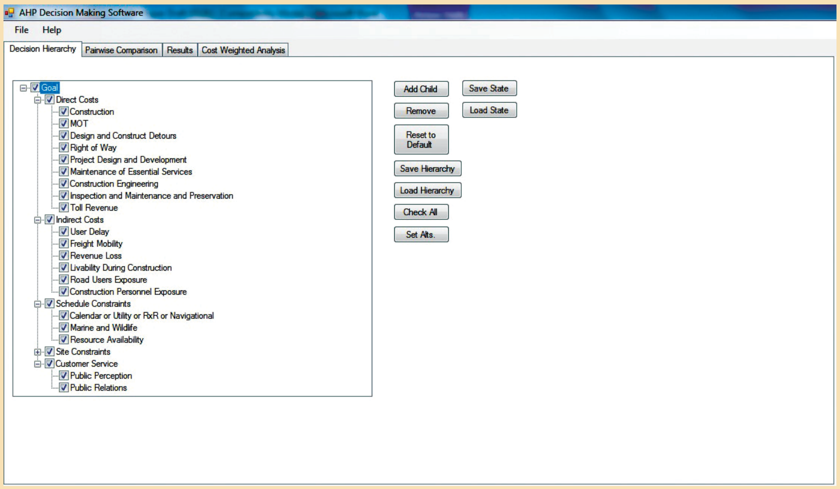
Source: TPF 5(221) pooled fund study.

Criteria Weights for Keg Creek Bridge Analysis



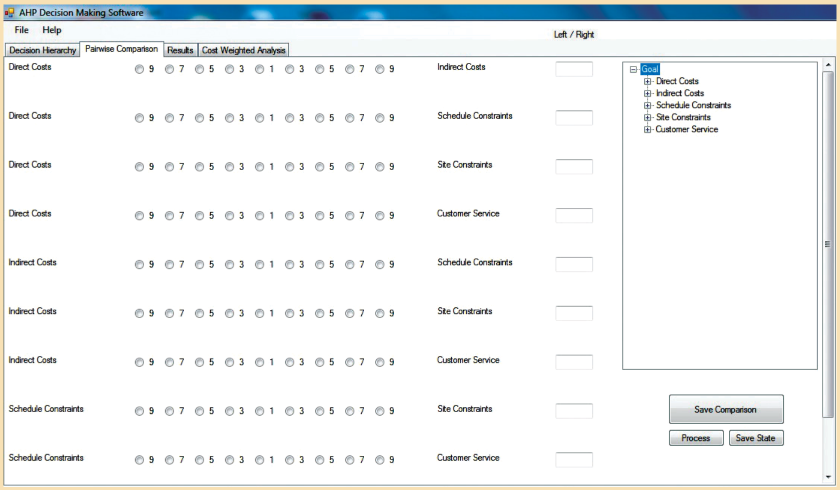
Source: TPF 5(221) pooled fund study.

First Tab in ABC Software



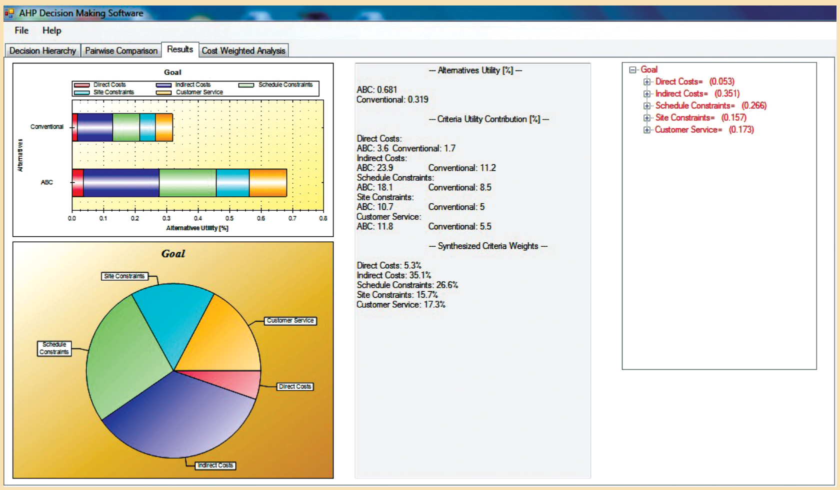
Source: TPF 5(221) pooled fund study.

Interface for Completing All Pairwise Comparisons



Source: TPF 5(221) pooled fund study.

Interface for Reviewing Results of AHP Analysis



Source: TPF 5(221) pooled fund study.

The tool has been tested on projects from seven States (California, Iowa, Montana, Oregon, Texas, Utah, and Washington). A final version of the software will be available for download at FHWA's Web site at the completion of the project in January 2012. Case study results for all the projects that have been analyzed to date are posted as well.

Toni Doolen, Ph.D., is a professor and associate dean at Oregon State University. Her research uses both quantitative and qualitative methodologies to study organizational processes. Doolen received her B.S. in electrical engineering and materials science and engineering at Cornell University, M.S. in manufacturing systems engineering from Stanford University, and Ph.D. in industrial engineering at Oregon State University.

Benjamin Tang, P.E., is an ODOT bridge preservation manager in Salem, OR. He manages the statewide preservation program for all coastal, historical, and movable bridges. Tang retired in 2008 from FHWA after 33 years of Federal service but continues to champion and contribute to the advancement of ABC technology. He holds a master's degree in structural engineering from the University of Illinois, Urbana-Champaign.

Amirali Saeedi is a Ph.D. student in the industrial engineering program at Oregon State University. He holds a B.S. from Sharif University of Technology and an M.S. from Oregon State University.

Samin Emami has a B.S. in industrial engineering from Sharif University of Technology. Currently, he is working on a master's in manufacturing systems engineering at Oregon State University.

For more information, see www.pooledfund.org/projectdetails.asp?id=449&status=6 and www.fhwa.dot.gov/bridge/abc or contact Toni Doolen at 541-737-5641 or doolen@engr.orst.edu or Benjamin Tang at 503-986-3324 or benjamin.m.tang@odot.state.or.us.

A new self-evaluation tool, an expert working group, and research on new paving systems are among the ways FHWA is helping transportation agencies meet present and future needs.

IN PURSUIT OF *Sustainable Highways*

by Benjamin W. Cotton

In the transportation industry, projects and systems serve many different and sometimes competing objectives, including safety, mobility, environmental protection, livability, and asset management. A *sustainable* approach seeks to meet all of these needs while hitting economic targets for cost-effectiveness throughout a highway's life cycle.

For the Federal Highway Administration (FHWA), a sustainable approach to highways means helping decisionmakers make balanced choices among environmental, economic, and social values—the triple bottom line of sustainability—that will benefit current and future road users. A sustainable approach looks at access (not just mobility), movement of people and goods (not just vehicles), and provision of transportation choices, such as safe and comfortable routes for walking, bicycling, and transit. Sustainability encapsulates a diversity of concepts as well, including efficient use of funding, incentives for construction quality, regional air quality, climate change considerations, livability, and environmental management systems.

Over the years, highway agencies have been adopting sustainable methods to comply with State or local regulations, to address environmental issues related to specific projects, or to meet other project or agency goals. Until recently, however, national-level guidance on just what it means to be a sustainable highway did not exist. That's why FHWA set its sights on developing the Infrastructure Voluntary Evaluation Sustainability Tool (INVEST), a Web-based collection of best practices that enables transportation practitioners to evaluate the sustainability of their projects.

(Above) Hot in-place recycling, as shown here, rehabilitates pavements with minimal use of new materials. Recycling and reuse of materials are among the 30 Project Development criteria represented in INVEST, FHWA's new sustainability self-evaluation tool. *Photo: Steve Muench, University of Washington.*

Development and pilot testing of the new self-evaluation tool, establishment of a sustainability working group, and creation of a Sustainable Pavements Program are among the efforts underway at FHWA to help State and local agencies document and improve the sustainability of the Nation's roadways.

Developing a Self-Evaluation Tool

How do you know if your highway project is sustainable? To help highway agencies answer this question, in 2010 FHWA began developing INVEST. Using this Web-based self-evaluation tool, transportation practitioners will be able to integrate sustainability best practices into their roadway projects and evaluate their projects against existing sustainability best practices, known as criteria in the tool's evaluation system.

Use of INVEST is voluntary and is not intended to rank highway projects or compare transportation agencies against each other. Rather, FHWA designed the tool to educate and offer support to those agencies interested in incorporating sustainable practices into their highway programs. Although measuring sustainability is an imperfect science, the tool can help agencies do the following:

- Learn more about sustainability practices in roadway planning, design, and construction.
- Track and assess progress against these practices.
- Make informed decisions about sustainability tradeoffs.
- Communicate highway sustainability benefits and goals to stakeholders.

The tool is structured around a scoring function that enables State, regional, and local transportation agencies to accumulate points based on sustainability efforts at a programmatic level or as incorporated into a specific transportation project. Criteria are grouped into three modules—System Planning, Project Development, and Operations and Maintenance—with the recognition that sustainability objectives evolve throughout the life of a highway. System Planning criteria focus on an agency's efforts to incorporate sustainability into the

GreenLITES: NYSDOT's Sustainability Rating Program

The New York State Department of Transportation (NYSDOT) created its own metrics-based, self-certification tool to raise awareness of sustainability practices already at work within the department and to expand the use of these and other emerging methods. Known as Green Leadership in Transportation Environmental Sustainability (GreenLITES), the tool helps the department evaluate its sustainability performance, identify effective internal practices and share them with the public, and discover new ways to improve sustainability.

NYSDOT is implementing GreenLITES in stages. The first phase was the launch of project design certification in 2008 for individual transportation projects. The next phase was operations certification in 2009 for sustainable practices in maintaining existing infrastructure and maintenance facilities.

The tool's project design module incorporates more than 175 sustainable practices, such as installing wildlife crossings and stormwater management ponds. The maintenance and operations module includes 95 green items, such as use of clean energy vehicles and context sensitive bridge repair.

GreenLITES certifies project designs in five categories:

1. *Sustainable sites*—credits designs that promote a project's overall setting, such as context sensitive solutions or measures that protect, enhance, or restore ecological habitat.
2. *Water quality*—credits designs that treat stormwater and reduce runoff.
3. *Materials and resources*—credits designs that incorporate recycled and local materials, reuse resources, and minimize hazardous materials.
4. *Energy and atmosphere*—credits designs that reduce petroleum and electricity consumption, improve traffic flow, incorporate nonmotorized transportation, or make air quality improvements.
5. *Innovation/unlisted*—credits designs that promote or incorporate innovative practices in transportation and environmental sustainability.

The tool awards points to projects based on their contributions to these categories. NYSDOT uses projects' cumulative scores to assign them to one of four GreenLITES ratings:

- *Certified*—the design incorporates some sustainable elements.
- *Silver*—the design incorporates sustainable elements, with several having a high level of impact or having advanced the state of the practice.
- *Gold*—the design incorporates sustainable elements, with a substantial number having a high level of impact, or having advanced the state of the practice.
- *Evergreen*—the design incorporates a wide variety of sustainable elements that have a very high level of impact and advance the transportation state of the practice.

NYSDOT

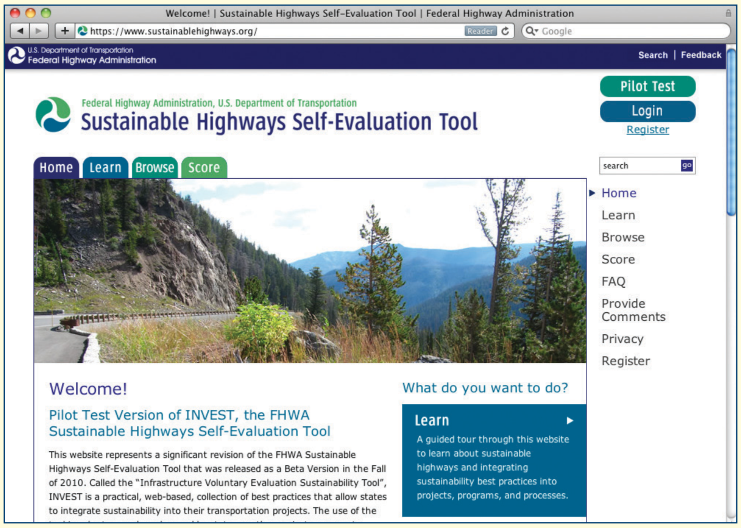
This artist's rendering shows one vision for applying sustainability practices to Route 347 in Long Island, NY. Sustainability features include transit facilities, landscaping with native vegetation, improved stormwater management, and state-of-the-art bicycle and pedestrian facilities.

"Incorporating sustainability into our design and operations practices is a new way of doing business for the State department of transportation," says NYSDOT Commissioner Joan McDonald. "We are excited to be a national leader for sustainability in transportation. To date, we have evaluated more than 465 projects, and our annual awards ceremony gives the department an opportunity to recognize the maintenance and capital construction projects that best incorporate environmental sensitivity in our State's transportation system."

For more information, visit www.nysdot.gov/programs/greenlites.

highway planning process; Project Development criteria target specific highway construction projects; and Operations and Maintenance criteria identify sustainable measures that an agency can incorporate throughout a highway's serviceable life. Each category is scored independently from the others, allowing agencies to apply the tool in ways that are relevant to current policies, programs, and projects, while shelving those components of the tool that are not immediately applicable.

The Project Development module, for example, can be applied in its basic format, which includes 20 criteria, or in its extended format,



Screenshot from FHWA's "INVEST" Web site.

INVEST Project Development Criteria

Criteria by Principles and Project Scoring Tool Categories

Criterion Number and Title	Triple Bottom Line Principles			Project Scoring Tool Categories	
	Environmental	Social	Economic	Basic (20)	Extended (30)
PD-1: Cost-Benefit Analysis	✔	✔	✔	•	•
PD-2: Highway and Traffic Safety		✔	✔	•	•
PD-3: Context Sensitive Project Development	✔	✔	✔		•
PD-4: Lifecycle Cost Analyses	✔		✔	•	•
PD-5: Freight Mobility	✔		✔	•	•
PD-6: Educational Outreach	✔	✔	✔	•	•
PD-7: Tracking Environmental Commitments	✔	✔		•	•
PD-8: Habitat Restoration	✔			•	•
PD-9: Stormwater	✔			•	•
PD-10: Ecological Connectivity	✔	✔	✔	•	•
PD-11: Recycle & Reuse Materials	✔		✔	•	•
PD-12: Create Renewable Energy	✔		✔		•
PD-13: Site Vegetation	✔		✔		•
PD-14: Pedestrian Access	✔	✔	✔	•	•
PD-15: Bicycle Access	✔	✔	✔	•	•
PD-16: Transit & HOV Access	✔	✔	✔		•
PD-17: Historical, Archaeological, and Cultural Preservation		✔		•	•
PD-18: Scenic, Natural, or Recreational Qualities		✔			•
PD-19: Low-Emitting Materials	✔	✔		•	•
PD-20: Energy-Efficient Lighting	✔		✔	•	•
PD-21: ITS for Systems Operations	✔	✔	✔	•	•
PD-22: Long-Life Pavement Design	✔		✔	•	•
PD-23: Reduced Energy and Emissions in Pavement Materials	✔	✔	✔		•
PD-24: Contractor Warranty	✔		✔		•
PD-25: Earthwork Balance	✔		✔		•
PD-26: Construction Environmental Training	✔				•
PD-27: Construction Equipment Emission Reduction	✔	✔		•	•
PD-28: Construction Noise Mitigation	✔	✔		•	•
PD-29: Construction Quality Control Plan	✔		✔	•	•
PD-30: Construction Waste Management	✔		✔		•

This table lists the criteria used in INVEST's Project Development module by principles and project scoring tool categories. *Source: FHWA.*

consisting of 30 criteria. The basic scorecard is applicable to projects such as small reconstruction jobs and bridge replacements that do not expand the capacity of the roadway; preservation projects for extending the service life of existing facilities and for safety enhancements; and initiatives to restore pavement structure, ride quality, and spot safety. The extended scorecard is intended for larger projects with more significant changes and investments and, therefore, more opportunities to apply sustainable solutions. These include construction projects for a new roadway facility or structure, as well as major reconstruction projects that add travel lanes to an existing roadway or bridge. The tool automatically tallies the score and assigns the project a bronze-, silver-, gold- or platinum-level status based on the project's sustainability characteristics.

FHWA developed INVEST with substantial input from State departments of transportation (DOTs) and industry trade organizations, including the American Association of State Highway and Transportation Officials (AASHTO). Already, FHWA has presented INVEST at numerous conferences and seminars, and the project team has held multiple webinars to demonstrate the tool's functionality and how it can benefit decision-making and project outcomes.

"The feedback received from AASHTO and other stakeholders was instrumental in helping us clarify our intentions, focus the tool, and simplify the criteria and scoring process," says FHWA Associate

Suzie Barber

A highway improvement project on Happy Valley Road in Peoria, AZ, included the reuse of existing pavements and structures, innovative contracting, and native site vegetation, and resulted in a 4-mile (6.4-kilometer) urban arterial with sidewalks, bicycle lanes, and noise walls.

Administrator for Planning, Environment, and Realty Gloria Shepherd.

Pilot Testing the Tool

FHWA released the pilot version of INVEST in three stages, available online at www.sustainablehighways.org. The Project Development module was released in April 2011, the Operations & Maintenance module in July 2011, and the Systems Planning module in September 2011.

The pilot version will be active throughout 2011 with several State, regional, and local agencies testing the tool's application on their projects and programs. FHWA emphasized the importance of testing the tool's versatility on projects ranging from bridge construction and intersection improvement to highway expansion and pavement restoration.

"FHWA is excited about our progress with the pilot test version of INVEST," says FHWA Executive Director Jeffrey Paniati. "[The pilot] is a great opportunity to test the tool on real-world highway projects and refine the scoring system based on the results. We look forward to making our findings available to our partners and stakeholders once the pilot test phase of the project is complete."

Sustainability Working Group at FHWA

In addition to developing the self-evaluation tool, in the summer of 2010, FHWA convened a sustainability working group to build capacity and encourage communication and coordination on sustainability concepts and practices within the agency. The group consists of engineers,

What Makes a Sustainable Highway? U.S. 97, Deschutes National Forest, OR

Some of the United States' best existing examples of sustainable highways projects are in the national forests. As a result of the policies and funding for sustainability through the FHWA Office of Federal Lands Highway, a number of highway improvement projects spearheaded by the U.S. Forest Service have incorporated many sustainable highways principles.

The Oregon Department of Transportation's $16 million Lava Butte project on U.S. 97 in Deschutes National Forest included an array of efforts that support sustainability. Consisting of a 3.8-mile (6.1-kilometer) stretch of U.S. 97 in southern Oregon, the Lava Butte project involved expanding capacity from three lanes to four lanes, creating a forested median, developing a full diamond interchange (four on-/off-ramps), and improving access to the popular Lava Lands Visitor Center.

Specific sustainability efforts included the following:

- Developing a construction quality plan that reviews all improvements to ensure adequate planning and completion of all efforts.
- Paving with long-life pavements.
- Constructing two wildlife underpasses to improve safety and allow for ecological connectivity.
- Using recycled or repurposed construction materials whenever possible.
- Developing facilities for safer access for bicyclists and pedestrians.
- Planting native vegetation in the new median.
- Using nonpotable effluent for all water-related activities except concrete.
- Creating an information kiosk to inform visitors of the sustainable activities involved in the project.

Sustainable features of the U.S. 97 Lava Butte project in Oregon include a wildlife connectivity underpass (left), an elevated tank containing nonpotable water (center), and an educational kiosk (right).

What Makes a Sustainable Highway?
Fernan Lake Road: Idaho Panhandle National Forest

In August 2008, the U.S. Forest Service embarked on a $14.6 million highway improvement project for Fernan Lake Road in the Coeur d'Alene District of the Idaho Panhandle National Forest. The primary purpose was to improve safety and stormwater management in a mountainous area prone to landslides and excessive runoff. Additional sustainability activities included the following:

- Managing stormwater runoff to prevent contamination of wetlands and promote proper recharge of the water table.
- Removing fill and building a bridge to create a wildlife underpass.
- Using recycled and repurposed construction materials whenever possible.
- Planting native vegetation to help stabilize steep slopes and minimize erosion.
- Conducting environmental training so construction workers would be familiar with the intentions of their activities and the processes used.
- Making all improvements within a context sensitive framework.
- Developing a construction quality plan that reviews all improvements to ensure adequate planning and successful completion of all efforts.

Fernan Lake Road (left) in Idaho Panhandle National Forest is traversed by wildlife (center) as well as vehicles. During construction (right), workers recontoured the steep slopes to better manage stormwater runoff and groundwater recharge.

scientists, planners, and economists with expertise in planning, design, construction, pavement, stormwater management, natural resources, and livability. It meets regularly to coordinate activities, foster increased application of sustainability principles, and provide guidance to FHWA on developing best practices and establishing standardized sustainability measures.

As with many initiatives at the national level, one of the biggest challenges facing FHWA's sustainable highways program is developing a system of best practices that is applicable to transportation agencies across the country. Given vast variations in climates, habitats, geological characteristics, and availability of construction materials throughout the United States, certain sustainable practices may be valuable to some highway projects but inconsequential to others.

For example, snow and ice control will vary significantly among regions, and sustainable techniques that work in ice-prone northern Texas are likely quite different from those effective in the snow belt of upstate New York. The sustainability working group works to shed light on these potential discrepancies, bringing together viewpoints from across the Nation to ensure that FHWA's programs and tools are flexible enough to accommodate the full range of highway needs across the country.

Another challenge stems from the differences in urban and rural corridors. Bicycle and pedestrian facilities in urban areas, for example, are often different from those appropriate for rural areas; that is, a wider roadway shoulder may be appropriate in a rural area, while a sidewalk would be necessary in an urban area. In addition, the number of people affected by planning decisions regarding walking and bicycling access in roadway development is likely to be much greater in urban corridors than in rural ones.

Illinois Tollway

Workers applied lime to stabilize the existing subgrade and base in order to reduce earthwork needs during a project to reconstruct and widen the Jane Addams Memorial Tollway (I–90) near Rockford, IL, in 2008.

WSDOT's Approach to Sustainable Transportation

Moving Washington is the Washington State Department of Transportation's (WSDOT) decisionmaking framework for planning, operating, and investing in statewide transportation. It is focused on safety and preserving assets and includes three key strategies: operating the system more efficiently, managing transportation demand, and strategically adding capacity.

Moving Washington is also WSDOT's approach for creating an integrated 21st century transportation system that is reliable, responsible, and sustainable. Sustainable transportation supports a healthy economy, environment, and community and adapts to weather extremes, diminished funding, and changing priorities. Further, a sustainable transportation system is built to last, uses fewer materials and energy, and is operated efficiently.

To make the system more efficient, WSDOT works to smooth traffic flow and conserve resources by recycling and using fewer building materials. The department focuses on maintenance to extend the life of roads and bridges and plants native vegetation along roadsides, reducing maintenance and herbicides. To manage demand, WSDOT provides travel options by expanding ridesharing, transit, and pedestrian opportunities. WSDOT strategically adds capacity aligned with operational and demand management strategies. These efforts target the most congested traffic areas to reduce bottlenecks, complete corridor gaps, finish critical bridges, implement express lanes, and apply advanced technologies.

In addition, WSDOT is pursuing sustainable efforts in electric vehicle and alternative fuel facilities, as well as reducing energy consumption and transportation emissions. The department cochairs the development of a statewide integrated adaptation response and works with partners to integrate sustainable transportation strategies into plans and business practices. Recognizing the connections between land use and transportation, the department also seeks to leverage transportation investments to encourage land uses that are accessible to and promote a variety of travel modes.

Visit www.wsdot.wa.gov/sustainabletransportation for more information.

Workers with the Washington State Department of Transportation are using warm-mix asphalt paving for the first time on I–90 near George, WA. Warm-mix asphalt lowers the required temperature for processing at the plant and application at the jobsite, saving energy and cutting air emissions. It also can improve compaction. *Photo: Craig Weiland, University of Washington.*

Similarly, dedicated wildlife crossings will not apply to many urban projects but are an important consideration in rural areas with high rates of collisions involving wildlife. FHWA's aim, therefore, is to provide universal metrics for measuring sustainability and to encourage participation by all who are interested.

Sustainable Pavements Program

Another related effort is FHWA's new Sustainable Pavements Program, initiated in fall 2010 to advance the knowledge and practice of sustainability in the pavements and materials area. The integrated program covers asphalt, concrete, granular, and recyclable materials used in pavement systems and promotes research into new sustainable materials and processes.

The goal is to support FHWA's livability and sustainability goals by raising the awareness and visibility of sustainability considerations in the design, construction, maintenance, and rehabilitation of pavement systems. Program objectives include developing guidelines for designing and constructing sustainable pavement systems; evaluating materials, processes, technologies, and tools to aid in the evaluation, design, and construction of sustainable pavement systems; and conducting technology transfer and deployment activities.

FHWA established a technical working group to provide input and feedback on pavement and material sustainability. The working group is composed of representatives from State DOTs, other government agencies, academia, and industry. "We are hopeful that we can address many sustainability issues faced by practitioners through open communication and information sharing," says Gina Ahlstrom, a pavement engineer at FHWA.

Many of the Sustainable Pavements technical working group members also played a role in the development of the pavement-related components of FHWA's INVEST tool.

Looking to the Future

For years, FHWA has supported research, development, and implementation efforts at the forefront of the sustainability movement. Now, with the creation of its sustainable highways program, FHWA hopes to consolidate those efforts under one umbrella.

As interest in sustainability principles and best practices among DOTs and the transportation industry continues to grow, FHWA will work to integrate INVEST into relevant future webinars, conferences, and National Highway Institute training courses. FHWA officials expect that the sustainable highways program will play a significant role in facilitating the creation and maintenance of the Nation's highway infrastructure in the years and decades ahead.

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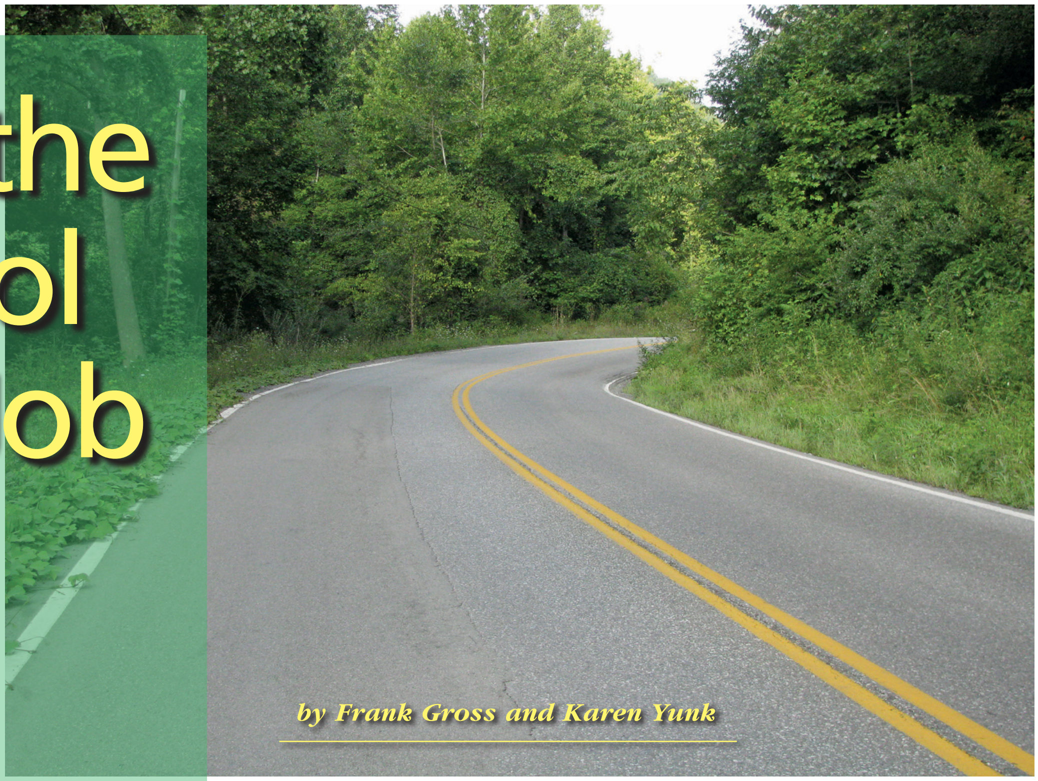
Finding the Right Tool For the Job

Crash modification factors, when used properly, can help transportation engineers identify and apply the most appropriate countermeasures for increasing roadway safety.



by Frank Gross and Karen Yunk

Transportation funding is a limited resource with many competing needs—maintaining existing infrastructure, constructing new facilities, and operating transportation systems safely. To help stretch their budgets available for highway safety, State and local transportation agencies work to identify and implement the optimal combination of countermeasures to achieve the greatest benefits. Equipped with the right tools, transportation engineers can make informed decisions to save money and reduce crashes.

Crash modification factors (CMFs) are tools that, when applied correctly, can help to identify the expected safety impacts of installing various countermeasures to reduce crashes. CMFs are multiplicative factors used to estimate the number of crashes after implementing a given countermeasure at a specific site. Combined with crash cost data and project cost information, CMFs can help transportation engineers compare the benefit-to-cost ratio of multiple countermeasures and then choose the most appropriate CMF for a given situation.

The Federal Highway Administration (FHWA) is leading a concerted effort to develop information on CMFs and make it available to State and local agencies to assist with highway safety planning. The CMF Clearinghouse, a free online database introduced in 2009 and accessible at www.cmfclearinghouse.org, details the varying quality and reliability of CMFs available to transportation professionals. (For more information, see "The CMF Clearinghouse: A Handy Safety Tool" in the November/December 2010 issue of PUBLIC ROADS.)

Today's challenge is to help State and local transportation agencies identify appropriate CMFs and then apply them effectively. What follows is a primer on how to choose the most applicable CMFs and apply them successfully to help reduce crashes and save lives.

(Above) Transportation engineers can apply CMFs to determine whether installing chevrons at a curve such as this one on a two-lane, rural road could help to reduce crashes. *Photo: Frank Gross, Vanasse Hangen Brustlin, Inc.*

Selecting CMFs

Selecting an appropriate CMF is similar to choosing the right tool for the job. In some cases, a tool that may not be perfect will still work well enough to get the job done. For example, a crescent wrench will tighten bolts even though an exact size wrench might be the ideal tool. Although the exact size may be ideal, the crescent wrench is adjustable and versatile and therefore can serve the purpose. The same can be true with CMFs. Even if a CMF is not a perfect match for the situation to which it is applied, it may work well enough to provide a reasonable estimation of the countermeasure's effect.

"You have to do the best you can with the information available," says Shawn Troy, a safety evaluation engineer with the North Carolina Department of Transportation (NCDOT). For example, NCDOT recently needed a CMF for total crashes for installing in-lane pavement markings as a supplemental measure to enhance guidance on a multilane facility. Based on a query of the CMF Clearinghouse, the engineers identified three CMFs for "mark pavement with supplementary warning." Only one dealt with total crashes, indicating an expected reduction of 6 percent. In addition, the CMF was general (that is, no specific indication of applicable roadway type, area type, or number of lanes) and was not rated due to a lack of supporting information. However, this

was the only information available for reference, so the NCDOT engineers made the decision to apply this general and unrated CMF until a more rigorous study is completed.

In other cases, using an improper tool may do more harm than good. For example, using a hammer to tighten bolts may not be effective at meeting the objective. Similarly, applying a CMF that does not fit the specific situation may not allow a reasonable estimate of the countermeasure's safety effectiveness. Selecting an inappropriate CMF may lead to one of two outcomes—the change in crashes will be over- or underestimated. "The risk of applying an inappropriate CMF is that you may end up selecting a less cost-effective treatment," says Troy.

Three main considerations are necessary to assure appropriate selection of CMFs: the availability of relevant CMFs, the applicability of available CMFs, and the quality of applicable CMFs.

Availability. The availability of a CMF that applies to a specific situation depends on whether research has been conducted to determine the safety effects of a particular countermeasure or combination of countermeasures, and whether researchers have documented it. The CMF Clearinghouse contains more than 2,900 CMFs and receives quarterly updates to include the latest research. The American Association of State Highway and Transportation Officials' *Highway Safety Manual* (HSM) also provides CMFs for various countermeasures but contains only a subset of those found in the clearinghouse. The HSM focuses on higher quality CMFs for specific roadway characteristics and countermeasures.

Applicability. Once a transportation professional determines that one or more CMFs exist for a specific countermeasure, the next step is to determine which CMF is the right one for the job, that is, which is most applicable. Applicability depends on how closely the CMF represents the situation to which it will be applied. For example, if a transportation engineer is trying to decide whether to install chevrons along a horizontal curve on a rural, two-lane road, the engineer will first identify the potential safety effectiveness of installing chevrons. The engineer then will evaluate the potentially applicable CMFs, eliminating any that are not appropriate for the situation. In this example, the engineer will eliminate the CMFs for combination treatments, even if they include chevrons, because this situation includes only the chevrons. Likewise, the engineer will eliminate CMFs for urban areas, since the situation at hand is in a rural setting. Any options that have a significantly different traffic volume thus also will be eliminated.

After dismissing the less appropriate CMFs, the engineer still may have multiple CMFs to choose from to estimate the effectiveness of the chevrons. Final selection of a CMF will depend on the objective of the analysis. If the objective is to estimate the reduction in fatal and injury crashes, then the engineer will choose the CMF noted for that specific crash type and severity. If the engineer chooses to use a CMF outside the range of applicability, the safety effect may be over- or underestimated.

"Several variables can be used to match a CMF to the scenario at hand," says Daniel Carter, senior engineering research associate with the Highway Safety Research Center at the University of North Carolina. "Transportation engineers can use treatment type, roadway type, area type, segment or intersection

Sample CMFs That Include Installing Chevrons

ID	Countermeasure	CMF	Crash Type	Crash Severity	Roadway Type	Area Type	Traffic Volume (Vehicles Per Day)
1.	Install combination of chevrons, curve warning signs, and/or sequential flashing beacons	0.606[1]	All	All	Principal Arterial	Not specified	7,400 to 13,975
2.	Install chevrons and curve warning signs	0.592[1]	All	All	Principal Arterial	Not specified	10,434 to 13,975
3.	Install chevrons	0.36[2]	All	All	Minor Arterial	Urban	Not specified
4.	Install chevrons	0.96[3]	Nonintersection	All	All	Rural	261 to 14,790
5.	Install chevrons	0.94[3]	Nonintersection Head-on, Run-off-road, and Sideswipe	All	All	Rural	261 to 14,790
6.	Install chevrons	0.84[3]	Nonintersection	Fatal, Serious injury, Minor injury	All	Rural	261 to 14,790

[1] Montella, A. "Safety Evaluation of Curve Delineation Improvements: Empirical Bayes Observational Before-and-After Study." Transportation Research Board 88th Annual Meeting Compendium of Papers CD-ROM. Washington, DC, 2009.
[2] Lalani, N. "Comprehensive Safety Program Produces Dramatic Results." *ITE Journal*, Vol. 61, No. 10, Washington, DC, 1991.
[3] Srinivasan, R., J. Baek, D. Carter, B. Persaud, C. Lyon, K. Eccles, F. Gross, and N. Lefler. *Safety Evaluation of Improved Curve Delineation* (FHWA-HRT-09-045). FHWA, Washington, DC, 2009.

Source: CMF Clearinghouse.

Steven Buckley, KDOT

The Kansas Department of Transportation (KDOT) applied a high-friction surface treatment, shown here, to this horizontal curve in Kansas. KDOT selected this site based on crash history, and the treatment was identified after a careful investigation of the contributing factors. A quality CMF does not currently exist for installing high-friction surface treatments, but this site will be included in a before-and-after evaluation as part of FHWA's "Evaluations of Low-Cost Safety Improvements Pooled Fund Study."

geometry, segment or intersection traffic control, traffic volume, and originating State to help them determine the best CMF to use."

Crash modification functions (CMFunctions) can help calculate point estimates of a CMF over a range of values for a given variable. For example, a CMF may change as traffic volume increases or decreases. In this case, a CMFunction would estimate the effectiveness of the countermeasure using the traffic volumes associated with the site, thereby resulting in a more applicable CMF. As the state of the knowledge advances, CMFunctions will replace CMFs because a single point estimate may not accurately describe the safety effects of a given countermeasure.

Quality. Often a search for applicable CMFs generates multiple CMFs for the same countermeasure. To help make a selection, an engineer will examine the quality of each CMF. According to Craig Lyon, a principal with Persaud and Lyon, Inc. and an international expert on developing CMFs, "not all CMFs are created equal." In other words, the quality of a CMF can vary greatly depending on several factors associated with the process of developing the CMF. The primary factors that determine the quality of a CMF are the study design, sample size, standard error, potential bias, and data source.

Both the HSM and the CMF Clearinghouse provide some indication of the quality of each CMF. The CMF Clearinghouse provides a star rating for each based on a scale of 1 to 5, where 5 indicates the highest quality. The most reliable CMFs in the HSM are indicated with a bold font.

In a case where two or more applicable CMFs for the same countermeasure have the same star rating but different CMF values, the engineer would use other details to determine whether one is more applicable to the situation in question. For example, an engineer in Virginia is considering the use of high-friction surface treatments to address wet-weather crashes on a horizontal curve. The engineer identifies two CMFs with an identical star rating, but one was developed based on data from Kansas and the other was developed based on data from North Carolina. The more appropriate selection might be the CMF from North Carolina because the climate, topography, and other characteristics are more similar to Virginia than those in Kansas.

Applying CMFs

Just as the application of an appropriate CMF can influence the decision to implement a particular project, the misapplication of a CMF can lead to misinformed decisions. Three main factors need to be considered when applying CMFs: (1) how to estimate the number of expected crashes without treatment (that is, to what number is the CMF applied), (2) how to apply CMFs by type and severity, and (3) how to apply multiple CMFs if multiple treatments are to be included in the same project.

Estimating expected crashes without treatment. Before applying CMFs, transportation engineers first need to estimate the expected safety performance without any treatment or countermeasures. The CMF then is applied to that number to estimate the expected crashes with treatment. The HSM presents several methods for estimating the expected safety performance of a roadway or intersection including the empirical Bayes method, which combines observed information from the site of interest with information from similar sites to estimate the expected crashes without treatment.

For example, consider a four-legged signalized intersection with 12 reported crashes in the past year. To estimate the expected crashes without treatment, an engineer will use the safety performance functions in the HSM to compute the predicted number of crashes. The predicted number of crashes (for this example, 7.7 crashes in a single year) is estimated based on the crash history at several nearby sites with similar characteristics (four-legged signalized intersections with similar geometry and traffic volumes). The empirical Bayes method then combines the observed (12) and predicted (7.7) crashes using a weighted average to estimate the expected crashes without treatment. Assuming a weight of 0.75, which favors the observed crashes, the expected number of crashes is: 0.75(12) + 0.25(7.7) = 10.9. If the engineer simply had used the observed crashes as an estimate of the expected crashes without treatment, he or she might have overestimated the potential effectiveness of a treatment.

Applying CMFs by type and severity. CMFs may apply to total crashes or to target crash types and severities. In many circumstances, estimating the change in crashes by type and severity is useful; however, transportation engineers only can use this approach when CMFs exist for the specific crash types and severities in question. The crash type associated with a CMF defines the crashes for which the related countermeasure is targeted. For example, a CMF for shoulder rumble strips may be applicable to run-off-road crashes. Crash severity is defined by the most severe outcome of the crash. For example, a CMF might apply to crashes resulting in fatalities, injuries, or property damage only.

Applying a CMF for a specific crash type or severity to other crash types and severities may lead to skewed estimates because a countermeasure may reduce certain crash types and severities but increase other crash types and severities. For example, roundabouts are expected to reduce fatal and injury crashes because they eliminate crossing-path collisions; however, there is the potential for an increase in property-damage-only crashes (such as rear-end and sideswipe crashes), particularly when drivers are unfamiliar with driving through a roundabout.

In the example provided earlier, an engineer was trying to estimate the potential safety effects of installing chevrons along a horizontal curve on a rural, two-lane road. If the engineer is interested in both the potential change in total crashes and the impact on crash type and severity, he or she will apply a CMF for total crashes and then also apply CMFs for the targeted crash types (head-on, run-off-road, and sideswipe) and severities (fatal, serious injury, and minor injury) separately. In each case, with the respective CMF, the engineer will use the general equation for estimating the number of crashes after treatment: Expected Crashes After Treatment = CMF x Expected Crashes Without Treatment.

Applying multiple CMFs. CMFs are available for many countermeasures, but most are related to only a single countermeasure. In real-world scenarios, transportation agencies commonly install more than one countermeasure. Engineers then must ask, "What is the safety effect of the combined treatments?" John Milton, chair of the Highway Safety Performance Committee of the Transportation Research Board (TRB) and director of risk management for the Washington State Department of Transportation, says, "At present, the answer is not so clear. However, research is underway to determine the best solution for calculating the safety effects of a combination of countermeasures."

Currently, the common practice is to assume that CMFs are multiplicative. In other words, each successive countermeasure will achieve an additional benefit when implemented in combination with other countermeasures. This is the current method presented in the HSM and in the CMF Clearinghouse. However, transportation agencies also are using other methods. Based on a recent survey of State departments of transportation conducted under National Cooperative Highway Research Program Project 17-25, "Crash Reduction Factors for Traffic Engineering and ITS Improvements," other methods include applying the CMF for the single countermeasure expected to achieve the greatest reduction, applying CMFs separately

CMF Application Training

The National Highway Institute offers two courses related to the development and application of CMFs and crash reduction factors (CRFs). Note that CMFs and CRFs are directly related: CRF = $100 \times (1 - \text{CMF})$. Reference to countermeasure effectiveness is now expressed as CMFs to be consistent with the *Highway Safety Manual*, and these courses will be updated to reflect the current terminology.

Application of Crash Reduction Factors (FHWA-NHI-380093). This course focuses on the application of CRFs to select countermeasures. The course covers the project development cycle (starting from network screening and site selection for safety review), diagnostics of safety concerns, cost-benefit evaluation, and countermeasure selection.

Science of Crash Reduction Factors (FHWA-NHI-380094). This course provides participants with the knowledge and skills needed to critically assess the quality of CRFs. The course covers concepts underlying the measurement of safety and the development of CRFs; statistical and methodological issues that affect the development of quality CRFs; and the general and methodological issues and statistical thresholds used to recognize quality CRFs.

For more information, visit www.nhi.fhwa.dot.gov.

Frank Gross, VHB

Engineers can use the empirical Bayes method to estimate expected crashes without treatment at sites such as this four-legged signalized intersection. Then, they can use CMFs to determine the expected safety and cost benefits of applying various treatments.

VHB/Lane Construction Corporation/VDOT

Although converting a four-legged signalized intersection to a roundabout, such as this one in Virginia, may reduce fatal and injury crashes, this treatment could increase property-damage-only crashes.

by crash type and summing them to get a project-level effect, and applying engineering judgment based on a review of crash patterns.

Assuming CMFs are multiplicative means assuming that the full benefit of each countermeasure is expected. However, this is unlikely when two countermeasures address the same crash types. For example, assuming the CMF for shoulder widening is 0.89 and the CMF for installing shoulder rumble strips is 0.85, the combined effect using the multiplicative rule is: 0.89 x 0.85 = 0.76. While shoulder widening is likely to reach its full safety benefit and rumble strips will add an additional benefit, it is not likely that the rumble strips will achieve the full expected reduction beyond the shoulder widening because they address similar crash types.

Regardless of the method employed, engineering judgment is required when combining multiple CMFs. If multiple countermeasures target the same crash type, engineers may consider applying only the most effective CMF, or use the multiplicative method for combining CMFs and reduce the CMFs for additional treatments by a percentage. The HSM presents a method for combining multiple CMFs that assumes they are multiplicative and that the user may estimate the combined effect of multiple treatments as the product of the respective CMFs.

"Regardless of the method an agency chooses to handle the application of multiple CMFs, it is important to apply the method consistently throughout the agency to ensure a fair comparison of projects," says TRB's Milton.

Summary

To help prevent misapplication of CMFs, which can lead to over- or underestimating potential benefits and subsequently making misinformed decisions, each agency needs to apply CMFs consistently for its projects.

Identifying and selecting applicable CMFs is the first step toward achieving consistency. Applicable CMFs are those that closely match the situation at hand. Factors that influence the applicability and selection of a CMF include the treatment type, roadway type, area type, segment or intersection geometry, segment or intersection traffic control, traffic volume, and originating State. If multiple applicable CMFs are available for a given treatment, the quality of a CMF is another factor engineers can consider to differentiate the results.

Applying CMFs also requires engineers to consider multiple factors for consistency. The three main factors are estimating expected crashes, applying CMFs by type and severity, and applying multiple CMFs. The key to applying CMFs is to apply them only to situations for which they were developed.

Example of Applying CMFs by Type and Severity

Countermeasure	Crash Type	Crash Severity	Expected Crashes Without Treatment	CMF	Expected Crashes With Treatment
1. Install chevrons	Nonintersection	All	4.5 crashes/year	0.96	4.5 x 0.96 = 4.32 crashes/year
2. Install chevrons	Nonintersection, Head-on, Run-off-road, Sideswipe	All	3.9 crashes/year	0.94	3.9 x 0.94 = 3.67 crashes/year
3. Install chevrons	Nonintersection	Fatal, Serious injury, Minor injury	2.1 crashes/year	0.84	2.1 x 0.84 = 1.76 crashes/year

CMFs are multiplied by the expected crashes without treatment to determine the expected crashes after treatment. The first example in the table above is for total crashes (all nonintersection, all crash severities), while the second and third examples are for target crash types (nonintersection, head-on, run-off-road, sideswipe) and severities (fatal, serious injury, minor injury), respectively. In these examples, the expected numbers of crashes without treatment (4.5 crashes/year, 3.9 crashes/year, and 2.1 crashes/year) are estimated from the 5-year crash history of the site, not by using the empirical Bayes method as presented in the HSM.

Future Research

While the HSM, CMF Clearinghouse, and other related resources provide nearly 3,000 CMFs for various safety strategies, several knowledge gaps and opportunities still exist. In fact, the American Association of State Highway and Transportation Officials' Subcommittee on Safety Management task force overseeing the HSM has identified the development of additional CMFs as a high-priority research need for the second edition of the HSM. There are several planned and ongoing efforts to develop CMFs, including FHWA pooled-fund studies, National Cooperative Highway Research Program projects, and research at the Turner-Fairbank Highway Research Center. The CMF Clearinghouse also provides a link for users to submit current CMF needs, which FHWA uses to guide future CMF research projects.

Moving forward with the development of new CMFs, researchers are focusing on producing the most reliable CMFs using appropriate methods. In the meantime, transportation engineers must weigh the strengths and weaknesses of the various methods and existing CMFs developed from those methods. In December 2010, FHWA published *A Guide to Developing Quality Crash Modification Factors* (FHWA-SA-10-032) to help highway safety analysts identify appropriate methods for developing CMFs. The guide provides an overview of each method and the data required to employ a given method. A safety analyst can use the guide to identify data requirements for various methods and select the most appropriate method based on the data available to them. The guide also outlines the strengths and weaknesses of various methods, which practitioners may use to determine the relative quality of CMFs.

Future research also will focus on developing guidance for applying multiple CMFs. The primary issue is that current methods for combining multiple CMFs may overestimate the potential safety effects, particularly if the treatments target similar crash types. Currently, FHWA is exploring existing methods for applying multiple CMFs to better define the issues and propose alternative methods.

"The key moving forward," says Monique Evans, director of the FHWA Office of Safety Research and Development, "is to ensure that future efforts target knowledge gaps and develop high-quality CMFs through rigorous analysis."

Assigning a Dollar Value to Predicted Changes in Crashes

CMFs enable transportation engineers to predict changes in crashes, which agencies then can quantify monetarily and use in benefit-cost analyses.

The change in expected crashes is calculated as the difference between the expected crashes with and without treatment. For example: 4.5 expected crashes per year without treatment − 4.32 expected crashes per year with treatment = reduction of 0.18 crash per year.

To complete the benefit-cost analysis, agencies then associate a monetary value with the annual reduction in total crashes and compare this to the annualized installation cost. The associated benefit, or the value of the crash reduction, is the average cost of a given crash type or severity multiplied by the change in expected crashes. According to FHWA, the average cost of a crash is $24,248. For example: 0.18 crash per year × $24,248 per crash = $4,365 per year.

This process can be completed for each potential treatment at a given location to determine the most cost-effective countermeasure. The process also could be completed for a single countermeasure across a series of sites to determine where the treatment will be most cost effective.

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Frank Gross, VHB

Combining a CMF for shoulder widening with one for shoulder rumble strips (such as those shown here) could increase the safety benefit.

A Living Outdoor Laboratory

by Benjamin B. McKeever, Deborah Curtis, and Kari Beasley

FHWA's new Cooperative Vehicle-Highway testbed will serve as a proving ground for wireless technologies that connect vehicles with infrastructure.

The growing demand for research on transportation operations is due, in large part, to the increasing congestion on U.S. roads and the need for improved highway services to support the growth of the Nation's economy. One aspect of this research is investigating the use of electronics, information processing, and communications technologies to improve the safety and efficiency of the existing surface transportation system.

To support this type of research, the Federal Highway Administration's (FHWA) Office of Operations Research and Development (R&D) recognized the need to enhance its onsite capabilities. This recognition led to development of the concept of a Transportation Operations Laboratory (TOL), commitment of resources, and awarding of a contract in early 2011 to design and build the laboratory and develop a companion research plan.

Located at the Turner-Fairbank Highway Research Center (TFHRC), the TOL consists of three components: (1) a Concepts and Analysis testbed (see "Modeling Transportation Systems: Past, Present, and Future," in the September/October 2011 issue of PUBLIC ROADS); (2) a Cooperative Vehicle-Highway testbed (CVHT); and (3) a Data Resources testbed (to be discussed in an upcoming article in this three-part series). The Concepts and Analysis testbed and the Data Resources facility will be housed inside TFHRC, while the CVHT will primarily be housed outdoors on surrounding TFHRC property.

The laboratory's three testbeds are intended to provide FHWA researchers, other onsite researchers, and external customers with reliable, comprehensive, and accessible resources to facilitate high-quality research in a robust and cost-effective manner. The testbeds will operate as an integrated whole so that research performed at each facility can take advantage of the synergistic capabilities of the entire TOL. For instance, the best concepts from the Concepts and Analysis testbed could be evaluated in the field at the CVHT, and data produced and managed by the CVHT could be archived in the Data Resources testbed for additional research.

(Above) The TFHRC intelligent intersection, shown here, was the predecessor of the Cooperative Vehicle-Highway testbed and remains its key facility.

FHWA launched the TOL's initial operating capability (including all three testbeds) on September 29, 2011. "Our new state-of-the-art research facility, combined with methods that integrate all three of our testbeds, has the potential to make the TOL a unique venue for exploring innovative cooperative vehicle-highway concepts and hosting demonstrations of those concepts," says Joseph I. Peters, director of the FHWA Office of Operations R&D.

Vision for the CVHT

The Cooperative Vehicle-Highway testbed will serve as an outdoor proving ground for the testing and demonstration of advanced technologies and applications, such as vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) wireless communications that support a variety of safety, mobility, and environmental applications. One such application, for example, involves transmitting signal phase and timing (SPaT) data through V2I communications to provide invehicle warnings to drivers who are in danger of running red lights. This application and similar U.S. Department of Transportation (USDOT) efforts will benefit from the ability to conduct onsite testing at the CVHT outdoor laboratory.

"The need to conduct validations to support cooperative vehicle-highway projects, which have the potential to fundamentally change the way transportation systems are managed, is expected to grow," says Peters. "Meeting the need to conduct comprehensive research will require a facility that is equipped to conduct forward-thinking, cooperative vehicle-highway studies."

Background

The concept for an FHWA outdoor transportation operations laboratory began in 2003 with the installation of an intelligent intersection at TFHRC. Built through cooperation between FHWA and the Virginia Department of Transportation (VDOT), the intersection originally was used to test early Vehicle Infrastructure Integration (VII) concepts. Researchers field-tested a number of prototype VII applications at the intersection.

One application, for example, was a signal-violation warning system that alerted drivers when they were in danger of running a red light. The drivers were warned using special visual cues, such as a light-emitting diode (LED) sign with strobe flashers installed on the signal mast arm. Researchers also field-tested an LED sign that provides a visual warning to drivers indicating when it was unsafe to make a left turn due to oncoming traffic. The intelligent intersection has evolved into what is now the main facility of the CVHT.

Key Current Research at the CVHT

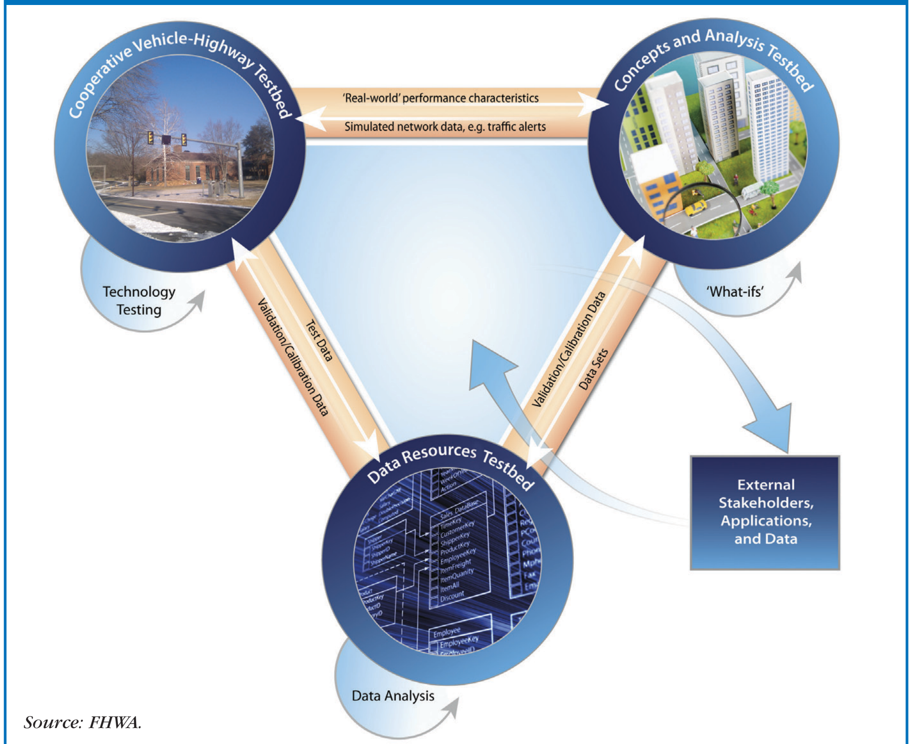
TFHRC already has begun using existing onsite capabilities to support the development of cooperative vehicle-highway systems. Most of the ongoing research is assisting the Intelligent Transportation Systems (ITS) Joint Program Office's connected vehicle program, which has a relatively short-term focus. In the future, the CVHT will test more far-reaching concepts.

One of the current projects involves developing a SPaT prototype, which will define a common interface between mobile devices and traffic signal controllers. By using technologies defined in current standards (SAE J2735 for the mobile devices and NTCIP 1202 for traffic signal controllers), the interface will be open and nonproprietary. This feature will facilitate revisions to the interface whenever standards change and evolve. Being nonproprietary, the interface also will enable any brand of traffic signal controller to broadcast critical information about the state of the phase or movement (red, amber, or green). Also, the interface will show the time remaining in that signal phase or movement, if that value is known.

Applications will be able to use this information to warn drivers who may be about to violate red lights or to regulate the speed of vehicles to maximize fuel efficiency. The interface is a two-way link that also will enable the signal controller to receive "requests for service" such as signal preemption from transit vehicles or priority calls by emergency vehicles. Researchers at the CVHT will test the first two prototype controllers to use this new interface in late 2011 and early 2012.

Ground-truth testing of positioning systems on Here-I-Am safety message broadcasting devices and other aftermarket equipment is another key foundational CVHT research activity. In January 2011, CVHT researchers conducted tests using onboard equipment on the CVHT's test vehicle. The research involved roadway grids that had been surveyed

The TOL Concept



Source: FHWA.

Here, researchers are ground-truth testing a global positioning system in the CVHT's test vehicle. The surveyed roadway grid shown here was used as a ground-truth point of reference for assessing the positioning accuracy of various devices installed in the vehicle.

using high-accuracy survey methods and a high-speed video camera capable of capturing 5,000 frames per second and linked to a global positioning system (GPS) time reference.

Using the CVHT vehicle's onboard equipment that referenced the same GPS time, the researchers were able to quantify exactly where the vehicle was located at an exact point in time. They also were able to capture where the vehicle believed it was at that point. By comparing two locations at a common point in time for multiple iterations and at varying speeds, the researchers could quantify any error associated with the vehicle's positioning device. By knowing this value, they were able to account for each device's systematic error observed in the positioning data.

They repeated the same test methodology for the Here-I-Am devices that are being developed for use in the Connected Vehicle Safety Pilot program, a major research initiative that will test how ordinary drivers in real-world driving conditions will respond to wireless safety messages. The safety pilot started in August 2011 and is scheduled to run through the first half of 2013.

A key aspect of the safety pilot is to establish a deployment test site for a real-world model for enabling wireless communications among vehicles and with roadside equipment for use in generating data for driver safety warning systems. USDOT issued a request for proposals (RFP) in March 2011 to seek a set of partners from both the public and private sectors as a test conductor for the model deployment site. The award was announced in August 2011. To support the model deployment, USDOT is purchasing roadside equipment and has selected four vendors through a competitive procurement. The FHWA researchers will install the equipment at the CVHT for trial-run experiments.

The units that pass initial testing requirements based on the vendors' self-certification and basic functionality tests at the CVHT will be field-deployed at the model deployment site. After that, FHWA will place the passing units on a qualified provider's list, and they will be eligible for purchase by the safety pilot's test conductor.

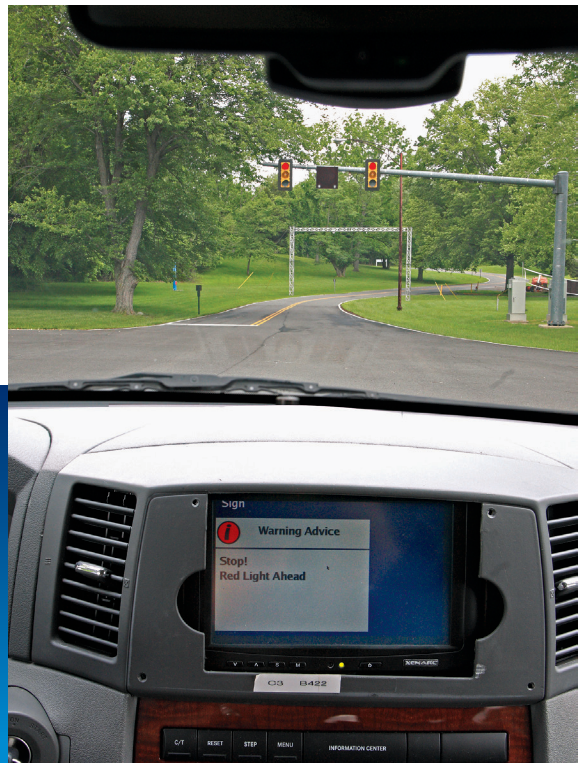
Recent CVHT Demonstration

On December 7, 2010, Secretary Ray LaHood and FHWA Administrator Victor Mendez participated in two showcase events at TFHRC: a tour of the center's laboratories and a town hall meeting with all TFHRC employees and invited onsite contractors. During the CVHT segment of the tour, LaHood and Mendez tried out the intelligent vehicle as it communicated wirelessly in real time with the intelligent intersection and a network operating center in Oak Ridge, TN. The center, which communicates to the intersection over the Internet, enables managers to send messages to the intelligent vehicle and receive them from it.

With invehicle messages broadcast from Oak Ridge through the CVHT intelligent intersection, the intelligent vehicle was able to demonstrate capabilities that could be deployed in the not-so-distant future. For example, "Use Caution, Icy Roads Ahead" appeared on the vehicle's computer screen along with an audible beep, demonstrating an advisory function while approaching an operational road weather information system. "Stop! Red Light Ahead" and an audible beep were the warnings presented as, hypothetically, the driver approached the intelligent intersection's red signal at a dangerous speed. These samples illustrate the types of messages that could be communicated to vehicles and drivers based on their specific positions, situations, or vehicle types.

At the end of the demonstration trip, the researchers showed LaHood and Mendez a map display of georeferenced waypoints left by the vehicle and the vast array of data yielded by clicking on any one of the waypoints. These data are examples of those that might be available to a future traffic management center or a research laboratory.

Building on the success of this demonstration, the CVHT researchers have continued to provide



An advisory message, "Stop! Red Light Ahead," appears on a display on the dashboard in the CVHT's intelligent vehicle as it approaches the intelligent intersection. The message is an example of a real-time safety alert that could be provided to motorists.

After a tour of the CVHT in December 2010, Secretary Ray LaHood (center, in red scarf) and Administrator Victor Mendez (on LaHood's right) are pictured with partners in the connected vehicle program: representatives from FHWA's Office of Operations, the Research and Innovative Technology Administration's (RITA) ITS Joint Program Office, and VDOT.

similar tours to a variety of groups. The researchers are looking forward to sharing the experience with others and making the laboratory available for cooperative research with partners in government, industry, and academia.

Looking Forward

One of the advantages to being a living outdoor laboratory is that the CVHT has ample opportunities to expand. To support ongoing and planned research, the CVHT researchers hope to add additional intersections equipped with roadside equipment and other enabling technology to expand the range of concepts and applications they can test. These intersections may be on existing TFHRC property or, through a potential partnership with VDOT, on actual roads in Virginia.

Other planned expansions include additional test vehicles equipped with the current onboard equipment and enhanced control features. The enhanced features could support advanced mobility applications, such as cooperative adaptive cruise control and speed harmonization.

In summary, enhancements to the CVHT may include the following:

- Additional locations outfitted with roadside equipment that provides V2I communications, including roadside equipment integrated with a traffic signal controller to transmit SPaT data.
- Additional vehicles equipped with onboard equipment that supports dedicated short-range communications with the roadside equipment and provides the invehicle infrastructure needed to support cooperative vehicle-highway applications.
- Network links to USDOT's other V2I technology testbed through the network operating center in Oak Ridge. There is an existing link and testbed in Michigan, and in the future there may be links to testbeds in California, Florida, and New York.
- Support equipment, such as high-speed cameras, vehicle sensors, and devices that can monitor and record transmissions of dedicated short-range communications.

These CVHT enhancements will position FHWA to perform cutting-edge research in support of numerous USDOT programs, including FHWA's Exploratory Advanced Research (EAR) Program, Dynamic Mobility Applications, V2I Communications for Safety, and Applications for the Environment: Real-Time Information Synthesis (AERIS). In addition, the enhancements will enable the CVHT to perform research on broader transportation operations research topics, such as adaptive traffic signal control systems.

"We look forward to developing and refining new transportation operations concepts at TFHRC and then testing and evaluating them with the help of the CVHT," says Peters. "In addition, where safe and appropriate, we can partner with State and local governments to investigate the roadworthiness of these new concepts. FHWA is committed to being a key contributor to cooperative vehicle-highway research and will lead the development and testing of related technologies and applications with the help of the new CVHT."

Benjamin B. McKeever, P.E., is the team leader of the Transportation Operations Applications Team in FHWA's Office of Operations R&D. Currently, he is leading development of the CVHT at TFHRC and supporting USDOT's Dynamic Mobility Applications and V2I Communications for Safety programs. McKeever holds an M.S. in civil engineering from The University of Texas and a B.S. in applied mathematics from the University of Virginia.

Deborah Curtis is a highway research engineer on the Transportation Operations Applications Team in FHWA's Office of Operations R&D. She has been working at TFHRC for 18 years and specializes in traffic signal systems and the connected vehicle research program. She has a B.S. in civil engineering from West Virginia University.

Kari Beasley is an industrial engineer at Science Applications International Corporation (SAIC), currently supporting the build-out and initial operations of the TOL. Beasley holds a B.S. in industrial and systems engineering from Virginia Tech.

The authors would like to acknowledge the contributions from SAIC, which provided content from its Concept of Operations document in support of TFHRC's TOL. The authors also would like to acknowledge the contributions from Joe Peters, director of FHWA's Office of Operations R&D, and Bob Ferlis, technical director of FHWA's Office of Operations R&D. These colleagues conceptualized the TOL and CVHT years ago.

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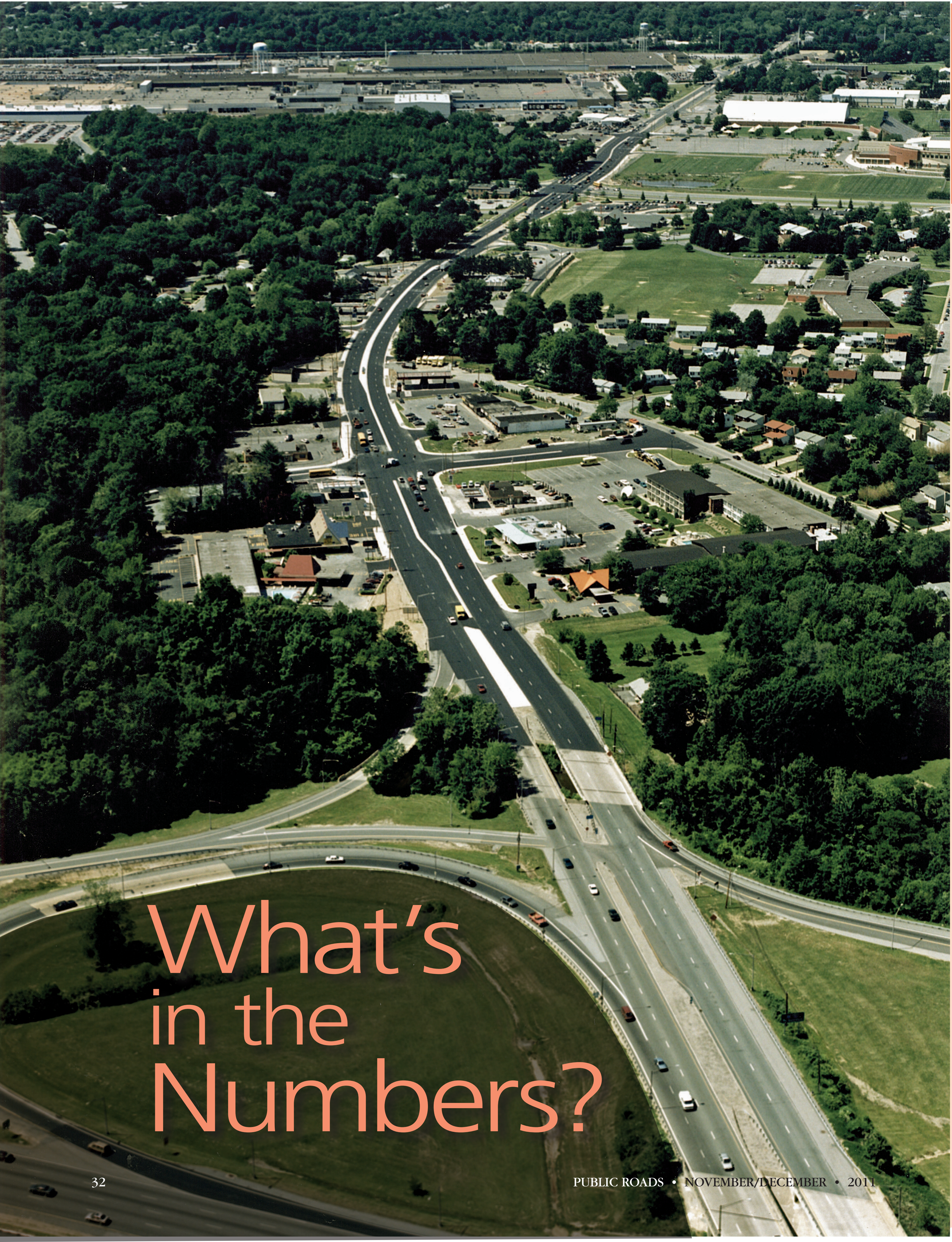
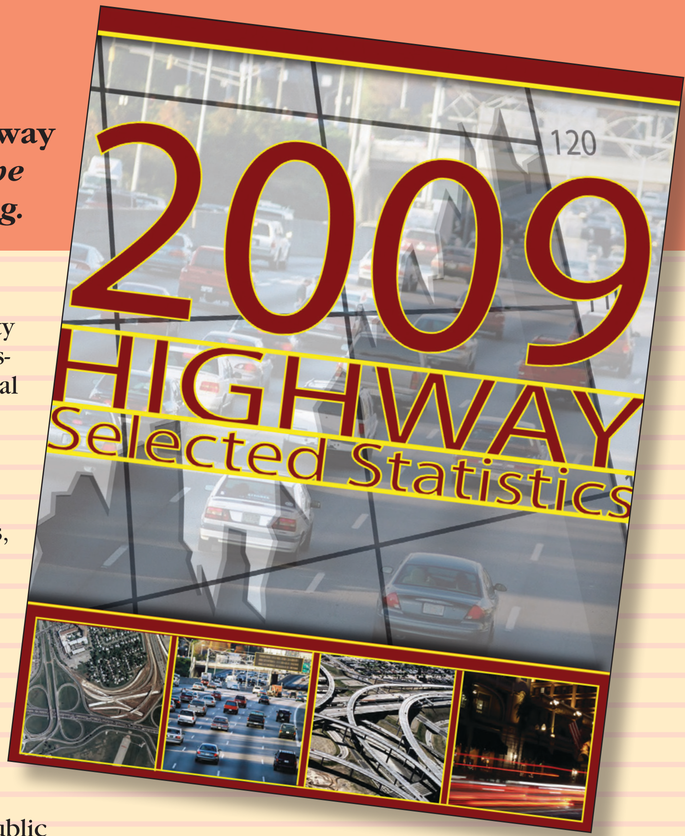


What's in the Numbers?

by Brian Lomax

Here's a snapshot of the history of FHWA's* Highway Statistics *and a sampling of the data that make the publication so highly respected and so fascinating.



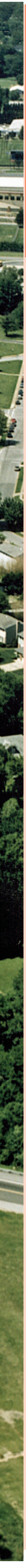
The data collected and published in FHWA's annual *Highway Statistics* are used by all levels of government and the public to assess the performance of the highway system.

Monday morning. As alarm clocks go off all across the country, Americans gather themselves to begin their workdays. Showered, dressed, and having finished their first cups of coffee, millions of Americans begin their daily commutes. Although some use public transportation, walk, or bicycle, many more will hit the roads in cars or trucks or on motorcycles only to find themselves…stuck in traffic.

Devising solutions to address the Nation's traffic problems and improve the transportation system's performance depends on the availability of high-quality data for decisionmaking. One critical data source is the Federal Highway Administration's (FHWA) annual *Highway Statistics*, which provides a comprehensive snapshot of the U.S. population's use of the roadway system.

"The goal of the *Highway Statistics* publication is to provide the most accurate statistical data," says FHWA Motor Fuel Analyst Marsha Reynolds. These data cover highway infrastructure, motor fuels, driver licensing, vehicle registration, State and local finance, and commercial and personal travel. Some of these data are crucial in apportioning funds to the States for various Federal highway programs.

Produced by the FHWA Office of Highway Policy Information, *Highway Statistics* compiles data used extensively by Federal, State, and local governments, institutions of higher learning, industry, consultants, professional organizations, and the public for a host of purposes. Policymakers, researchers, and academics have used the data to assess the performance and quality of the Nation's highway system and to identify potential problems and solutions.



(Left) FHWA's *Highway Statistics* publication compiles a variety of data on the Nation's roads, including vehicle miles traveled, driver demographics, and the performance of existing infrastructure like this suburban highway.

The history of the *Highway Statistics* publication, followed by a selection of its key statistics and figures, demonstrates the diversity of data that FHWA publishes in each issue of *Highway Statistics*.

Early History of *Highway Statistics*

Highway Statistics dates back to 1945, when FHWA's predecessor, the Public Roads Administration, released the publication's first issue. According to the preface of the inaugural issue, *Highway Statistics* would compile "statistical and analytical tables of general interest on the subjects of motor fuel consumption, motor vehicle registration, State highway user taxes, financing of State highways, and highway mileage."

The preface to the following year's publication acknowledged that "the favorable public reception of *Highway Statistics 1945* indicates that the issuance of the tables in assembled, permanent form makes the data much more convenient and serviceable to…users."

In 1965, the U.S. Congress mandated that FHWA report biennially on the conditions, performance, and future investments needed by the Nation's street and highway systems. At that time, statistical data were fragmented, archaic, and incomplete, necessitating the assembly of large staffs to meet the objectives and data reporting requirements that Congress had outlined. These staffs made use of regularly reported data as well as ad hoc reports specific to each biennial reporting cycle.

Out of this manpower-intensive effort, a more streamlined approach emerged in 1978—a continuous, sample-based monitoring program that requires annual data reporting instead of relying on special studies every 2 years. FHWA dubbed the new approach the Highway Performance Monitoring System (HPMS). The new system featured an integrated database that contained basic information on the entire public road system and was capable of estimating current and future needs for program development and legislative initiatives. The HPMS contained State-specific data that met the needs of the *Highway Statistics* publication, as well as those of Federal-aid apportionment formulas and other purposes in the transportation community.

The content of *Highway Statistics* has evolved with new demands on FHWA for information and new ways to meet those demands. The development of the HPMS was followed in 1979 by the issuance of *A Guide to Reporting Highway Statistics.* The guide consolidated 16 separate State reporting forms into one volume. It also included instructions for collecting highway-related data on fuel consumption, vehicle registration, driver licensing, and the sources of funding for State and local government highway programs. Further, the guide served as a consolidated reference and promoted a unified reporting concept with an understanding of interrelationships among different reporting areas.

Highway Statistics evolved to turn HPMS tables into useful forms for the public and to take advantages of new data sources such as surveys and technology-based data. The most important, long-term survey conducted by FHWA is the National Household Travel Survey, started in the 1960s as the Nationwide Personal Transportation Survey. This survey is designed to measure the reasons why people travel and the consequences of that travel. Data collection technology is improving the efficiency and accuracy of surveys and has revolutionized FHWA's approaches to measuring traffic and infrastructure.

Technological Evolution

Significant technological advances in the 1980s and 1990s led to development of more sophisticated data collection equipment. For example, the collection of traffic data shifted from a manual observation activity to the use of pneumatic rubber hoses placed on the roadway for vehicle detection. This approach was followed by the use of magnetic loops embedded in the pavement. Corresponding advances took place in retrieving data, as traffic managers now could query remote sites in real time from a central location, which negated the need to visit local sites to gather data.

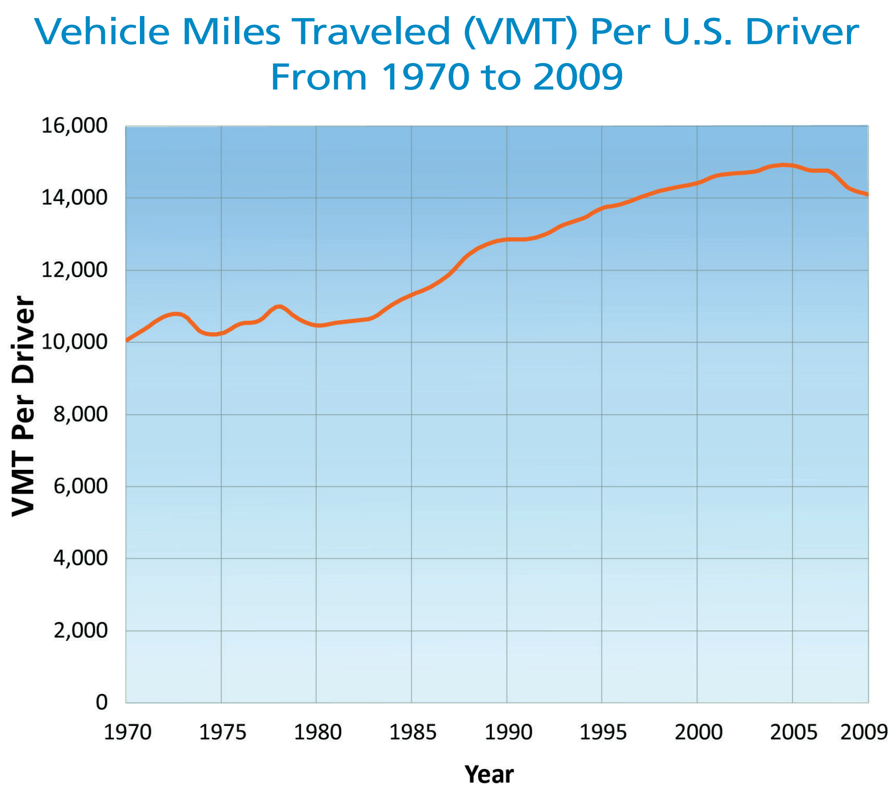
Also, the use of new technology, such as video logging, global positioning systems, geographic information systems, and electronic devices to measure pavement roughness, has streamlined roadway inventorying.

Today, compiling and analyzing data to publish *Highway Statistics* is one of the most important tasks performed by the Office of Highway Policy Information. FHWA uses these data to assess highway system performance under its strategic planning and performance reporting process developed in accordance with requirements of the Government Performance and Results Act of 1993, a series of laws designed to improve government project management. The act requires agencies to engage in

Key Data Collected in *Highway Statistics*

- Apportionments, Obligations, and Expenditures
- Bridges
- Conditions and Safety
- Debt Obligations for Highways
- Highway Infrastructure
- Highway Travel
- International and Metric
- Motor Fuel
- Performance Indicators
- Revenue
- Travelers (or System Users)
- Vehicles

In 2008 and 2009, motorists traveled a total of 6 trillion miles on U.S. highways, including this section of I–78 near the Berks/Lebanon County border in Pennsylvania.



Source: FHWA.

project management tasks such as setting goals, measuring results, and reporting their progress.

"Retaining a historical context as we approach present policy is crucial to effective policy formation," says independent transportation consultant Alan Pisarski. "For much of my work, *Highway Statistics* going back to 1945 provides the fundamental source of historical trends in American travel behavior. *Highway Statistics* demonstrates to all of us how valuable that historical context can be."

Adds FHWA Office of Highway Policy Information Director David Winter, "the longevity of Highway Statistics is remarkable. There aren't that many reports that have been produced every year since 1945!"

Sample of the Data: VMTs

Highways are the transportation backbone of the country, providing a conduit along which people and goods move from coast to coast and everywhere in between. According to *Highway Statistics 2009* (the latest year for which data were available at press time), Americans logged nearly 3 trillion vehicle miles traveled (VMT) that year, and it was essentially the same in 2008. Of that amount, 717 billion VMT (24 percent) of those miles were traveled on interstates, and two-thirds of all VMT were on urban roads.

"The VM-1, VM-2, and VM-3 tables in *Highway Statistics* are some of our most widely used tables," says Winter. "They combine highway mileage, travel, motor fuel, and registered vehicle data in a way that tells a story."

Table VM-1 is a summary of estimated travel by vehicle type and system. FHWA derives the total travel values from the highway functional system data contained in table VM-2, while pulling the vehicle type breakdowns from HPMS summary data. Simply put, the VM-1 table presents a picture of what the Nation's vehicles are doing on the interstate system. Economists, environmentalists, the Federal Government, and other stakeholders can use the table to provide an accurate assessment of the driving habits of motorists traveling in trucks, cars, and motorcycles.

"VMT has increased continuously since 1980 but declined from 2008 to mid-2009, reflecting economic conditions, "says Brad Gudzinas, a transportation specialist in the FHWA Office of Highway Policy Information. "Since early 2010, VMT resumed increasing until March of this year [2011]."

But despite a decline from 2007 to 2008, light-duty truck VMT (which includes travel in passenger and small commercial vehicles) showed a rebound in 2009. Light-duty truck VMT increased 0.8 percent to 2.7 trillion in 2009. Truck VMT declined for both single-unit and combination trucks in 2009. Light trucks, used primarily for personal transportation, track with automobile VMT. VMT for single-unit trucks, which includes commercial vehicles and some recreational vehicles, declined 5 percent to 121 billion in 2009. VMT for combination trucks, which includes tractor trailers and other large commercial vehicles, declined 9 percent to 168 billion in 2009. VMT of single-unit and combination trucks, which are mostly commercial vehicles, are greatly affected by the business cycle; in the current situation, commercial truck VMT is down significantly.

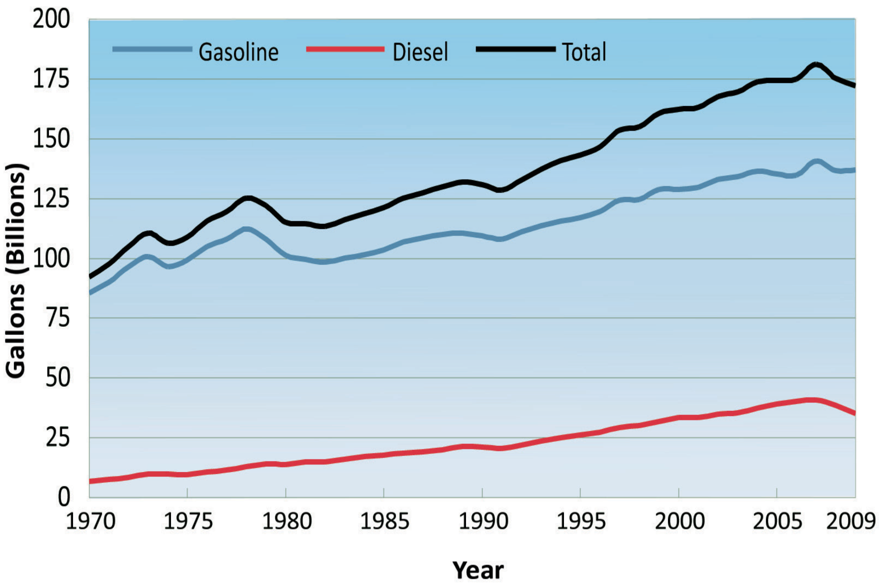
Data on Personal Vehicle Types

As the U.S. population grows and more cars take to the road, FHWA relies on its National Household Travel Survey, some results of which are reported in *Highway Statistics*, to learn more about the personal traveling behaviors of the American public. The 2009 survey, which does not include information about freight movement and truck ownership, asked respondents about the make, model, and year of private vehicles in their households.

The average age of private vehicles has continued to increase. In 2009, the average vehicle age was 9.4 years. In 1990, the average age of vehicles was 7.7 years, and in 2001, 8.9 years. In 2009, only 6 percent of vehicles were 1 model year old or newer.

The 2009 National Household Travel Survey also asked respondents whether any household vehicles were hybrids or alternative fuel vehicles, which includes those powered by ethanol, biodiesel, natural gas, propane, and hydrogen. Respondents indicated that 5 percent of household vehicles were either hybrid or powered by an alternative fuel.

U.S. Fuel Consumption From 1970 to 2009



Note: "Diesel" is actually special fuels.

Source: FHWA.

Demographics of Noncommercial Drivers

Obtaining a driver's license marks a rite of passage for adolescents, while many older Americans view retaining one as a sign of continuing independence. "Our senior citizen drivers value their independence and mobility," says Gudzinas. "Many continue to work or volunteer well beyond what is thought of as retirement age. They appreciate that having a vehicle available helps them stay active."

In 2009, 87 percent of the driving-age population (age 16 and over) had a license—a total of 210 million licensed drivers. In 1960, just a few years after all States required driver licensing, there were 487 drivers for every 1,000 residents. As of 2009, that number had increased to 683 drivers for every 1,000 residents.

Highway Statistics also reveals insights on changes in the gender balance of the driving public. In 1970, 112 million drivers held licenses, and there were 1.3 male drivers for every female driver. However, by 2009, the number of licensed female drivers exceeded the number of licensed male drivers by 1 percent.

The number of licensed drivers per 1,000 residents differs significantly from State to State, ranging from 580 licensed drivers per 1,000 State residents in New York to 864 licensed drivers per 1,000 residents in Indiana. Alabama, Connecticut, Delaware, Maine, New Hampshire, and Vermont have among the highest numbers of licensed drivers per capita. States in the more rural northern Midwest and western mountain areas, such as Montana, Nebraska, Oregon, Washington, and Wyoming, also have higher numbers of licensed drivers per capita.

Those Americans between the ages of 45 and 54 had the greatest numbers of licensed drivers in 2009. Mirroring the population in general, 80 percent of licensed drivers are between the ages of 20 and 64. Five percent of licensed drivers are under the age of 20, while 16 percent are age 65 or older.

Data on Fuel Consumption

With more people driving—and driving for more years of their lives—fuel availability and options are taking on a greater role in the national discourse. As the cost of oil per barrel rises, so does the price for a gallon of gas. Although the Federal and State governments and industry researchers are devoting resources to developing alternative fuels and technologies to power motor vehicles, at this point gasoline, diesel, natural gas, and other petroleum-related products remain the primary sources of fuel for motor vehicles. In fact, U.S. vehicles consumed a total of more than 172 billion gallons of fuel in 2009. Of this total, 137 billion gallons (80 percent) are gasoline, and the remaining 35 billion gallons (20 percent) are special fuels such as diesel.

From 2008 to 2009, vehicle consumption of gasoline increased 0.3 billion gallons (0.2 percent), while special fuels consumption decreased 3.3 billion gallons (9 percent). Overall, vehicle fuel consumption decreased 1.7 percent from 2008 to 2009. Since 1970, total highway fuel consumption has increased 86 percent from 92 million gallons, an annual growth rate of 1.6 percent. Special fuels consumption is five times greater than in 1970, an annual growth rate of 4.3 percent.

At the State level, the five with the highest total fuel consumption—California, Florida, New York, Pennsylvania, and Texas—consume 56 billion gallons of fuel, which is 33 percent of total vehicle fuel consumption nationwide. The five States consuming the most diesel fuel—California, Illinois, New York, Pennsylvania, and Texas—consume 11 billion gallons, which is 30 percent of all diesel vehicle fuel consumption nationwide. These States lead in fuel consumption due to their high populations, as they are all within the top seven in terms of State population, with California and Texas being among the largest States in the country as well.

Making Statistics Reliable And Accessible

High-quality data on the Nation's highways can reveal much about both the economy and where the country stands in terms of mobility, fuel use, infrastructure condition, safety, and other critical issues. Other publications produced by FHWA have some of the same content as *Highway Statistics* but with different approaches and purposes. *Our Nation's Highways*, for example, is a graphical presentation for audiences using the *Highway Statistics* data in a more dynamic way. The *Travel Volume Trends* is a monthly publication and is presented in table format in *Highway Statistics* at the end of

After more than 65 years in publication, *Highway Statistics* continues to provide the transportation industry and the public with data to guide policy decisions for roads like this one outside Reidsville, NC.

each year. The National Bridge Inventory is a table included in *Highway Statistics* in recent years. Also, FHWA's safety data program uses data on miles driven and age of drivers from *Highway Statistics* for transportation policy decisionmaking.

Throughout its history, *Highway Statistics* has evolved with the times as FHWA has strived to increase the publication's information value, improve the quality of its presentation, and expand its accessibility to the public. As time and technology have changed the way FHWA's Office of Highway Policy Information conducts business, *Highway Statistics* has moved into the technological age. In an effort to cut costs while considering the economic impact, the manual itself, once a massive undertaking of tables, numbers, and words, has been downsized to a "selected" booklet, featuring 25 to 30 of the most viewed and requested tables. The remaining tables are available, free of charge, at FHWA's "Office of Highway Policy Information" Web site (www.fhwa.dot.gov/policyinformation/index.cfm). Other technological advances, such as the creation of the Microsoft® spreadsheet software, Excel®, have made data entry, calculations, and graphing more efficient and less time consuming. Now available online in multiple formats such as HTML and PDF, the data in *Highway Statistics* are easier than ever for users to access and analyze.

"*Highway Statistics* may be the ultimate example of the cooperative joint Federal-State transportation process," says Pisarski, "each element bringing its skills together to produce a better final product."

Brian Lomax is a journalist working in the FHWA Office of Policy. He graduated in 2010 from Salisbury University with a degree in communications, specializing in journalism and public relations.

For more information, visit www.fhwa.dot.gov/policyinformation/statistics.cfm or contact Brian Lomax at 202-493-0599 or brian.lomax@dot.gov.

Along the Road

Along the Road is the place to look for information about current and upcoming activities, developments, trends, and items of general interest to the highway community. This information comes from U.S. Department of Transportation (USDOT) sources unless otherwise indicated. Your suggestions and input are welcome. Let's meet along the road.

Policy and Legislation

FHWA and FEHRL Sign Memorandum Of Cooperation

The Forum of European National Highway Research Laboratories (FEHRL) recently signed a memorandum of cooperation with the Federal Highway Administration (FHWA) to establish a business protocol to optimize international collaboration on highway research. A registered international association based in Brussels, Belgium, FEHRL is engaged in road engineering research and other activities. The association provides a coordinated structure for the interests of more than 30 European national research and technical centers, and other associated institutes around the world.

Shown here, Federal Highway Administrator Victor Mendez (left) and Joris Al, president of FEHRL, prepare to sign a memorandum of cooperation to work collaboratively to enhance the quality of research products.

The memorandum sets forth a strategy to address transportation challenges that are common to both organizations by capitalizing on points of synergy and to facilitate knowledge sharing between member and associate highway research laboratories. A highlight of the business protocol is to establish a platform to pool funds from FHWA and FEHRL, leveraging funding as well as knowledge to improve the conduct of research and enable faster development and implementation of technology and innovation.

Each organization already has identified projects where its counterpart's research is further along. The organizations will select research topics based on FHWA's program plans and roadmaps and FEHRL's Strategic European Road Research Programme.

For more information, contact Debra Elston at 202-493-3181 or debra.elston@dot.gov.

Technical News

FHWA Helps Develop Product To Analyze Aggregates

An FHWA Technology Partnerships grant enabled Pine Instrument Company of Grove City, PA, to develop a tool to improve the analysis of aggregates used in paving. The Aggregate Image Measurement System (AIMS2) uses digital imaging technology to conduct accurate and rapid analyses of the characteristics of aggregates.

For use by aggregate suppliers, highway agencies, academic institutions, and pavement engineers, AIMS2 combines proprietary software with hardware that captures real-time digital images of paving material samples. The software analyzes aggregate characteristics that affect pavement quality, structural integrity, durability, skid resistance, and, consequently, road safety. Comparing digital images of samples to a reference database helps remove the subjectivity typically associated with aggregate classification, which can lead to inconsistencies in measurement, quality assurance, and mix design.

Growing use of innovative paving technologies has focused the highway industry's attention on the need for accurate aggregate characterization. As a result of industry trends and exposure that AIMS2 received during the Technology Partnerships evaluation, the device is developing a user base at highway agencies and among aggregate producers in the United States and abroad.

Through the Technology Partnerships Program, which funded projects to refine eight prototypes under real-world conditions, FHWA offered technical expertise and acted as a broker to help the private sector and State and local governments demonstrate and promote the technologies.

For more information, visit www.fhwa.dot.gov/hfl/partnerships/aims.cfm.

Pine Instrument Company

AIMS2, developed through an FHWA Technology Partnership grant, includes a computer and monitor, the AIMS software, and the image acquisition hardware, as shown here.

Public Information and Information Exchange

Winners of Connected Vehicle Technology Challenge Announced

USDOT's Research and Innovative Technology Administration recently announced six winners of a competition seeking ideas for using wireless technology to enable vehicles to communicate with each other. The winning ideas from the Connected Vehicle Technology Challenge may be incorporated into research on using technology to improve vehicle safety and transportation operations.

Entries had to use dedicated short range communications, a wireless technology similar to Wi-Fi. A USDOT panel selected five entries, while the sixth winning entry received the most votes from registrants on the competition Web site at http://connectedvehicle.challenge.gov. Winning entries featured the following innovations:

- A real-time crash awareness system to accelerate emergency response and assist with traffic management.
- A guidance system that helps drivers choose safer routes and avoid locations with frequent crashes.
- Enhancements to the accuracy and security of GPS by autocorrecting illegally jammed signals.
- An automated system for trading pollution credits among high- and low-emissions vehicles in which the level of pollution allowed is capped and credits are given to less-polluting vehicles.
- A system that enables improved location measurements to within 3.2 feet (1 meter).
- An intelligent transportation platform that can assist drivers with a range of tasks from choosing a route to reserving a parking space.

The Connected Vehicle Technology Challenge is based on the belief that innovative thinking and advanced technology are keys to improving safety and efficiency on roads and highways. The challenge aims to produce ideas that will help to propel the U.S. transportation system into the future.

Peer-to-Peer Program Assists With Road Safety Audits

FHWA has identified road safety audits (RSA) as one of nine proven safety countermeasures effective at reducing injuries and fatalities on the Nation's roadways. An RSA is a safety-focused field inspection of a particular roadway or intersection conducted by a multidisciplinary team of experts in road safety, traffic operations, and highway design. FHWA's Office of Safety has established a peer-to-peer (P2P) program to assist road owners with technical or procedural questions regarding RSAs.

The P2P program is available to public agencies at no charge. The program provides convenient access to experienced RSA professionals to help agencies understand the process and offers onsite assistance to ensure successful completion of the first RSA. Further, the program supplies guidance on RSA team composition, information that should be collected in advance of the RSA, and funding options available for performing RSAs.

In addition to this program, FHWA offers other P2P programs for agencies looking for assistance in areas such as roundabouts and local and rural road safety. To request peer assistance, call the P2P Help Line at 866–727–3492 or email safetyp2p@dot.gov.

For more information or to submit a request online, visit http://safety.fhwa.dot.gov/p2p.

Internet Watch

by Adella Santos

Web-Based Tools Help With Travel Data Analysis

Why do people travel? What modes of transportation do they use? How long are their trips? Where do they go? The answers to these questions and more are what the Federal Highway Administration's National Household Travel Survey (NHTS) seeks to collect and provide to the transportation community. The NHTS data enable transportation decisionmakers to assess initiatives, review programs and policies, study current mobility issues, and plan for the future.

The NHTS serves as an inventory of the Nation's daily travel. The 2009 NHTS dataset contains data for more than 150,000 households across the United States with information on household characteristics, vehicles, and daily trips. The 2009 survey marked 40 years of data collection, with previous surveys conducted in 1969, 1977, 1983, 1990, 1995, and 2001.

The NHTS Web site at http://nhts.ornl.gov provides readily available data to a wide range of individuals and organizations. Hosted by the Center for Transportation Analysis at the Oak Ridge National Laboratory, the site provides a full range of services, including access to disaggregate datasets in a variety of formats, publications, survey methods, materials and data documentation, news briefs, a user forum, and browser-based data analysis tools.

"The NHTS is the most important national survey for transportation planners," says Jana Lynott, senior strategic policy advisor for AARP, whose organization is using the survey to examine changes in the travel patterns of older adults. "The robust sample size and questionnaire enable researchers to answer an almost unlimited number of transportation policy questions."

Analyzing Data With NHTS's Online Tools

Online tools accessible from the home page of the NHTS Web site support data analysis for the three most recent surveys (1995, 2001, and 2009). From readymade tables of frequently requested data to customized data tabulations, the tools help a variety of users with differing data analysis experience meet their needs.

For the casual NHTS user, the Frequently Asked-for Tables feature provides more than 25 tables populated with data such as the number of vehicles by household income and the number of trips by mode and purpose. For users who require more specific data tables, NHTS Table Designer facilitates creation of customized tabulations of travel behavior and characteristics of households, household members, and vehicles. Advanced options enable users to customize response categories (such as income level) by collapsing responses and to subset the records of analysis (such as add-on State data). Table Designer users can save their table specifications. Users can view both Frequently Asked-for Tables and tabulations generated with the Table Designer in HTML format and export them to Microsoft® Excel®. To date,

NHTS has approximately 6,000 registered users who generate an average of 900 custom tables per month.

Another popular tool is the online Codebook Browser, which provides the list of dataset variables and their characteristics, including ways to sort, filter, and search. For example, a keyword search of "inc" will locate all variables related to household "income." Codebook information includes the data type, question number, data file membership, and variable values and meanings.

The Web site also features a transferability tool, which uses statistical methods to transfer NHTS data to small geographic areas such as Census Tracts and Transportation Analysis Zones. This tool helps transportation planners estimate regional or local travel, including vehicle trips and miles of travel, and person trips and miles of travel, by trip purposes.

Introducing the Data Extraction Tool

NHTS staff recently created a data extraction tool that provides an easier way to dig into the datasets and generate trend analysis statistics ready for export. This tool enables users to obtain data from the 1995, 2001, and 2009 surveys to examine total travel (person trips and miles traveled, and vehicle trips and miles traveled), and easily extract data from all three surveys.

To use the data extraction tool, which is accessible from the NHTS home page, the user chooses elements using selection criteria—essentially a menu of parameters—to generate a customized dataset. The user then can download the customized dataset in comma separated values format for additional analyses.

"FHWA strives to enhance its ability to transform numbers into information and knowledge and to democratize all complex data," says David Winter, director of the FHWA's Office of Highway Policy Information. "The NHTS online analysis tools offer a portal for not only the professional data analyst, but more important, for the general public to understand travel behavior in the United States."

Adella Santos is the NHTS program manager at FHWA.

Training Update

NATIONAL HIGHWAY INSTITUTE

by Lilly Pinto

Updated Course Can Help With Designing Safer Highways

In 2010, the Federal Highway Administration (FHWA) expanded the Crash Prediction Module of the Interactive Highway Safety Design Model (IHSDM), a suite of software tools that analyze the safety of design decisions on two-lane rural highways, multilane rural highways, and urban and suburban arterials. The update included implementing the American Association of State Highway and Transportation Officials' *Highway Safety Manual* Part C, which provides a predictive method for estimating the expected average crash frequency of a highway facility. The updates support an industry-wide push to evaluate the safety of highway designs quantitatively.

To reflect the changes to the IHSDM, the National Highway Institute (NHI) recently released an updated version of its IHSDM training course. The updated course, Using IHSDM (FHWA-NHI-380100), is based on an instructor-led course that was released in 2003. The course is offered in a blended format that includes both Web conferences and independent self-study portions, greatly expanding the accessibility of the training to more transportation professionals.

"As a result of the 2010 update, the Crash Prediction Module of IHSDM has become a faithful implementation tool for the *Highway Safety Manual*," says Clayton Chen, a highway research engineer on the Safety Management Team in FHWA's Office of Safety Research and Development. "IHSDM's critical role in advancing the state-of-the-practice in quantifying highway safety is why NHI's updated IHSDM blended training course is so important."

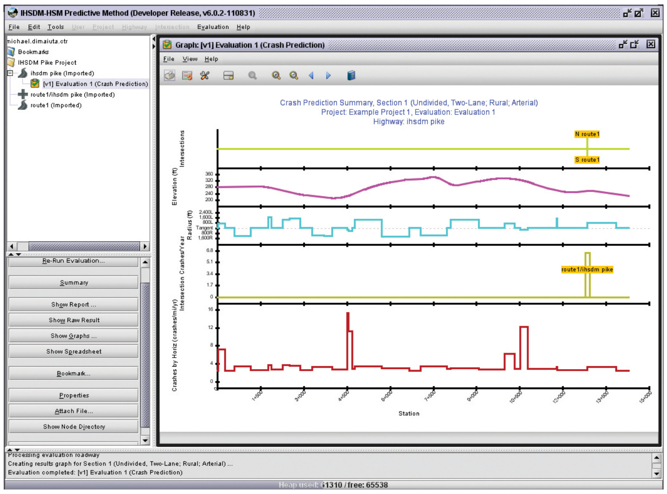
Increased Training Availability, Flexibility

Before the change in format, many transportation professionals who could benefit from the course were not being reached through the classroom-based delivery method. Among them were highway project planners, designers, and traffic and safety reviewers in State and local highway agencies and engineering consulting firms. "By and large there is not a large user community in any one location, making face-to-face training difficult to schedule, especially with many agencies' limitations on travel," says Thomas Elliott, NHI's training program manager for highway safety, business, and public administration and quality. "So, when FHWA updated the IHSDM, it was the perfect opportunity to update the delivery format as well as the course materials."

The course now is delivered through a series of self-paced activities (including Web-based trainings and evaluation activities) and virtual instructor-led sessions known as Web-conference trainings. This blended format eliminates the need for participants in remote locations to travel to a centralized location, saving travel costs and enabling a much larger segment of the target audience to benefit from the training. In addition, the new delivery method provides participants with greater flexibility because it eliminates travel time and enables them to complete the Web-based trainings as their schedules permit.

What's Covered in the IHSDM Course

NHI's updated course instructs participants on how to use and apply the IHSDM software, and it provides guidance on interpreting the output data. Developed primarily for highway design professionals and traffic and safety reviewers, the IHSDM software gives users the opportunity to make and justify their design decisions. The course is highly interactive; participants receive hands-on experience with the software by working through tutorial exercises to evaluate a case study and generate outputs. Participants also are encouraged to experiment with real project data.



This screen capture from the Crash Prediction Module of IHSDM shows crash prediction summary results for a sample highway. *Source: IHSDM.*

During the Web-conference trainings, the instructor presents lecture materials on IHSDM functionality and capabilities, including the six IHSDM Evaluation Modules (crash prediction, design consistency, policy review, traffic analysis, intersection review, and driver/vehicle). After each Web-conference training, participants complete self-paced activities with the IHSDM modules to evaluate various highway design alternatives. In the last Web-conference training, participants work in small groups to select a preferred alternative design for the highway that they have evaluated throughout the course. Each group then reports back to the entire class to explain and justify its selection.

"The IHSDM blended training is effective because participants actually use the system, not simply watch an instructor move through screens," says Elliott. "This enables the participant to explore, modify, change, and manipulate data, and see the effects. Results are in real time and in the same kind of outputs that participants will use on actual projects."

Lilly Pinto is a contractor for NHI.

Communication Product Updates

Compiled by Zachary Ellis of FHWA's Office of Corporate Research, Technology, and Innovation Management

Below are brief descriptions of communications products recently developed by the Federal Highway Administration's (FHWA) Office of Research, Development, and Technology. All of the reports are or will soon be available from the National Technical Information Service (NTIS). In some cases, limited copies of the communications products are available from FHWA's Research and Technology (R&T) Product Distribution Center (PDC).

When ordering from NTIS, include the NTIS publication number (PB number) and the publication title. You also may visit the NTIS Web site at www.ntis.gov to order publications online. Call NTIS for current prices. For customers outside the United States, Canada, and Mexico, the cost is usually double the listed price. Address requests to:

National Technical Information Service
5301 Shawnee Road
Alexandria, VA 22312
Telephone: 703–605–6000
Toll-free number: 1–888–584–8332
Web site: www.ntis.gov
Email: customerservice@ntis.gov

Requests for items available from the R&T Product Distribution Center should be addressed to:

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Szanca Solutions/FHWA PDC
13710 Dunnings Highway
Claysburg, PA 16625
Telephone: 814–239–1160
Fax: 814–239–2156
Email: report.center@dot.gov

For more information on R&T communications products available from FHWA, visit FHWA's Web site at www.fhwa.dot.gov, the FHWA Research Library at www.fhwa.dot.gov/research/library (or email fhwalibrary@dot.gov), or the National Transportation Library at ntl.bts.gov (or email library@dot.gov).

Performance Evaluation of One-Coat Systems On New Steel Bridges (TechBrief)
Publication No. FHWA-HRT-11-047

Current bridge coating practices typically involve multilayer coating consisting of a zinc-rich primer over an abrasive blast-cleaned surface and two additional coating layers on top of the primer. This three-coating approach offers improved protection against corrosion of steel bridges, but the overall cost is relatively higher than for its lead-based predecessors. This TechBrief presents details of an FHWA study that looks at the performance characteristics of several commercially available high-performance coating materials that can be applied to steel bridges as one-coat systems.

Researchers evaluated eight one-coat systems and two controls that performed well in the field and in prior FHWA studies. They also analyzed a three-coat system and a two-coat system using accelerated laboratory testing and outdoor exposure conditions. The researchers evaluated performance based on variations in color and gloss, changes in adhesion strength, changes in pencil scratch hardness, the development of surface defects, and rust creepage.

Several of the one-coat systems showed promising performance in accelerated laboratory testing and outdoor exposure conditions. Glass flake-reinforced polyester and high-build waterborne acrylic were among the top performing systems. The two-coat system developed many coating defects in accelerated laboratory testing and showed significant gloss reduction and rust creepage in outdoor exposure conditions, resulting in a low overall ranking. The three-coat system was the best performing system.

The document is available at www.fhwa.dot.gov/publications/research/infrastructure/bridge/11047/index.cfm. Printed copies are available from the PDC.

Investigating Advanced Traffic Signal Control: Examining the Effect of Traffic Probe Data on Traffic Signal Operations (Fact Sheet)
Publication No. FHWA-HRT-11-044

Poor traffic signal timing accounts for an estimated 10 percent of all traffic delay on major roadways alone, according to a study by the Oak Ridge National Laboratory. The goal of Advanced Traffic Signal Control Algorithms, a project under FHWA's Exploratory Advanced Research (EAR) Program, is to fundamentally rethink traffic signal operations based on the impending widespread availability of traffic probe data. This fact sheet includes information regarding changing signals, control concepts, efficient solutions, and research expectations.

The study looks at three control concepts: mobility, environment, and safety. The first, mobility, discusses strategies to avoid traffic saturation in the middle of a grid network. The aim is to use measurement samples to predict traffic, average travel times, and the proportion of stopped vehicles. The environmental concept examines fuel consumption and emissions results, and how signal phase and timing can be used to save fuel and lower emissions. The final concept, safety, looks at how to take full

advantage of connected-vehicle data to analyze intersection geometry and detect approaching and waiting vehicles that may come into conflict. In addition, intersection priority could be given to emergency vehicles, transit vehicles, or individual vehicles under low-traffic conditions, reducing delays and the need to stop.

Research for the Advanced Traffic Signal Control Algorithms project is focused on the concept of vehicle-to-infrastructure cooperation via the Intelligent Transportation Systems program, an effort that could provide real-time information on the movements of vehicles throughout the road network, lead to changes in how traffic is controlled, and address the problem of congestion along arterial routes.

The document is available at www.fhwa.dot.gov/advancedresearch/pubs/11044/index.cfm. Printed copies are available from the PDC.

Eyes on the Road: Developing a Dynamic Model of Driver Vision (Fact Sheet) Publication No. FHWA-HRT-11-033

Driving at night is substantially more dangerous than driving during the day—the fatality rate, based on vehicle miles traveled, is three to four times higher. Development of Methodologies to Evaluate Nighttime Safety Implications of Roadway Visual Scene Under Cognitive Task Loads, an EAR Program study, takes a novel approach to developing greater understanding of how drivers acquire visual information in order to determine how roadway features can improve or detract from the safety of driving at night. This fact sheet discusses building a dynamic model of driver vision, capturing data on looking and lighting, and identifying some likely activities moving forward.

For this study, researchers have been deploying new technology and developing a new framework within which the variables that affect nighttime driving visibility and driver behavior can be measured and analyzed more accurately. Drivers process data through two visual modes—focal and ambient—at the same time. One danger of nighttime driving is that while focal vision is confined to the narrow, short area lit by headlamps and any overhead lighting, ambient vision, which provides information about speed and direction, is relatively unimpaired. The driver's continued sense of competence in guiding the vehicle masks the danger of diminished focal vision. This study is exploring whether various roadway features and driving conditions affect these two ways of viewing the environment differently.

After the project data are analyzed, FHWA and the research team will convene an expert peer-review panel for a real-world demonstration and model review. On the basis of the expert review and additional data collected, the investigators will revise the driver visual model and formulate directions for continuing research.

The document is available at www.fhwa.dot.gov/advancedresearch/pubs/11033/index.cfm. Printed copies are available from the PDC.

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Paula Magoulas, Editor-in-Chief
September 28, 2011

Conferences/Special Events Calendar

Date	Conference	Sponsors	Location	Contact
January 22–25, 2012	NAPA 57th Annual Meeting	National Asphalt Pavement Association (NAPA)	Palm Desert, CA	Sandy Palacorolla 888-468-6499 sandy@hotmix.org www.hotmix.org
February 2–4, 2012	11th Annual New Partners for Smart Growth Conference	Hosted by Local Government Commission	San Diego, CA	Melissa Harper-Barton 916-448-1198, ext. 327 mbarton@lgc.org www.newpartners.org
February 12–16, 2012	ATSSA 42nd Annual Convention and Traffic Expo	American Traffic Safety Services Association (ATSSA)	Tampa, FL	Melanie McKee 540-368-1701 melanie.mckee@atssa.com www.atssa.com
March 4–7, 2012	ITE Technical Conference and Exhibit	Institute of Transportation Engineers (ITE)	Pasadena, CA	Sallie C. Dollins 202-785-0060, ext. 149 sdollins@ite.org www.ite.org
March 13–15, 2012	World of Asphalt Show and Conference (colocated with AGG1 Aggregates Forum & Expo)	Association of Equipment Manufacturers, NAPA, and National Stone, Sand & Gravel Association	Charlotte, NC	Show Management 800-867-6060 info@worldofasphalt.com www.worldofasphalt.com
March 18–22, 2012	ACI Spring 2012 Convention	American Concrete Institute® (ACI)	Dallas, TX	Event Services 248-848-3795 conventions@concrete.org www.concrete.org
March 29–31, 2012	Structures Congress	Structural Engineering Institute of the American Society of Civil Engineers	Chicago, IL	Debbie Smith dsmith@asce.org http://content.asce.org/conferences/structures2012/index.html
April 16–18, 2012	9th National Conference on Transportation Asset Management	Transportation Research Board	San Diego, CA	Matthew Miller 202-334-2608 mamiller@nas.edu Tom Palmerlee 202-334-2966 tpalmerlee@nas.edu www.trb.org/conferences/assetmanagement2012

Bridging the Education Gap

NHI's geotechnical courses help transportation engineers get that extra edge.

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Drilled Shafts	132014
Earth Retaining Structures	132036
Geosynthetics Engineering Workshop	132013
Highway Slope Maintenance and Slide Restoration	132081
Implementation of LRFD Geotechnical Design for Bridge Foundations	132083
LRFD for Highway Bridge Substructures and Earth Retaining Structures (4-Day)	130082B
LRFD Seismic Analysis and Design of Transportation Structures, Features, and Foundations	130094
Subsurface Investigations	132031

Of the more than 300 courses offered by the National Highway Institute (NHI), those focused on geotechnical engineering are among the most popular year after year. The courses are designed to provide engineers at every level with the training to advance their careers to the next stage.

Visit **www.nhi.fhwa.dot.gov** for complete course descriptions.

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