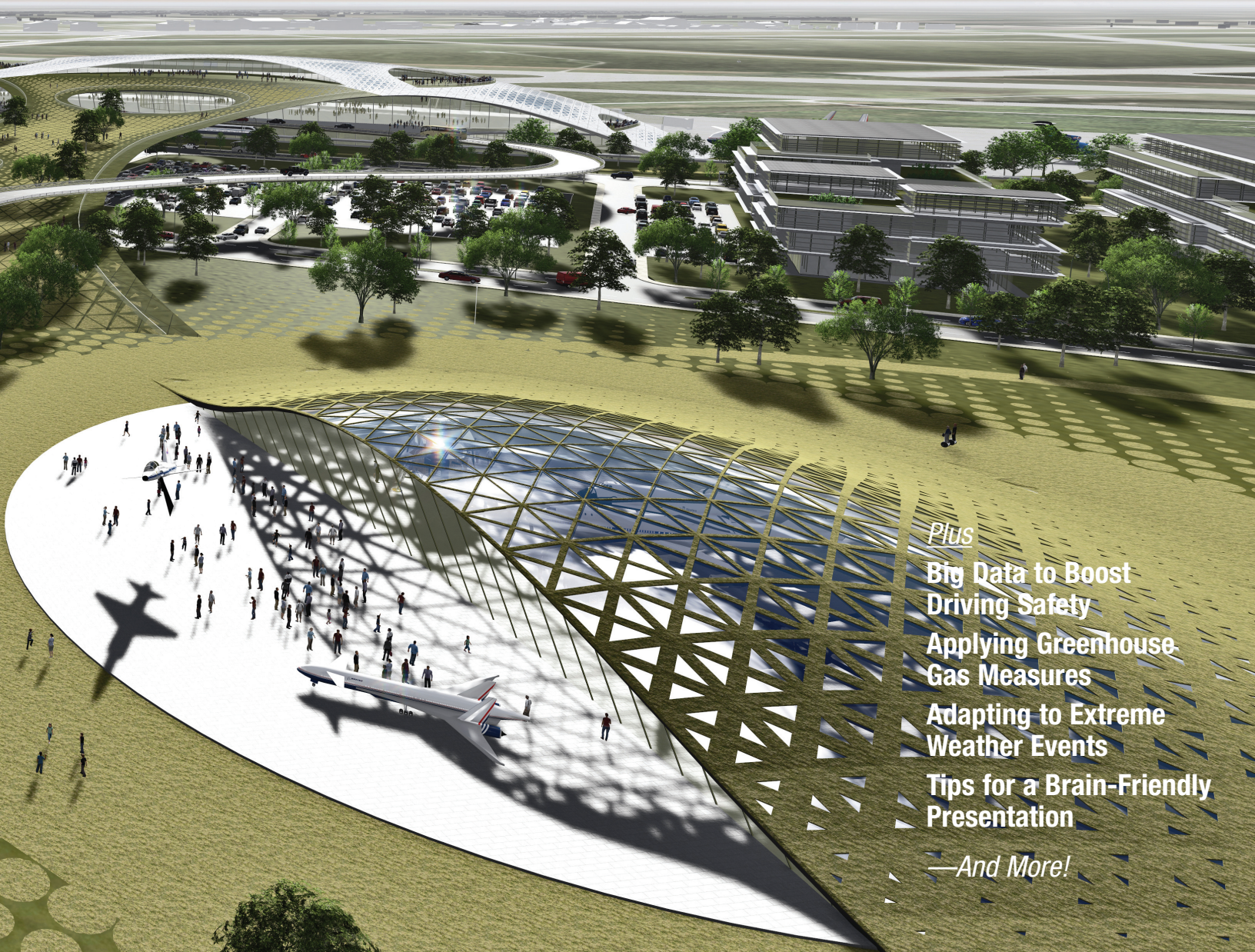
TRB TRANSPORTATION RESEARCH BOARD

TR NEWS

NUMBER 300

NOVEMBER–DECEMBER 2015

Commercial Spaceports



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Applying Greenhouse Gas Measures

Adapting to Extreme Weather Events

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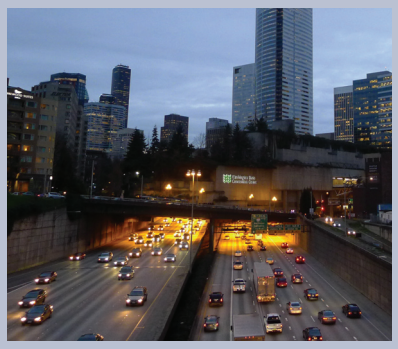

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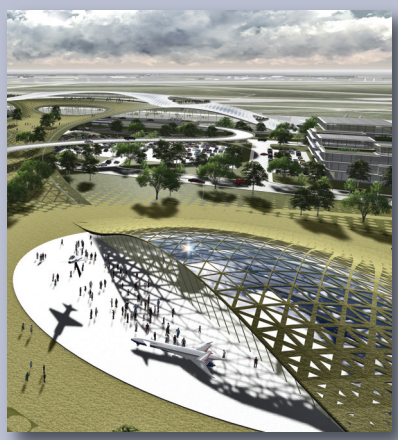

COVER: A rendering of the Houston Spaceport in Texas, which contains a terminal facility, aviation museum, and aerospace industries. In June the Federal Aviation Administration approved Ellington Airport to host the 10th licensed commercial spaceport in the United States. (Photo: Houston Airport System)

TR NEWS

features articles on innovative and timely research and development activities in all modes of transportation. Brief news items of interest to the transportation community are also included, along with profiles of transportation professionals, meeting announcements, summaries of new publications, and news of Transportation Research Board activities.

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The Transportation Research Board 2015 Annual Report is included in this issue as a special insert between pages 22 and 23.

ALSO IN THIS ISSUE:

COMING NEXT ISSUE

The January–February 2016 *TR News* features the annual overview of trends and developments in policy and practice at state departments of transportation and other agencies—particularly research needs, research in progress, and applied research—based on reports from the state partnership visits by TRB senior program officers in 2015. Other features supplement the state agency focus: setting a budget for steps in the preconstruction process, such as design and planning; improving the reliability of traffic signals in an urban environment; and lessons from Germany's measures to reduce the carbon dioxide emissions from daily travel—plus summaries of research projects requested by the states: responding to extreme weather events, a performance-based analysis of the geometric design of highways, assessing the productivity impacts of transportation investments, and capacity modeling for shared-use passenger and rail freight operations.

Photo: Christopher Koepke, Caltrans

Mud flow on State Route 58 near Bishop, California. Increased precipitation in 2015 created safety problems along transportation corridors in many states—including flooding, rockfalls and landslides, and erosion at bridge abutments and piers.

Big Data Hit the Road

The First Year of Use of the SHRP 2 Safety Databases

JOHN NJORD AND KIRK STEUDLE

Njord is Executive Vice President, Tom Warne and Associates, Murray, Utah, and Chair of TRB's Safety Data Oversight Committee. He is the former Director of the Utah Department of Transportation. Steudle is Director, Michigan Department of Transportation, Lansing, a member of the Safety Data Oversight Committee, and past chair of the Oversight Committee for the second Strategic Highway Research Program (SHRP 2). Both Njord and Steudle have served as Chair of the TRB Executive Committee.

The second Strategic Highway Research Program (SHRP 2) conducted a naturalistic driving study (NDS) that was unprecedented in size and scope. The study collected data from more than 3,500 volunteer passenger-vehicle drivers, ages 16 to 98, during a three-year period, with most drivers participating for one to two years.

The study was conducted at sites in six states: Florida, Indiana, New York, North Carolina, Pennsylvania, and Washington. The two predominantly rural sites, in Indiana and Pennsylvania, covered about 10 counties each; the other four urban or mixed sites covered one to three counties each. The total study area encompassed more than 21,000 square miles.

Data collected included vehicle speed, acceleration, and braking; vehicle controls, when available; lane position; forward radar; and video views forward, to the rear, and on the driver's face and hands. The NDS data file contains approximately 35 million vehicle miles, 5.4 million trips, 2,705 near-crashes, 1,541 crashes, and more than 1 million hours of video. All together, these amount to 2 petabytes of data—"big data" by any definition.

The companion Roadway Information Database (RID) contains detailed roadway data collected on 12,538 centerline miles of highways in and around the study sites—approximately 200,000 highway miles of data from the highway inventories of the six study states, and additional data on crash histories, traffic and weather conditions, work zones, and ongoing safety campaigns in the study sites. The NDS and RID data can be linked, so that driving behavior and outcomes can be associated with the roadway environment.

Unparalleled Data

The central goal of the NDS was to produce unparalleled data from which to study the role of driver performance and behavior in traffic safety and the effects of the interaction between drivers and the roadway environment on the risk of crashes. Driver error is a contributing factor in more than 90 percent of all crashes.

Understanding the human side of driving is critical for making large-scale improvements in traffic safety. Improvements require an understanding of how the driver interacts with and adapts to the vehicle, traffic conditions, roadway characteristics, traffic control devices, and other environmental features. After-the-fact crash investigations can estimate these interactions only indirectly.

PHOTO: VIRGINIA TECH TRANSPORTATION INSTITUTE

(*Above*:) A composite image assembles each of the four camera views of a participant in the Naturalistic Driving Study. Images from 5.4 million trips were part of the 2 petabytes of driving data gathered during the three-year study.

(*Below*:) Images preceding a crash. Video views of a driver's face and hands allow researchers to examine driver behavior; other views present the vehicle and roadway environment.

PHOTO: VTTI

The NDS data record how drivers actually drive, what they are doing just before they crash or almost crash, and how they successfully avoid incidents the vast majority of the time. The NDS and RID data will serve for years in developing and evaluating safety countermeasures to prevent or reduce the severity of traffic crashes and injuries.

Assembling the Database

Collecting and assembling the data—a massive

Photo: VTTI

An installer equips an NDS car in Buffalo, New York, with instrumentation for recording acceleration, braking, speed, and other data.

undertaking—involved hundreds of people. In total, the SHRP 2 NDS collected 6,559,367 files.

A trip file usually encompassed a trip from 30 seconds after the ignition was turned on until the ignition was turned off. The data ingestion and database assembly processes aimed to preserve as much of the usable data as possible, even if a trip was short or if some of the data were missing.

In the end, approximately 1 percent of the trip files had to be excluded from the final database, mainly because video was missing or unusable. According to experts, the proportion of trip files lost was exceptionally low, given the extensive size of the project, the newly designed data acquisition system, and the lack of experience with large-scale naturalistic driving data collection at the six sites.

Only the participants who signed an informed consent agreement could be considered in the study, which required a manual review of each trip file to exclude data from drivers who had not consented. Data reductionists reviewed nearly 99 percent—or 6,483,997—of the trip files. The review assigned the correct participant identification number to each trip file, facilitating access by researchers to the drivers of interest for specific studies.

In total, the SHRP 2 NDS database included approximately 85 percent of the collected and usable trip files (see Table 1, page 5). The largest category of excluded trip files consisted of drivers who had not consented—these accounted for approximately 10.5 percent of the manually reviewed trip files.

Photo: VTTI

At driver assessment workstations, study participants answered demographic, health, and driving questionnaires and underwent vision tests and other assessments.

Structure and Guidance

While the SHRP 2 research program was under way and the data were being collected and assembled, an advisory committee explored the long-term stewardship of the safety data. The Long-Term Stewardship Committee—assembled in accordance with the Federal Advisory Committee Act—recommended a multiphase approach. During the first five-year period, or Phase 1, the safety data would not be moved, to build a more complete base of knowledge about the data demand and use and on the resources required to guide the remainder of implementation. Phase 1 is an experimental operational period for the safety data, during which a variety of research projects will be under way using the database.

A memorandum of understanding, signed on June 26, 2014, governs activities in Phase 1 by four partners: the Federal Highway Administration (FHWA), the American Association of State Highway and Transportation Officials (AASHTO), the National Highway Traffic Safety Administration (NHTSA), and the Transportation Research Board (TRB).

A cooperative agreement between FHWA and TRB provides the funding for Phase 1 activities by TRB staff, committees, and contractors. The objectives of the cooperative agreement are to promote conditions for making the SHRP 2 safety data available to qualified users and to gain experience and data to support decisions about the implementation and oversight of the data after Phase 1.

A Safety Data Oversight Committee (SDOC) provides policy guidance for Phase 1. Members include executives from state transportation agencies, representatives from the automotive industry, academics with expertise in big data and information technology, and traffic safety researchers; representatives from the four partners serve as ex officio members.

Expert Task Groups

Several expert task groups (ETGs) provide technical advice to the SDOC. An ETG established in mid-2014 has advised on statements of work for database management contracts, on a request for information released in January 2015, and on data sharing and privacy protection policies. This ETG included technical experts on information technology, databases, human factors research, transportation safety, statistics, and big data; the ETG disbanded with the conclusion of SHRP 2.

TRB has established two additional ETGs since March 2015—and may establish others—to address such issues as privacy protection, user community

development and outreach, information technology considerations, and sustainable business models for database operations after Phase 1. The SDOC and the ETGs include representatives from the health care industry, which has considerable expertise in analyzing large, complex data sets that involve privacy protection.

Phase 1 Issues

Phase 1 will address many issues associated with the SHRP 2 safety data. The cooperative agreement outlines some of the most important issues:

- Data usage, research interests, and the potential market for the data;
- Institutional structures and responsibilities;
- Costs, users' willingness to pay, funding sources, cost sharing, and user fee structures;
- Types of facilities, skills, management processes, and technologies for user access and for the protection of personally identifying information in the data;
- Performance measures for data marketing, delivery, dissemination, and access;
- Protection of personally identifiable information;
- The effectiveness of user tools and support;
- The types of information to be generated by the selected testing of options within the constraints of the Phase 1 program; and
- Options for implementation and oversight of the SHRP 2 Safety Data Program after Phase 1, including the pros and cons for each option.

Accessing Data and Metadata

The SHRP 2 NDS collected approximately 2 petabytes of data, which can be categorized as shown in Table 2 (page 6). Extensive work was needed to make the sheer volume of data more accessible and usable for researchers; the face of the usability efforts is the InSight website.[1]

InSight facilitates use of the vast data set by the transportation research community and other researchers. The website answers some research questions directly and provides the information necessary for planning ways to answer other questions that require more in-depth exploration of the SHRP 2 NDS. The website also includes thorough dictionaries of data and variables—for example, the SHRP 2 *Researcher Dictionary for Video Reduction Data*—to assist with interpretation.

Special care was taken to exclude any personally identifying information on the website, to minimize restrictions on access. Although the initial InSight website is complete and in operation, enhancements are expected. The website's query page is designed to assist researchers in interacting with the data on vehicles, drivers, trips, and events.

[1] https://insight.shrp2nds.us/.

TABLE 1 Number of SHRP 2 Trip Files in Each Driver Category

Driver Category	Number of Trip Files	Percent of Total Files
Consenting driver	5,512,900	85.02
Unknown (likely not consenting)	684,733	10.56
Trip before consent	39,936	0.62
No driver (e.g., car warming up in a driveway)	221,051	3.41
Data collection site technician	12,829	0.20
Multiple drivers	12,548	0.19
Total	6,483,997	100.00

Exploring InSight

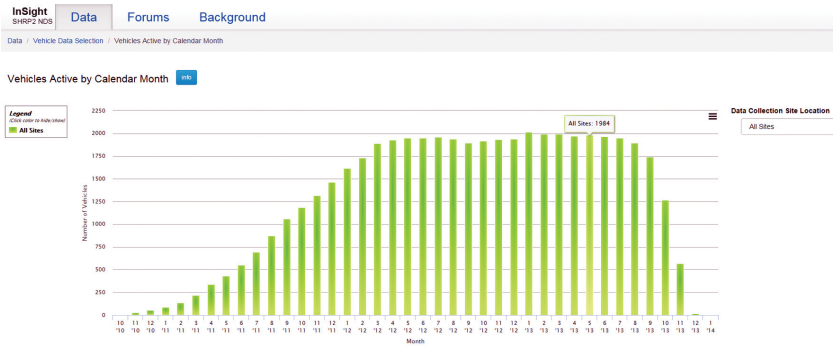
Expectations are that researchers will use InSight most frequently for work with data from the following sources:

- Detailed participant assessments, including demographic questionnaires, health and driving questionnaires, and vision tests, completed by more than 3,100 drivers.[2]
- Vehicle information—for example, safety and entertainment options—for all 3,358 vehicles.
- Summary variables for more than 5.5 million trip files—for example, the maximum speed reached, the maximum deceleration achieved, and the duration of each trip).
- Interactive heat maps detailing the roads driven—and the number of times—by drivers in the study at each of the six data collection sites. A SHRP 2 research report describes in detail how the heat maps were developed and how researchers can link the NDS and RID portions of the safety database (*1*).

[2] Detailed information and documentation on participating driver characteristics and assessments are available via InSight at https://insight.shrp2nds.us/data/category/drivers#/list.

PHOTO: VTTI

Researchers can take online training and earn certification in the use of the databases.



The vast NDS data set is accessible to researchers on the InSight website.

◆ Event data from the crashes, near-crashes, and baselines that were identified and selected. The Virginia Tech Transportation Institute has prepared a report on the crashes, near-crashes, and baselines in the NDS database (2).

Users can establish an account for basic access to InSight. To gain additional functionality and access to features, users can take online training, including the ethics of human subjects research; after passing a quiz and providing an electronic certificate, a user becomes a qualified researcher. The training typically takes one hour.

TABLE 2 Categories of Data Collected in the SHRP 2 Project

Participant Assessments	Demographic questionnaire Driving history Driving knowledge Medical conditions and medications Screening for attention deficit–hyperactivity disorder Risk perception Frequency of risky behavior Sensation-seeking behavior Sleep habits Results of visual, physical, and cognitive tests Exit interview
Vehicle Information	Make, model year, and body style Vehicle condition (tires, battery, etc.) Safety and entertainment systems
Continuous Data	Face, forward, rear, and instrument panel video Vehicle network data Accelerometers: gyroscopes, forward radar, GPS Additional sensor data
Trip Summary Data	Characterization of trip contents Start time and duration of trip Minimum, maximum, and mean sensor data Time and distance driven at various speeds, headways Vehicle systems usage
Event Data	Crashes, near-crashes, baselines 30-second events with classifications Postcrash interviews Other crash data
Cell Phone Records	Subset of participant drivers Call time and duration Call type (text, call, sending or receiving photos or videos, etc.)
Roadway Data	Matching trip GPS to roadway database Roadway classifications Other roadway data

InSight Users

Approximately 1,000 researchers have registered to use the InSight web portal. The majority of registered users—approximately 80 percent, as of May 2015—are from U.S. Internet domains, perhaps reflecting the location of the six collection sites. Nevertheless, the international contingent of InSight users is considerable, with approximately 10 percent of all users from European countries. The remaining 10 percent are largely from China, Canada, Japan, and Australia.

More than half of the InSight users come from academia—university faculty, staff, and graduate and undergraduate students. Another 20 percent are staff from federal, state, or local governments. Other sizable groups of InSight users are from Internet domains associated with nonprofit organizations, motor vehicle and subsystem manufacturers, and automobile insurance companies.

Going InDepth

A broader array of data is available beyond the InSight website. Through InDepth, qualified researchers with a standard data use license (DUL) can access a subset of SHRP 2 safety data to meet the needs of a research problem statement.

In most cases, once the DUL is in place, a research database is assembled and made available to the qualified researcher. The DUL specifies the purpose for which the data are to be used and the period of time for use. If the research involves personally identifying information, such as in-vehicle video, the DUL will specify the requirements for use in a secure data enclave that prevents copying.

Before the completion of the database, SHRP 2 undertook three pilot projects using the safety data. The undertaking was inherently difficult, akin to flying an airplane that is still being built; the research results proved valuable for several critical safety topics (see the sidebar, page 7).

InDepth Users and Topics

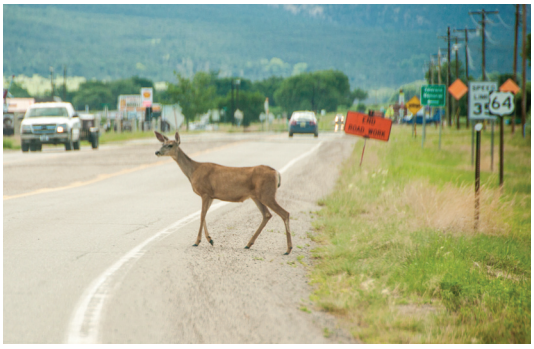
Several organizations have completed research projects, have projects under way, or are arranging to use the SHRP 2 safety data via InDepth. Customers include organizations in North America and in Europe, from universities, private consulting firms, automotive original equipment manufacturers, state departments of transportation (DOTs), national laboratories, federal agencies such as FHWA and NHTSA,

public health organizations, nonprofit research institutions, and the automobile insurance industry.

FHWA and AASHTO are sponsoring almost a dozen implementation assistance projects, known as Concept to Countermeasure, applying the SHRP 2 safety data. These projects involve partnerships between state DOTs and research organizations such as universities (see the sidebar on page 8).

The diversity of the InDepth user base is encouraging, and the diversity of the research topics is impressive. Past, current, and pending research topics include driver behavior and safety on curves; offset left-turn lanes; lane departure warning systems; driver distraction and inattention; rural intersections; vehicle safety defects; speeding; animal–vehicle collisions; road rage; driver fatigue; crash risk by gender and age; seatbelt use; crash risk and driver health conditions; markings at pedestrian crossings; driver impairment risk and personality; autonomous vehicle safety systems; speed limits, roadway geometry, and driver behavior; closely spaced freeway interchange ramps; roadway departure; work zones; inclement weather, driver behavior, and traffic safety; and fuel economy and vehicle operating costs.

The last topic indicates the potential for using the database for research in nonsafety areas such as traffic operations, transportation planning, energy conservation, and environmental protection.



Data from the NDS are facilitating studies on animal–vehicle collisions, crash risk, seatbelt use, and more.

Early Uses of the Safety Data

Practical Findings from Pilot Projects

Even as the safety databases were being assembled, SHRP 2 undertook a series of research projects to verify the value of the naturalistic driving data and the roadway information data. The SHRP 2 Project S08 series analyzed the early NDS data to address high-priority topics, including safety on rural two-lane curves, driver inattention, and offset left-turn lanes.

In Part 1 of the S08 projects, four research teams worked on proofs of concept; three of the four teams moved forward to conduct full analyses in Part 2. Results from these projects could be used to design or refine cost-effective measures to reduce roadway departure crashes, warn inattentive drivers, and help state departments of transportation to design intersections that balance crash risk with construction and maintenance costs. The experience in analyzing then-incomplete SHRP 2 NDS and RID data helped establish efficient methods for identifying, extracting, and analyzing data that now benefit all users.

Photo: Chris Ford, Flickr

Early projects mined NDS safety data to study horizontal curves on rural two-lane highways.

The three projects approved for full analyses in early 2013 were completed in 2014:

◆ Project S08A, led by SAFER at Chalmers University in Sweden, focused on the interaction between driver inattention—including distraction—and crash risk. This research is continuing under another funding source and has indicated that even short periods of inattention could be hazardous under certain driving conditions—for instance, in heavy traffic on multilane roadways.

◆ Project S08B, led by MRI Global of Kansas City, Missouri, considered the safety effect of offset left-turn bays, including positive, neutral, and negative offsets. The results indicate that positive offset left-turn lanes—which allow drivers a more unobstructed view of oncoming traffic—may have significant benefits for safety and for traffic flow.

◆ Project S08D, led by Iowa State University in Ames, focused on roadway departures on horizontal curves of rural two-lane highways. The research examined the ways that drivers negotiated the curves, and the findings indicated that correctly placed advance warning devices—such as raised pavement markings and chevrons—provide valuable advance information and warnings.

Additional information on the three S08 pilot projects, including the published research reports, is available at www.trb.org/Publications/PubsSHRP2ResearchReportsSafety.aspx.

Leading to Breakthroughs

Following are examples of the safety research under way or planned:

◆ A university in the Midwest is using time-series and GPS data, as well as forward video from crashes and near-crashes in the NDS database, to help a neighboring state DOT explore how crashes happen and are avoided in highway work zones.

◆ A major motor vehicle manufacturing company is developing a comprehensive database to examine driver distraction. Part of this project involves developing an algorithm to identify episodes of distracted driving from the SHRP 2 data. The company has indicated interest in making the resulting database available to other researchers.

◆ A nonprofit research organization is assisting a federal traffic safety regulatory agency with two major research projects examining speeding and the nonuse of safety belts. Each project is tapping into a variety of continuous data sources.

Efforts such as these should expand the literature on highway safety and lead to breakthroughs in making highways safer through an improved understanding of driver behavior. The first findings from the SHRP 2 safety data are beginning to appear in research journals.

References

1. McGlaughlin, S. B., and J. M. Hankey. *Naturalistic Driving Study: Linking the Study Data to the Roadway Information Database*. SHRP 2 Report SD-S31-RW-3, Transportation Research Board of the National Academies, Washington, D.C., 2015.
2. Hankey, J. M., M. A. Perez, and J. A. McClafferty. *Description of the SHRP 2 Naturalistic Database and the Crash, Near-Crash, and Baseline Data Sets*. Virginia Tech Transportation Institute, Blacksburg, 2015.

Concept to Countermeasure

FHWA and AASHTO Spearhead Use of SHRP 2 Safety Data

In August 2014, FHWA and AASHTO selected 10 states to participate in a proof-of-concept effort under the SHRP 2 Implementation Assistance Program (IAP), Concept to Countermeasure: Research to Deployment Using the SHRP 2 Safety Databases. The program has designated approximately $3 million in financial and technical assistance for research on 11 topics.

Photo: Anita Gould, Flickr

Traffic slows to a crawl in a snowstorm near Toms River, Maine. Winter weather conditions and other research topics received early implementation assistance from FHWA and AASHTO.

IAP grant recipients are using the SHRP 2 safety data to conduct research on their topics and will pilot and promote any promising countermeasures identified. A long-term goal is the development of new countermeasures for national adoption. In partnership with researchers, state agencies are managing the research, will implement the findings, and will deliver the authorized results.

The effort is proceeding in three phases, to simplify the process and to reduce the risk and uncertainty for the participants. In the first, 9-month phase, participants used a reduced set of NDS and RID data to demonstrate that the research concept was viable and that an analysis with a larger data set would answer the question more definitively.

At the end of Phase 1, FHWA and the AASHTO Safety Task Force undertook a review of the work to determine whether the results are promising enough for the research to continue to Phase 2. The agencies selected for Phase 2 will have access to the full SHRP 2 safety data set and will negotiate a work plan, budget, and schedule.

If Phase 2 produces meaningful results likely to lead to an implementable countermeasure or a new behavioral strategy, FHWA would provide additional financial or technical support for Phase 3, which would address implementation. The implementation would not involve additional research but would include engineering or other support to update national manuals or policies or to develop strategies for incorporating the countermeasure and endorsing it for national adoption. Phase 3 also may include pilot-testing the safety countermeasure in the field, implementing public outreach, or other measures to improve highway safety.

The 30 applications from states for the IAP funds exceeded expectations; each of the 10 state DOTs selected received approximately $100,000 for each proposal. Research using the two safety databases started up in January 2015, and reports on findings were submitted in September from Florida, Iowa, Michigan, Minnesota, Nevada, New York, North Carolina, Utah, Washington, and Wyoming. Washington State DOT received two awards for separate research topics.

The topics researched include pedestrian–vehicle interactions, roadway departures, speeding, work zones, horizontal and vertical roadway curves, interchange ramps, adverse weather conditions, and roadway lighting.

Additional information about Concept to Countermeasure is available at www.fhwa.dot.gov/goshrp2/Solutions/Safety Topic/NDS/Concept_to_Countermeasure__Research_to_Deployment_Using_the_SHRP2_Safety_Data.

Commercial Spaceports

Building the Foundation of a Commercial Space Transportation Network

RICHARD M. ROGERS

The author is Spaceport Planning Lead, RS&H, Inc., Merritt Island, Florida.

PHOTO: NASA/MASTEN

(Above:) Xombie, a vertical-takeoff, vertical-landing experimental rocket, lifts off from Mojave Air and Space Port in a test for the National Aeronautics and Space Administration's Jet Propulsion Laboratory; the project is evaluating an algorithm for planetary pinpoint landing of spacecraft. *(Below:)* Commercial spaceports may expedite the recreational space travel imagined in the 1902 French silent film *A Trip to the Moon.*

IMAGE: WIKIMEDIA COMMONS

The word "spaceport" may trigger visions of some far-off place, millennia into the future, with spacecraft zipping around between planets. Yet spaceports are here, on Earth, and are inching ever closer to the spaceports envisioned in the imagination and depicted in the movies. In the not too distant future, spacecraft will be zipping people from the surface of the Earth into space and back again. Space flight no longer will be the privilege of a few astronauts. The Commercial Space Transportation Network is in development now.

Diversified Space Race

Traditionally, spaceports were federally owned facilities for launching large government rockets. Kennedy Space Center and Cape Canaveral Air Force Station in Florida and Vandenberg Air Force Base in California are the primary government facilities that have managed rocket launches in the United States for more than 60 years.

In the past two decades, the U.S. Congress has passed several pieces of legislation that are ushering in a new commercial space race. The legislation promotes the use of government assets for access to space, including commercial launch facilities, rockets, personnel, and missions.

After the retirement of the Space Shuttle in 2011, NASA programs—such as Commercial Crew and Cargo—have inspired several private companies to fill the gaps in space access. Some companies are building on past designs; others are working for a cheaper, more accessible, way to space by applying new ideas, new designs, and unique engineering. New designs in development are attempting to build-in significant cost savings. Some of the innovations are revolutionary—such as stage reusability, vertical takeoff–vertical landing, and horizontal reusable launch vehicles.

The Federal Aviation Administration (FAA) Office of Commercial Space regulates many aspects of the commercial space sector. FAA has licensed 10 commercial spaceports, each with a unique role and capability.

The U.S. spaceport network includes several types of facilities, government- and commercially owned. Some require large expanses of land with gigantic

After its retirement in 2011, the Space Shuttle was flown over Washington, D.C., on delivery to the Air and Space Museum. Private companies now are working to fill the gaps in space access.

steel infrastructure; some only need small pads of concrete. Some are located at airports, mostly on the coasts, although recently some are inland. Each serves a specific purpose and a specific subset of launch vehicles.

Types of Launch Sites

For spaceports, one size does not fit all. The addition of commercially owned and operated launch facilities to the repertoire of federal launch sites has allowed diverse missions and users to gain access to space. Commercial launch facilities and operations can be more businesslike than their government counterparts. Each of the following types of launch sites has commercial and federal versions:

◆ **Traditional vertical launch sites** require an infrastructure specific to the rocket. Many of the vehicles are large and require substantial storage depots for propellants, as well as secure safety areas.

◆ **Sites for vertical takeoff–vertical landing vehicles** also require specific infrastructure for launches and a clear area for landing. Smaller traditional rockets and vertical takeoff–vertical landing rockets require a similar type of infrastructure with an expanse of land. The rocket-specific infrastructure of these sites limits the number of users.

◆ **Launch facilities that cater to large rockets** also occasionally handle the smaller sounding rockets. A sounding rocket does not require as much room, but if the rocket is unguided and launched with a rail launcher, a location near a coast may be necessary. These types of launches do not receive the media coverage that launches of larger satellites attract but are important to the scientific community, enabling short, recoverable, suborbital flights into microgravity at a much lower cost.

◆ **Sites for winged launch vehicles**—or horizontal takeoff-and-land launch vehicles—have gained interest, and many are in development. The Virgin Galactic SpaceShipTwo and XCOR Aerospace Lynx aim to conduct space tourism, carrying passengers and payloads into suborbital space flight. Other versions of these horizontal takeoff-and-land launch vehicles use an expendable second stage to insert payloads into orbit. Winged launch vehicles take off horizontally via a runway and operate similarly to an airplane until rocket ignition.

A spaceport that can support horizontal takeoff-and-land launch vehicles typically is colocated at an airport and is known as an aerospaceport. FAA has licensed four spaceports at active airports: Cecil Spaceport in Jacksonville, Florida; Houston Spaceport in Texas; Oklahoma Air and Space Port in Burns

A rendering of the Houston Spaceport at Ellington Airport in Texas, which was approved by the Federal Aviation Administration in June to host the 10th licensed commercial spaceport in the United States.

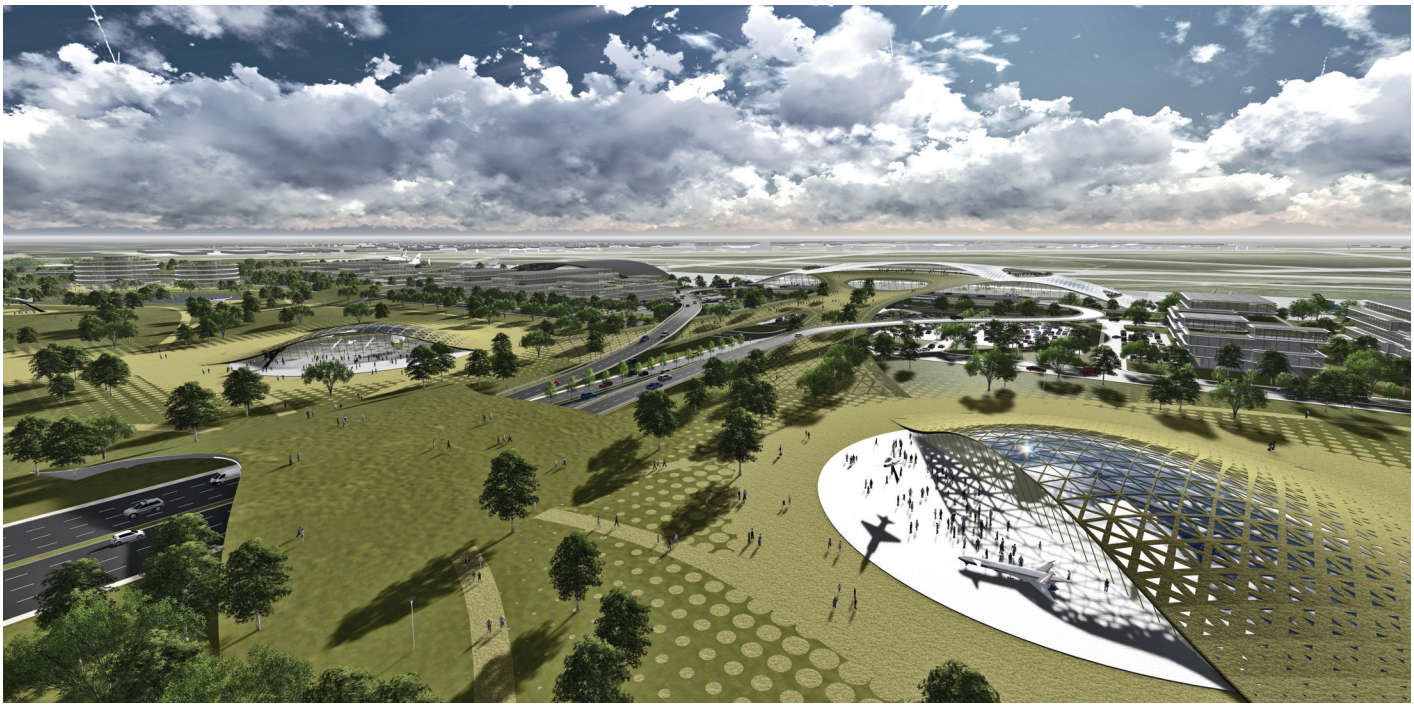


Photo: Houston Airport System

Photo: Tony Gray and Tim Powers, NASA

The SpaceX Falcon 9 rocket carries NOAA's Deep Space Climate Observatory spacecraft from a traditional launch site at Cape Canaveral Air Force Station in Florida.

Flat; and Midland International Air and Space Port in Texas. Sometime in the future, aerospaceports also will be used for high-speed, point-to-point transportation.

Spaceport Services

Spaceports offer much more than the infrastructure to launch a rocket. A spaceport offers a range of services to users and to the supporting aerospace industry:

- Aerospace design and manufacturing capabilities, to support the launch vehicle and the payload providers;
- Range support and telemetry services for safe launches and for the transmission of data during a launch or test;
- Payload processing and integration facilities, to support satellite development, manufacturing, and testing; and
- Other services, such as propellant supply and storage, secure facilities, weather monitoring, lightning protection, and more.

These same manufacturing, integration, and engineering services also may extend beyond the aerospace industry to support research and development for the Department of Defense, universities, and commercial manufacturers.

Many transportation modes play a role at a spaceport. Large rocket components, such as propellant tanks or solid boosters, commonly are fabricated at locations away from the launch site. Delivery of these components requires a coordinated logistics effort that often spans every mode—air, ground, ship, and rail. The commercial spaceport network relies on the local transportation infrastructure to support launch operations.

Several secondary industries also are associated with spaceports, such as spaceflight and pilot training, museums, tours, education, and retail outlets. As the commercial spaceflight network grows, the neighboring aerospace industries increase, helping to build the community economically and socially.

Inspiration and Motivation

The array of services and capabilities offered by a spaceport also inspires the growth of the commercial space network. High technology, science, and engineering

Photo: 24oranges.nl

A model of an XCOR Aerospace Lynx on display at Mediamarkt Amsterdam, Netherlands. XCOR and other winged launch vehicles are being developed to conduct payloads into suborbital space flight.

Photo: Kim Shiflett, NASA

The NASA Railroad train transports the final set of solid rocket booster segments for the Space Shuttle to the Kennedy Space Center. A multimodal infrastructure is required to move equipment and parts to launch sites.

jobs are often abundant in the area surrounding a spaceport and provoke community interest in space. A spaceport and related aerospace industry can inspire local children to pursue studies in science, technology, engineering, and mathematics through tours, launches, and classroom experiments.

The Department of Defense, NASA, and communications companies are interested in putting satellites into orbit for the Global Positioning System, telecommunications, and weather research. But the motivations for space flight are more extensive. The biomedical industry, for instance, seeks access to space to research new medicines, biological products, and medical devices. Other industries, such as aerospace, technology, optics, and materials, want to use space to research and develop new manufacturing techniques, materials, and devices. University researchers, scientists, and students may need to conduct microgravity experiments on a suborbital or orbital mission. As the number of spaceports within the commercial spaceport network increases, so does the access to space.

Regulations and Standards

Originally, government organizations such as the Department of Defense and NASA exclusively operated spaceports. The commercialization of space has involved FAA in licensing and regulations for spaceport operators and for launch vehicle operators.

Commercial space regulations in the *Code of Federal Regulations* (CFR) cover safety, launch sites, launch vehicles, experimental permits, and human space flight requirements.[1] The CFR section titled

[1] 14 CFR Part 411 through Part 461.

What Happens at a Spaceport?

WAYNE FINGER

Everything necessary for a flight into space comes together at a spaceport. Components arrive by air, rail, water port, or highway. The major parts of the rocket are integrated to create the fully assembled launch vehicle. Propellants—both fuels and oxidizers—arrive at the spaceport and are stored, awaiting transfer to the launch vehicle just before the launch. Space flight participants, crew, and their families arrive, complete orientation, and prepare for the flight. Cargo and experiments arrive and are stored in a controlled environment. Researchers, educators, and students participate in the final preparations, and the experiments are loaded on board.

The space flight mission originates at the spaceport, which monitors the weather and coordinates with air traffic control to ensure that the flight corridor has accounted for public safety. Some launch vehicles eventually may go beyond earth orbit and not return. For now, most will return intact to a spaceport, will have components that return to a spaceport, or will fall into the ocean.

In essence, a spaceport is a multimodal transportation facility that integrates air, water, ground, and space transportation. This span of responsibilities requires special technological, safety, and environmental approaches for successful operations—and opens vast opportunities for research.

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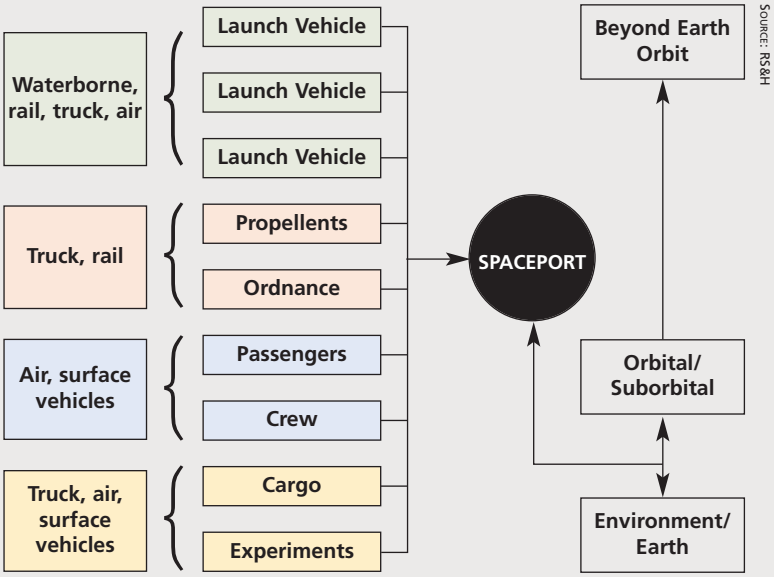

Figure 1 What happens at a spaceport.

"License to Operate a Launch Site" specifically governs spaceports.[2]

The section describes a detailed application process to ensure the safe operation of a launch vehicle. The application requires analyses that consider hazardous chemicals, safety operations, security, airspace and flight paths, risk, and environmental assessments. Updates and revisions to the regulations are continual, reflecting the approval and implementation of new industry standards.

Depending on the mission and launch site, other regulations may apply. Launches that use the Department of Defense Launch and Test Range System, which provides support for commercial spacecraft launches and for aeronautical testing missions, must meet specific safety guidelines. Government-sanctioned launches follow the department's guidelines, and launches for a NASA program must meet the appropriate NASA standards. Many of the requirements overlap or mimic each other but are necessary for fulfilling a specific mission.

Advisory Groups

Several ongoing industry efforts are attempting to bridge the gap between users and regulators. The Commercial Space Transportation Advisory Committee (COMSTAC) was established to provide FAA with information, advice, and recommendations on issues related to the commercial space transportation network. COMSTAC consists of industry representatives who meet biannually in sessions open to the public. The membership and the working groups discuss industry concerns and develop recommendations for FAA.

The Commercial Spaceflight Federation (CSF) is an industry group that includes the major spaceport operators, launch vehicle operators, and aerospace companies. The federation addresses industry issues, policies, and regulations; promotes industry growth; and engages in public outreach.

The industry also has pursued other avenues to raise awareness, establish standards, advocate for regulatory changes, and discuss challenges. Many professional societies and groups have formed standing committees, subcommittees, and working groups to explore issues and interests in commercial space—notably the American Institute of Aeronautics and Astronautics and the Transportation Research Board (TRB). Many of these groups are focusing on specific industry issues.

Regulators and industry users have been working together to build the commercial spaceport network. The openness of regulators to recommendations and to change, along with the collaborative efforts of industry users through COMSTAC, CSF, and other groups, are contributing to the growth of commercial spaceflight activities.

PHOTO: NASA

Space opens many new possibilities for research in a range of fields; NASA Flight Engineer Tracy Caldwell Dyson works on experiments requiring cryogenic refrigeration aboard the International Space Station.

Spaceport Research Needs

The rapid growth of the commercial spaceflight network offers many opportunities for research to assist and benefit the industry. Many research needs relate to facilities and operations for horizontal takeoff-and-land and for vertical takeoff–vertical landing vehicles. Nevertheless, research to support the development and establishment of vertical rocket launch sites that can support a variety of users is also needed.

Another key subject for research involves the integration of spaceport operations into an airport—license applications for aerospaceport arrangements are increasing. Reviewing the lessons learned from the two recently licensed aerospaceport facilities could identify challenges and solutions that would be instructive for other facilities and that could identify operations approaches that are common throughout the commercial spaceport network.

For example, vertical takeoff–vertical landing launch vehicles offer challenges not encountered with expendable launch vehicles. Developing and publicizing safe operating procedures, methods, and analyses for vertical takeoff–vertical landing could enhance system and public safety.

Additional topics for research on the integration of a spaceport with an airport include propellant storage, loading methods and mechanisms, aircraft rescue and firefighting procedures, modifications to airport design standards to accommodate a spaceport, and the development of passenger processing operations.

[2] 14 CFR Part 420.

A prototype of the GL-10, a hybrid diesel–electric tiltwing aircraft with vertical takeoff–vertical landing (VTOL) ability, hovers after takeoff. Research into VTOL vehicles can open up new avenues of launch site design.

PHOTO: DAVID C. BOWMAN, NASA LANGLEY

A New Phase

This is a new phase in U.S. spaceflight history: NASA is producing a new Space Launch System that is larger and more powerful than the Saturn V rocket that took astronauts to the moon. Commercial companies regularly are carrying cargo into space and soon will carry people. Regularly scheduled commercial space tourism is imminent.

The industry is evolving into a commercial spaceport network; competition and innovation will drive launch costs down and the frequency of launches up. Pushing the boundaries of spaceflight will open many possibilities and benefits.

As the U.S. space launch landscape undergoes changes, TRB has a role in providing advice and research to support an emerging commercial spaceport network. Adopting an excited, interested, and solution-focused attitude to industry changes related to commercial spaceflight may result in a spaceport nearby.

Advising on Aerospace Technology

Informing Policies, Procedures, and Research Agendas

MICHAEL H. MOLONEY

The Aeronautics and Space Engineering Board (ASEB) at the National Academies of Sciences, Engineering, and Medicine was established in 1967 "to focus the talents and energies of the engineering community on significant aerospace policies and programs." In fulfilling this charge, ASEB oversees ad hoc report-writing committees that recommend priorities and procedures for achieving aerospace engineering objectives and brings engineering and other related expertise to bear on aerospace issues of national importance.

Issues include the research and development aspects of the Next-Generation Air Transportation System, or NextGen; NASA's aeronautics research program; national aeronautics research and development policy and its implementation; space policy and programs, with a focus on human spaceflight, space technology, and space operations; commercial space activities; and other aerospace engineering topics.

PHOTO: NASA

Commander Barry (Butch) Wilmore holds a science sample container that took 2 hours to make with a 3-D printer on the International Space Station; NASA seeks to make objects in space instead of delivering them. The Aeronautics and Space Engineering Board is advising NASA on 3-D printing in space and other research.

Recent activities have included studies on 3-D printing in space, a research agenda for autonomy in civil aviation, a major review of the goals and direction of human spaceflight, NASA's flight research program, and priorities for NASA's space technology development roadmaps. Current studies include the establishment of a research agenda for low-carbon propulsion and energy systems for civil aviation and a review of changes to NASA's space technology development road maps.

ASEB also oversees the work of the Aeronautics Research and Technology Roundtable and the Space Technology Industry, Government, and University Roundtable. The roundtables convene senior-level representatives from industry, universities, and government to define and explore critical issues of shared interest related to NASA's research agendas for aeronautics and space technology; to frame systems-level research issues; and to explore options for public–private partnerships that could support rapid, high-confidence knowledge transfer. These forums facilitate a candid dialogue among the participants, foster greater partnership within the NASA-related aerospace community, and—when appropriate—convey awareness of the consequences to the wider public.

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Applying Greenhouse Gas Performance Measures to Inform Transportation Planning and Decision Making

JOHN DAVIES AND MICHAEL GRANT

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In recent years, transportation agencies have begun to apply performance-based approaches to support decisions. The Moving Ahead for Progress in the 21st Century Act (MAP-21) established performance-based requirements for statewide and metropolitan transportation planning. Although MAP-21 did not require an analysis of energy and greenhouse gas (GHG) emissions, state DOTs and metropolitan planning organizations (MPOs) may want to incorporate performance measures for GHG emissions into the planning process. This would address the emissions primarily linked to global climate change, which is often cited as the greatest environmental and social challenge of this era.

Transportation agencies can play a key role in specifying performance measures for reducing GHGs, in conducting analyses, and in developing targets that support a public vision of sustainable transportation and climate policy. Recent publications from the Federal Highway Administration (FHWA) describe how agencies can identify policy-relevant performance measures for GHG emissions, apply analysis techniques, and use this information to support investment choices and to enhance decision making.

GHG Performance Measures

GHG emissions can be calculated several ways—transportation agencies have many options in selecting a GHG performance measure or measures. The choice specifically should support public policies to reduce GHG emissions. Selection is not merely a technical issue but should assist an agency or region in implementing its vision for GHG reduction or for transportation sustainability.

The key questions to consider when selecting GHG performance measures are the following:

1. What sources of emissions should be addressed?
2. How should these emissions be quantified?
3. How should the results be expressed?

PHOTO: SEATTLE DOT

In developing a performance measure for greenhouse gas (GHG) reduction, an agency should determine whether it wants to address emissions from passenger travel, from total on-road travel—which includes freight—or from another category of travel.

Transit, freight, and commuter traffic moves through the Sarbanes Transit Center in Maryland. The economic and regulatory drivers of freight and passenger travel are not always the same.

Emissions Sources

The first step in selecting a GHG performance measure involves determining which transportation sources to address and which gases to consider. Carbon dioxide (CO_2) accounts for more than 95 percent of transportation GHGs with potential for global warming; including other GHG emissions, however, may be worth consideration—for example, methane (CH_4) and nitrous oxide (N_2O), both of which are estimated in the Environmental Protection Agency's Motor Vehicle Emissions Simulator (MOVES) model.

Transportation agencies should determine the sources of emissions to address—for example,

- **Light-duty vehicles**, which primarily reflect passenger travel;
- **Total on-road vehicles**, which include freight trucks;
- **Total transportation**, which includes rail, aircraft, and waterborne sources; and
- **Life-cycle processes**, including infrastructure construction and maintenance, the fuel cycle, and the vehicle cycle.

In making the selection, agencies should consider which sources are influenced most directly by planning activities and which are most relevant to regional policy and investment decisions. For instance, regional and local decisions on land use, transportation investments and services, and demand management strategies affect light-duty passenger travel; in contrast, broader economic factors related to interstate and interregional goods movement largely influence freight travel.

California's Sustainable Communities Act recognizes the primary role of transportation and land use decisions in passenger travel; the state law requires MPOs to analyze light-duty vehicle GHG emissions. Agencies may want to examine all on-road sources, however, to develop strategies that reduce freight emissions. The ease of calculating emissions is a key practical consideration, as is maintaining consistency with the analysis of regional criteria pollutant emissions, accounting for emissions from all on-road vehicles.

Quantifying Emissions

The geographic scope of the analysis is another key consideration:

- A **geographic analysis** accounts for the GHG emissions from all vehicle travel within the boundaries of a region or state—similar to the regional emissions analysis approach for determining transportation conformity with criteria pollutant emissions standards.
- Alternatively, a **trip-end analysis** accounts for GHG emissions from vehicle trips beginning or ending within the boundaries of a region or state; the analysis does not include through trips.

In determining the geographic scale and scope of an analysis, an agency should consider the following issues:

- **The role of pass-through travel.** Regions, states, and localities with a large volume of pass-through travel may choose to limit GHG estimates to vehicle trips that begin or end within their boundaries, by using a trip-end analysis to focus on travel by residents and businesses within the region or state. California MPOs use this approach in calculating regional GHG emissions in accordance with state law SB 375.

◆ **Strategies under consideration.** If a region has a large amount of interregional or interstate travel into adjacent regions or states, a trip-end analysis may focus on the GHG emissions most directly affected by regional transportation strategies. In contrast, a geographic analysis that includes all on-road activity will capture the effects of strategies on all traffic, including traffic flow improvements and freight strategies.

◆ **Consistency with neighboring jurisdictions**. A trip-based analysis may not account for some GHG emissions, particularly from pass-through trips. Transportation agencies can minimize the risk of not accounting for some emissions by coordinating with neighboring jurisdictions to align analysis approaches. Under SB 375, California DOT conducts an aggregate analysis of regional plans to account for emissions from pass-through trips and from interregional travel.

Photo: Pennsylvania State University

Among the emission sources for transportation agencies to consider are vehicle life-cycle processes.

The Fuel Factor

Other considerations include expected changes in vehicle fuel economy and in the carbon content of fuels, which could contribute appreciably to future reductions in on-road emissions. Addressing these effects in an agency's performance measure has pros and cons.

Because transportation agencies have limited influence over consumer choices of vehicles and fuels, these factors are generally beyond the scope of an agency's transportation plan. In addition, the GHG reductions from these improvements can obscure the impact of transportation investments and policies that increase sprawl and travel demand, Moreover, the reductions could indicate that emissions controls are "headed in the right direction," when further reductions are both possible and desirable through planning decisions. Consequently, some agencies, such as California MPOs, control for the impact of vehicle technology, to focus on the incremental effect of the agency's planning efforts.

Conversely, the public may be interested in total GHG emissions from the transportation system as a

Photo: Ken Lund, Flickr

The Fort McHenry Tunnel carries I-95 traffic underneath Baltimore Harbor in Maryland. A region's amount of pass-through or interstate travel factors into any GHG emissions analysis.

way to track progress toward multisector emissions goals. In practical terms, including the effect of future changes in vehicle fuel economy in a performance measure may be advisable, because the MOVES model, used to estimate GHGs and other air emissions, accounts for changes in fuel efficiency.

Expressing Emissions

Transportation agencies can express emissions in the following ways:

- A total emissions figure, generally expressed in tons or kilograms of emissions; or
- A metric normalized to account for population or economic growth, expressed on a per capita or per household basis.

A normalized metric may be the more intuitive approach, allowing the public to conceptualize emissions more easily at the individual or household level; moreover, carbon calculators and other tools commonly use this metric.

Another approach expresses GHG emissions by unit of economic output; this addresses the effect of economic shifts on GHG emissions. These approaches, however, may conceal trends in overall GHG emissions—for example, a decline in per capita emissions may be offset by population growth, yet the metric would indicate a reduction in emissions despite a net increase in overall GHG emissions.

The metrics in Table 1 (below) illustrate approaches to address the relationship between metrics for GHG emissions and the reduction strategies available to transportation agencies. For example, California MPOs use a per capita metric for light-duty vehicle emissions that controls for advances in alternative vehicles and fuels, because state policies include light-duty fuel-efficiency standards, a low-carbon fuels standard, and measures to increase the efficiency of heavy-duty vehicles.

By controlling for the effect of these state policies, the MPO metric focuses on the GHG emissions that are most responsive to regional transportation and land use planning. The metric is designed to encour-

TABLE 1 Strengths and Limitations of Various GHG Performance Measures

GHG Measure	Agencies Using the Metric	Strengths	Limitations
Total on-road related CO_2 emissions (light duty plus freight)	National Capital Region Transportation Planning Board at the Metropolitan Washington Council of Governments[a] Puget Sound Regional Council[b]	Accounts for the vast majority of GHG emissions Easy to assess progress toward national or state goals	Emissions from freight sources may be difficult for transportation agencies to address. Outcomes may be affected by population growth.
Light-duty vehicle CO_2 emissions per capita	Portland Metro[c]	Focuses on light-duty emissions, which are most responsive to transportation policies and strategies	Does not account for benefits of freight-related improvements
Light-duty CO_2 emissions per capita (removing effect of reductions from state fuel and vehicle policies)	All California MPOs[d]	Focuses on light-duty emissions, which are most responsive to transportation policies and strategies Controls for improvements due to fuel efficiency that are outside of agencies' control	Does not account for benefits of freight-related improvements Requires additional analysis of technology-related reductions
Total on-road and off-road related transportation GHG emissions	Massachusetts DOT[e] Maryland DOT[f]	Accounts for all major sources of GHG emissions Easy to assess progress toward national or state goals	Emissions from freight and nonroad sources may be difficult for transportation agencies to address. Outcomes may be affected by population growth and other exogenous factors.

NOTE: GHG = greenhouse gas.

[a] www.mwcog.org/clrp/performance/air_quality.asp.

[b] http://www.psrc.org/assets/4847/T2040FinalPlan.pdf.

[c] Oregon established a target for a 20 percent reduction in per capita light-duty CO_2 by 2035. See www.oregon.gov/LCD/CLIMATECHANGE/pages/metropolitan_greenhouse_gas_reduction_targets.aspx. Before the establishment of this target, the Metro 2035 Regional Transportation Plan also included an aspirational target for total CO_2 emissions from on-road sources. See http://library.oregonmetro.gov/files//2035_rtp_final_document_as_submitted_and_approved_by_dlcd_usdot_web.pdf.

[d] www.arb.ca.gov/cc/sb375/scs_review_methodology.pdf.

[e] www.massdot.state.ma.us/Portals/0/docs/GreenDOT/finalImplementation/FinalGreenDOTImplementationPlan 12.12.12.pdf.

[f] www.mdot.maryland.gov/Office_of_Planning_and_Capital_Programming/Plans_Programs_Reports/Documents/ Climate_Change_2011.pdf.

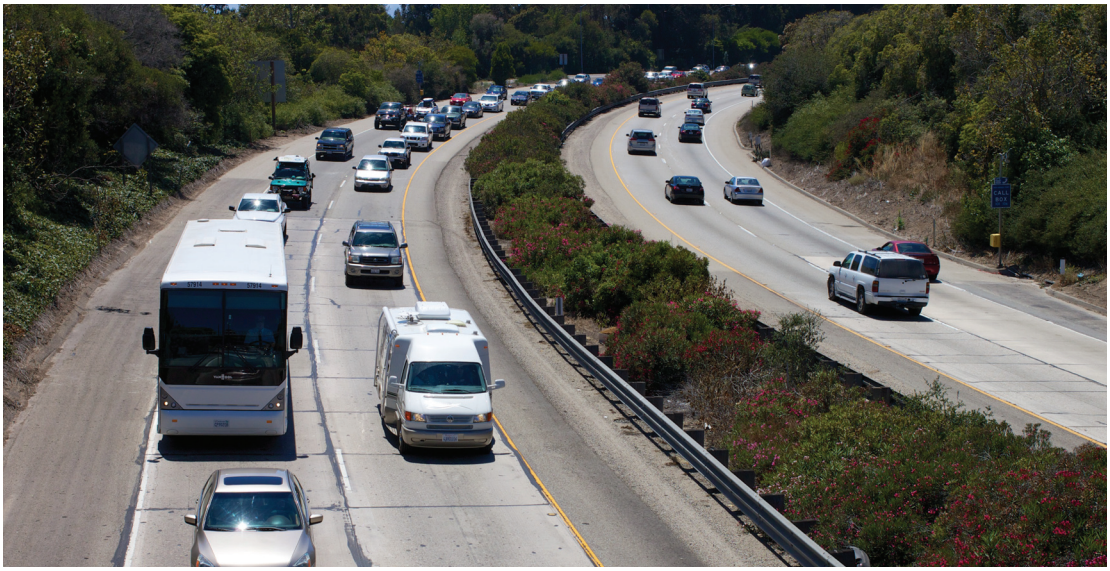

Photo: Oran Viriyincy, Flickr

By controlling for the effect of state policies on fuel-efficiency and on low carbon fuel standards, agencies can target GHG emissions that are most responsive to planning.

age sustainable planning practices, such as land use policies and transportation investments that reduce vehicle travel.

In contrast, the Massachusetts Department of Transportation (DOT) uses a GHG reduction metric that accounts for a broader scope of emissions. The agency is considering GHG reduction strategies that address alternative fuels and light- and heavy-duty vehicle efficiency. In both cases, the GHG metrics reflect the scope of the emissions targeted in the reduction strategies.

Trends and Targets

Although a performance measure by definition evaluates outcomes, a performance-based approach also benefits from targets that specify levels of performance to achieve within a time frame. Transportation agencies may express GHG targets in three primary ways:

1. **Directional**, indicating the direction of the desired impacts;
2. **Aspirational**, signaling the importance of the issue to the community or to policy makers, without a detailed analysis; and
3. **Analytical**, accounting for available resources, policies under consideration, and other factors affecting performance; these are set at a level considered attainable.

Whatever the approach, practitioners should understand the baseline conditions, which include the sources of current emissions and the factors influencing future levels of emissions. Planners can inform this process by helping decision makers understand the impact of policies, as well as the time frame for measuring outcomes and setting targets.

Reporting Performance

Transportation agencies can frame the challenges of climate change to the public, inform decisions, and characterize progress toward climate goals. Communicating information to policy makers and the public can have significant implications for agency and program support.

An agency should not simply release data but should use the information to explain outcomes—such as changes in GHG emissions—and to quantify the impact of planning and programming decisions. This information can help engage partners—including local governments, state legislatures, developers, and the private sector—who can play strategic roles in reducing GHG emissions.

By communicating transportation's role and initiatives in addressing GHG emissions, transportation agencies can build interagency partnerships and an informed public dialogue to expand the success of these policies.

Additional Resources

Grant, M., J. D'Ignazio, A. Bond, and A. McKeeman. *Performance-Based Planning and Programming Guidebook.* Report FHWA-HEP-13-041, Federal Highway Administration, September 2013. www.fhwa.dot.gov/planning/performance_based_planning/pbpp_guidebook/.

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Photo: Carsten Fonsdal Mikkelsen, Flickr

Risk Mapping Major Danish Roads for Flooding

Blue Spot Model and Results

CHRISTIAN AXELSEN AND MARIE VENNER

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(*Above:*) A rainstorm caused severe flooding in Bornholm, Denmark, in 2008.

Accidents, wildlife, and extreme weather events challenge the task of ensuring safety and mobility on roads. Extreme weather has gained attention in recent years with increases in roadway flooding throughout the world. Europe has experienced increased occurrences of extreme precipitation comparable to the increases in the United States.

Forecasts by scientific authorities, such as the United Nations' Intergovernmental Panel on Climate Change, point unambiguously to a continued trend of rising global temperatures; these higher temperatures in turn will power extreme precipitation phenomena. Incidents of flooded roads therefore can be expected to increase and overwhelm the business-as-usual approach. Climate change will result in altered patterns of precipitation, and the consequences arguably are already apparent.

Adapting roads to handle greatly increased water drainage often requires expensive modifications, as well as disruptions to traffic during construction. In addition, adaptations vary vastly in cost and feasibility from rural to urban areas. Adaptations tend to be feasible only when resources can be allocated optimally.

The Danish Road Directorate developed a model to identify portions of roadways that are vulnerable to flooding and in which the consequences of flooding are severe. Addressing both the vulnerability and the consequences facilitated the identification of optimal investments in adaptations—the decisions integrate a socioeconomic perspective.

TABLE 1 Effects of Climate Change on Precipitation Patterns

Precipitation (mm)	Current Cycle (years)	2050 Cycle (years)	2100 Cycle (years)
45	5	2	1
47.5	10	5	2
54.6	20	10	5
58	25	20	10
65.2	50	25	20
74	100	50	25
97.3	500	100	100
142.8	1,000	500	500

Note: Based on Danish statistical data on precipitation patterns and on climate factors identified by the Intergovernmental Panel on Climate Change in 2007.

A "blue spot" is a stretch of road with a high likelihood of flooding that will have significant consequences. The model integrates climate factors to identify blue spots for current and future scenarios to 2050 (Figure 1).

The Danish Road Directorate builds roads that can drain the precipitation from a 25-year cycle. Table 1 illustrates how future climate conditions will cause more frequent extreme precipitation events in Denmark, effectively changing the precipitation during the cycle and decreasing safety and mobility—unless adaptation measures can be implemented.

The blue spot model generates a risk map that can guide the allocation of resources in the most cost-effective, focused, and informed manner, making climate change adaptation more feasible.

The adaptation measures for roads are often expensive initiatives but are necessary to maintain safety and mobility. Identifying blue spots has proved to be a valuable approach—mapping the risks enables priorities to be set for resources. In this way, adaptations for climate change have become more feasible, in technical and in political terms.

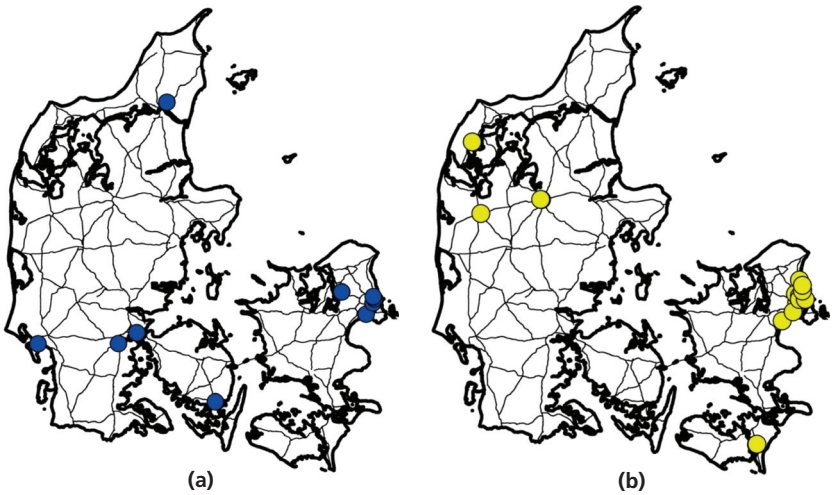

FIGURE 1 Geographic distribution of (*a*) blue spots for current climate scenarios and (*b*) additional blue spots for 2050 climate scenarios.

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM REPORT

Climate Change, Extreme Weather Events, and the Highway System

Impacts and Adaptation Approaches

MICHAEL D. MEYER

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Over the past 10 years, the transportation community has become increasingly concerned about the impact of climate change and extreme weather events on transportation infrastructure and services. Partly in response to extreme weather events and major natural disasters such as Hurricanes Sandy, Katrina, and Irene, massive flooding in the Midwest, and large forest fires in the West—as well as a growing awareness of the potential threats of climate change described in research and policy studies—transportation agencies are interested in understanding the risks associated with a changing climate.

Several states—such as California, Massachusetts, and Washington—have legislative and executive directives for formally considering extreme weather and climate change in policy making and agency decisions. At the federal level, a variety of initiatives provide additional motivation to include adaptation measures in decision making:

- The Federal Highway Administration's (FHWA's) Planning Order 5520, Transportation System Preparedness and Resilience to Climate Change and Extreme Weather Events;

Photo: Andy van der Raadt, Flickr

Extreme weather events can wreak havoc on a region's infrastructure.

- The pilot studies on adaptation and vulnerability assessments supported by FHWA and the Federal Transit Administration (FTA); and
- The Executive Order issued January 30, 2015, Establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Stakeholder Input.

Photo: Adam DuBrowa, Federal Emergency Management Agency

Flooding from Superstorm Sandy in 2012 destroyed sections of highway near Jersey City, New Jersey.

Pressures on Agencies

Although some may question the projections of future climate conditions, most agree that the nation has experienced record numbers of extreme weather events in the past several years. The frequency and severity of these events have seemed to increase, the infrastructure damage and the community costs have risen, and the impact of recovery costs on maintenance budgets and on regular operations activities has become significant. Moreover, public expectations for the quick and efficient recovery of the transportation system have increased the pressures on transportation agencies.

The pressures have led to organizational changes, the development of new management responsibilities—such as emergency management—the modifications of operating procedures, and the training of staff in the management and administration of recovery efforts.

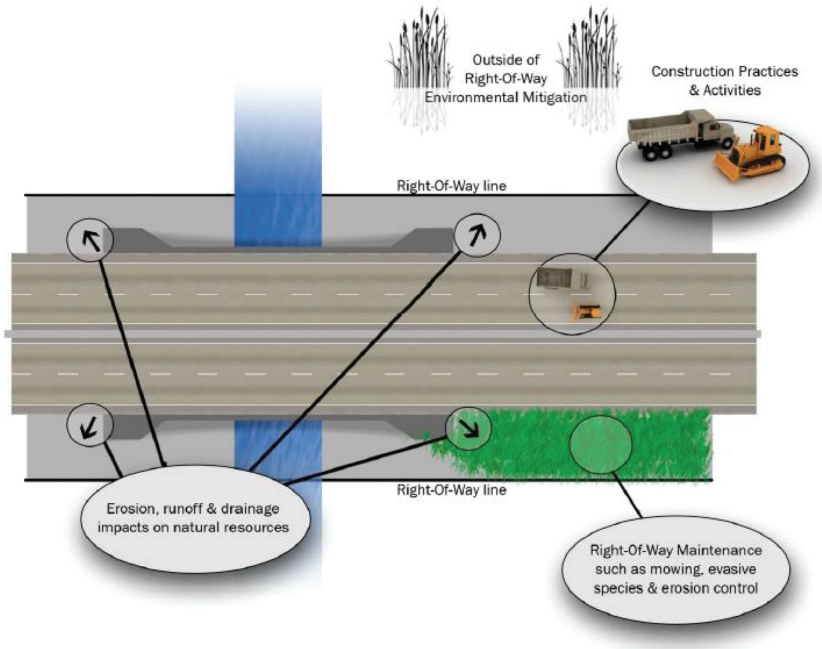
Emergency managers for Stewart County, Tennessee, map out operations logisics in a mobile emergency operations center after a natural disaster.

Photo: Ed Edahl, FEMA

NCHRP Report 450, Volume 2, *Climate Change, Extreme Weather Events, and the Highway System*, recommends steps for transportation agencies in preparing for extreme weather events, managing agency operations during an event, and conducting postrecovery operations (*1*). The volume is part of a series, Strategic Issues Facing Transportation, examining global and domestic long-range strategic issues and their implications for departments of transportation (DOTs).

NCHRP Report 750, Volume 2, systematically identifies a process for investigating the vulnerability of transportation infrastructure to extreme weather events and to climate change in the long term. A successful vulnerability assessment, as outlined in the report, incorporates an appreciation of the following points.

Corridor-level impacts of changing local environmental conditions, from NCHRP Report 750, Volume 2.



◆ **Climate change and extreme weather events present a range of stresses on the transportation system.**

The report identifies climate-related stresses and the possible impacts on the nation's road network. Understanding the types of stresses and impacts that are of most concern to highway system managers is one of the first tasks of any assessment of vulnerability to climate change.

Depending on the type of environmental stress caused by climate change and extreme weather, a range of impacts on the highway system can be anticipated. These impacts affect the infrastructure—and therefore the design and construction of facilities—as well as operations and maintenance.

In addition to the direct effects on highways, climate change will affect ecological dynamics that will have implications for transportation systems. The report identifies the types of impacts on transportation infrastructure and presents strategies to avoid or minimize the impacts.

The strategies for dealing with climate change and extreme weather events will differ by functional activity within a transportation agency. For example, climate change adaptation can be considered in planning, environmental analysis, design, infrastructure retrofit, construction, operations, maintenance, emergency response, and public outreach and communications. The report identifies the likely effects that a concern for climate change and extreme weather events will have on an agency's units.

◆ **Vulnerability assessments of highway assets require several areas of expertise, including a level of engineering expertise often lacking in policy and planning efforts.**

Conducting substantive climate vulnerability assessments that can lead to tangible and actionable measures is a challenge that requires experience and knowledge across a range of disciplines. Vulnerability assessments and adaptation require an understanding of the design and operational performance characteristics of assets and how these assets will respond to the stresses of climate and extreme weather.

This analysis draws on expertise from a range of engineering disciplines. For example, vulnerability assessments of flooding impacts require expertise in

Photo: Ann Fisher, Flickr

Sections of the Eisenhower Expressway in Chicago, Illinois, are closed after an extreme weather event.

hydrology and hydraulics, as well as geotechnical knowledge for assessing slope vulnerability.

After the vulnerabilities are identified, decision makers will want to know what the application of the adaptation strategy means for each asset or asset type. For example, cost is usually one of the most important considerations for decision makers and is a key to their willingness to implement asset-related adaptation strategies. The likely effectiveness of different engineering strategies, under differing site and climatic circumstances, also is pivotal.

◆ **Risk is a key factor in vulnerability assessments.** Researchers and highway officials are recognizing that climate change and extreme weather events are a threat to the highway system and warrant an investigation of the risks. Most agencies considering adaptation begin with a risk assessment of highway assets. Most of these risk assessments are qualitative and rely on professional judgment, although the report may present quantitative and qualitative approaches for considering climate change–related risks.

Climate-related risk involves impacts beyond the failure of an asset—namely, the consequences or magnitudes of the costs associated with the failure. The consequences may include the direct replacement costs of the asset, the direct and indirect costs to asset users, and the economic costs to society through the disruption to transportation—a road under water is unusable.

An integrated risk assessment of vulnerable assets considers the likelihood of impacts and their consequences. The intersection of these two factors determines the risk level for an asset. Adaptation options then can be considered for high- or medium-risk assets, with low-risk assets given lower priority.

◆ **Climate change stressors require specific approaches and methods of analysis.** Approaches to assessing vulnerability vary—coastal storm surge in the Gulf Coast, high-intensity stormwater runoff, and permafrost melting in Alaska require different strategies. Analyzing the impact of extreme precipitation events and flooding differs from analyzing the higher temperatures and drought that are increasing the intensity of forest fires.

For this reason, the print edition of NCHRP 750, Volume 2, contains a CD that allows transportation professionals to identify the environmental stresses, the databases and approaches most appropriate for analyzing the potential impacts, and the options available for the design process.

◆ **Data availability and quality are critical for adaptation analysis.** Every adaptation study depends on the availability of

After a 2013 fire in New Mexico's Santa Fe National Forest, members of the U.S. Forest Service Burned Area Emergency Response team inspect igneous rock near a roadway. The fire consumed nearly 24,000 acres.

Photo: U.S. Forest Service

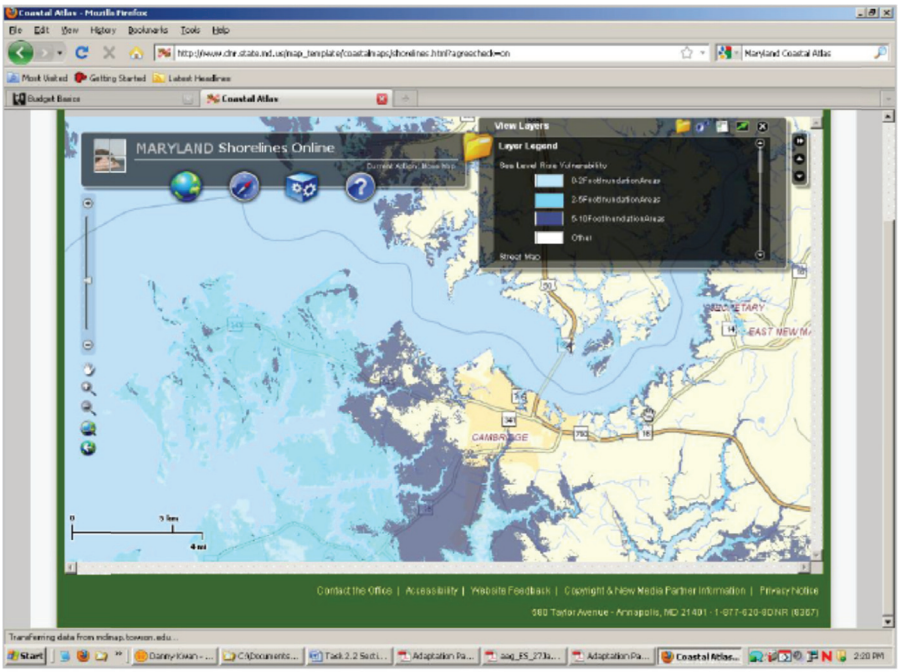
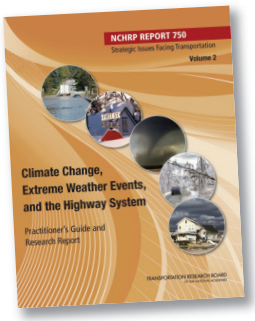


IMAGE: MARYLAND COASTAL ATLAS SHORELINE MAPPING TOOL

The Maryland Coastal Atlas shoreline mapping tool presents an analysis of sea-level rise in Maryland.



NCHRP Report 750, Strategic Issues Facing Transportation, Volume 2: Climate Change, Extreme Weather Events, and the Highway System: Practitioner's Guide and Research Report and accompanying CD are available from the TRB Online Bookstore, https://www.mytrb.org/store; the report can be viewed online at http://www.trb.org/Main/Blurbs/169781.aspx.

data that reflect actual conditions. A recent meeting of the grant recipients from the FHWA adaptation pilot studies noted that the available data limited the findings. Much of the data came from databases on pavement type, previous flooding records, average annual daily traffic, and the like, but other data had to be generated.

The lack of climate data that are relevant to engineering and are spatially precise—coupled with uncertainties about the quality of the data—raises obstacles, despite the best efforts of climate modelers. This lack, however, should not be an excuse for inaction.

Diagnostic Framework

NCHRP 750, Volume 2, presents a diagnostic framework that provides transportation professionals with a step-by-step approach for assessing climate change impacts and deciding on a course of action. The framework applies to the systems planning level, as well as to individual projects:

1. Identify key goals and performance measures for the adaptation planning.
2. Define policies on the assets, asset types, or locations to be considered for adaptation.
3. Identify climate changes and the effects on local environmental conditions.
4. Identify the vulnerabilities of assets to the changing environmental conditions.
5. Conduct a risk appraisal of the assets, given the vulnerabilities.
6. Identify the adaptation options for high-risk assets and assess the feasibility, cost-effectiveness, and defensibility of the options.
7. Coordinate agency functions for the implementation of the adaptation program, and if possible, identify the agency's or the public's risk tolerance and set trigger thresholds.
8. Conduct site analyses to modify designs, operating strategies, maintenance strategies, construction practices, and the like.

Multidisciplinary Approach

The eight-step process is multidisciplinary and collaborative. State transportation agencies are not likely to have staff expertise in climate science. In most cases, agencies can work with a local university or with the state climatologist.

Often the vulnerability and risk assessment depends on local input to identify the most critical assets in an urban area. Actions by local communities and governments—such as land use approval and street or drainage design—could have an impact on the ability of state assets to handle larger loads; therefore coordination among the jurisdictions is necessary.

As agencies adopt transportation asset management (TAM) approaches, opportunities will arise to integrate consideration of weather risk and climate change into TAM objectives, data collection, performance measurement, monitoring, and decisions about resource allocation. The integration of weather and climate information into TAM will help agencies make targeted investments or allocation decisions to increase the resilience of the network and of individual assets to changing environmental conditions. A section of the report explores the relationship between climate change and asset management.

Leadership Role

The report concludes with a discussion of agency actions and initiatives. As noted, leadership is critical. Strong mandates—either legislative or administrative—to consider adaptation and to provide relevant data greatly encourage adaptation activities. Nevertheless, mandates are not a prerequisite—strong state or local leadership concerned about climate change can spur action, as shown by most examples in the United States.

Reference

1. Meyer, M., M. Flood, J. Keller, J. Lennon, G. McVoy, C. Dorney, K. Leonard, R. Hyman, and J. Smith. *NCHRP Report 750, Strategic Issues Facing Transportation, Volume 2: Climate Change, Extreme Weather Events, and the Highway System: Practitioner's Guide and Research Report.* Transportation Research Board of the National Academies, Washington, D.C., 2014. http://www.trb.org/Main/Blurbs/ 169781.aspx.

The Americans with Disabilities Act and Transportation

25 Years of Enabling Access

SCOTT J. WINDLEY

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July 26, 2015, marked the 25th anniversary of the Americans with Disabilities Act (ADA), a landmark law that establishes and protects the civil rights of people with disabilities. The law passed with sizable majorities in both houses of Congress and was signed by President George H. W. Bush on the South Lawn of the White House with many advocates and leaders of the disability rights movement attending.

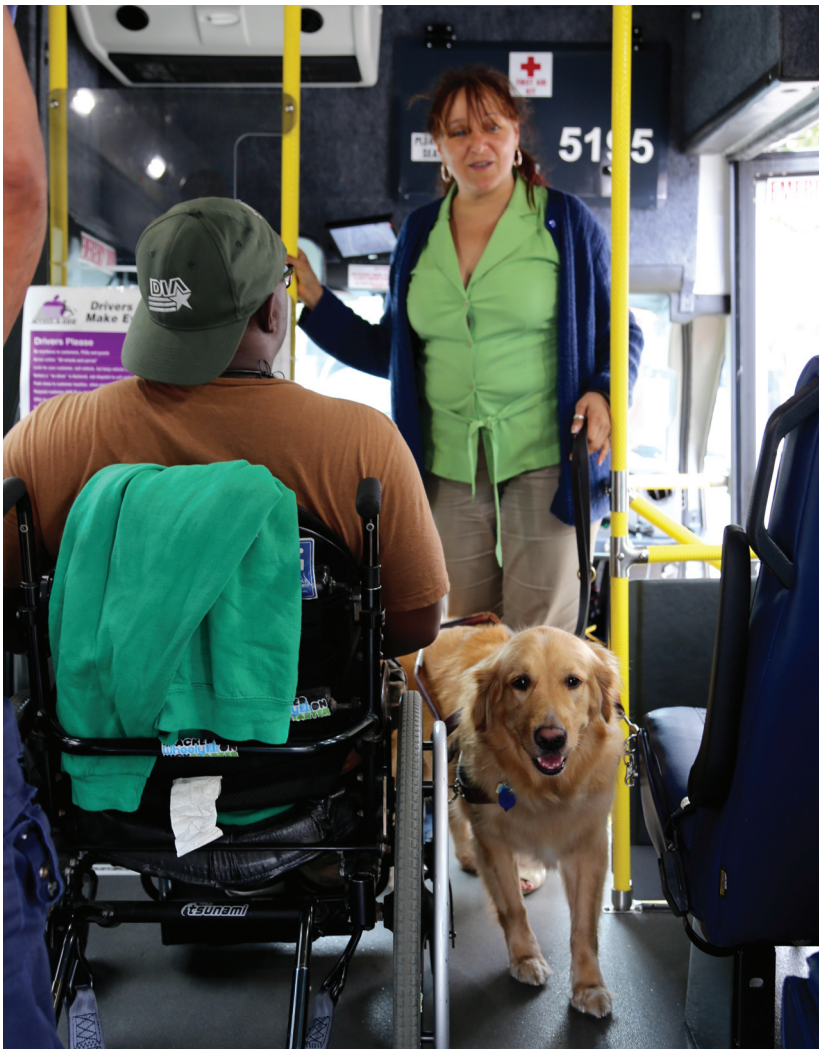


PHOTO: NEW YORK CITY DOT

The transportation provisions in the Americans with Disabilities Act (ADA) facilitated access to transit facilities and vehicles—and to services and employment—for people with disabilities.

"Three weeks ago we celebrated our nation's Independence Day," President Bush declared at the signing ceremony. "Today we're here to rejoice in and celebrate another independence day, one that is long overdue. With today's signing of the landmark Americans for Disabilities Act, every man, woman, and child with a disability can now pass through once-closed doors into a bright new era of equality, independence, and freedom."

The ADA comprehensively addresses equal access for people with disabilities. The law bans discrimination in the private and public sectors in employment, buildings and facilities, goods and services, communication, and transportation. The law's detailed language and statutory history reflect a clear understanding of the attitudinal and structural barriers that people with disabilities confront daily and of the opportunities and rights they routinely can be denied.

Developing Guidance

Some of the ADA's most detailed provisions pertain to transportation, which presented persistent and widespread barriers to access. The drafters of the law recognized that access to public accommodations, services, and employment would remain elusive if the means of reaching them remained off-limits. The drafters also recognized that the law's effectiveness depended on design requirements that specified what accessibility means in transit systems and in the built environment.

The ADA assigned the U.S. Access Board, an independent federal agency, the task of establishing minimum guidelines for the accessibility of buildings and facilities, including transportation facilities and vehicles. These guidelines serve as the basis for standards implemented by the U.S. Department of Transportation (DOT) to enforce the ADA.

Photo: National Museum of American History, Smithsonian Institution

President George H. W. Bush (*center*) signed the ADA into law in 1990, comprehensively barring discrimination against people with disabilities.

U.S. DOT also is responsible for regulating and enforcing other transportation provisions in the law, including those that apply to transit services, policies, maintenance, access to key stations, the provision of paratransit as a complement to fixed-route service, taxi service, and more. Other entities covered by the ADA—including places of public accommodation, commercial facilities, and state and local government properties—are subject to regulations issued by the Department of Justice; the regulations contain facility standards based on the U.S. Access Board's guidelines.

Transportation Standards

ADA standards for transportation facilities and vehicles were first issued in September 1991, a little more than one year after passage of the law. The Access Board's ADA Accessibility Guidelines (ADAAG) for Transportation Facilities formed the basis for the facility standards issued by U.S. DOT. The standards address new construction and alterations of bus stops and stations, rail stations, and other public transit system facilities.

At the same time, U.S. DOT adopted the Access Board's ADAAG for Transportation Vehicles as vehicle standards. These requirements cover access to new or remanufactured buses, vans, rail cars—in rapid, light, commuter, intercity, and high-speed systems—monorails, trams, and other public transportation vehicles.

The Access Board later conducted a comprehensive review and update of its ADA facility guidelines. This update introduced extensive changes to improve accessibility, facilitate compliance, and harmonize the guidelines with building codes—notably with the International Building Code—and with industry standards. In 2006, U.S. DOT adopted the updated guidelines as enforceable ADA standards; these remain in effect.

The Access Board is updating the ADA guidelines for transportation vehicles and—after public comment—is finalizing updates to the sections on buses and vans. Revisions to the section addressing rail cars will follow.

In 2013, the Access Board organized an advisory committee to review and recommend updates to the provisions for rail vehicles. The Rail Vehicles Access Advisory Committee included representatives from advocacy organizations, transit operators, rail car manufacturers, and other stakeholders. Last July, the committee submitted its report to the Access Board, which will complete a review and propose changes for public comment.

In addition to updating the vehicle guidelines, the Access Board is developing new guidelines for passenger vessels and for public rights-of-way.

U.S. DOT regulates and enforces ADA provisions for transit vehicles, such as the securement of mobility aids like wheelchairs.

Photo: Washington Metropolitan Area Transit Authority

Passenger Vessels

Requirements for passenger vessels have yet to be established under the ADA. The Access Board has proposed guidelines for cruise ships and other large vessels, including ferries, for public comment. The guidelines address challenges unique to vessels, such as coamings—or raised frameworks—at doorways, and establish criteria for onboard routes, vertical access between decks, guest rooms, and other elements.

The guidelines would apply to new or altered vessels that carry more than 150 passengers or at least 50 overnight passengers, or—in the case of ferries—100 or more passengers. The Access Board is finalizing the guidelines, which will become available for U.S. DOT to adopt as enforceable standards.

Photo: Bureau of Educational and Cultural Affairs, U.S. Department of State

ADA access guidelines for transportation vehicles cover access to buses, rail cars, trams, and passenger vans.

Public Rights-of-Way

The Access Board also is completing work on new guidelines for public streets and sidewalks. Sidewalks, street crossings, and other elements in the public right-of-way can pose challenges to accessibility. Although the current ADA standards for facilities address certain features common to public sidewalks—such as curb ramps—additional guidance is necessary to address conditions and constraints unique to public rights-of-way.

The new guidelines will cover pedestrian access to sidewalks and streets, including crosswalks, curb ramps, street furnishings, pedestrian signals, parking, and other components of public rights-of-way. The guidance will address a variety of issues, such as access for blind pedestrians at street crossings, wheelchair access to on-street parking, and the constraints posed by space limitations, roadway design practices, slopes, and terrain. The Access Board expects to issue the final guidelines in 2016.

Research sponsored by the National Cooperative Highway Research Program (NCHRP) has helped inform this rulemaking. NCHRP projects on accessible pedestrian signals and on roundabouts have collected data particularly helpful to this effort.

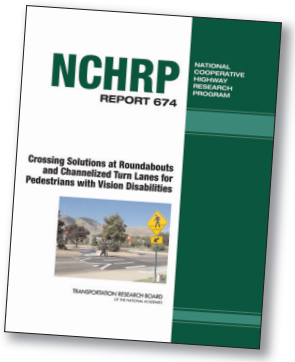
Resources

Besides writing and updating accessibility guidelines under the ADA and other laws, the Access Board provides technical assistance and training on the guidelines and on other aspects of accessible design. The Access Board operates a toll-free help line to answer questions about requirements in the ADA standards. The Access Board also conducts a free webinar series, and representatives regularly travel throughout the country on request to provide training at events and conferences.

The Access Board's website (www.access-board.gov) includes copies of all the accessibility standards and guidelines issued under the ADA, as well as information on guidance in development. Resources and related guidance also are available on the site.

The Access Board has launched a comprehensive, web-based guide to the ADA standards that features illustrated technical bulletins explaining and clarifying provisions, answering common questions, and offering recommendations for best practices. The guide also includes a series of animations on various accessibility-related topics.

The Federal Transit Administration and the Federal Highway Administration are key sources of information on the ADA and transportation. Both agencies post the U.S. DOT's ADA regulations, circulars, and other resources. FTA's website on accessibility is www.fta.dot.gov/civil_rights.html, and the FHWA website is www.fhwa.dot.gov/civilrights/programs/ada.cfm.



Several NCHRP reports, such as Report 674, *Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Vision Disabilities*, have informed Access Board decision making.

New York City DOT conducts hands-on accessibility tours of city streets. Crosswalk access for visually impaired pedestrians is addressed in the U.S. Access Board's new guidelines for public rights-of-way.

Photo: New York City DOT

Five Tips for Developing a Brain-Friendly Presentation

SHELLEY ROW

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The colors are vibrant and the images graphic and emotion-filled. Within moments the unfolding story captivates the beholder.

The Bayeux tapestry, located in Northern France, is a stunning work of art and a masterpiece of communicating a complex issue to an overwhelmed and distracted audience. The tapestry, 231 feet long and 20 inches high, was stitched in 1077 and depicts the Battle of Hastings, fought 11 years earlier.

The victors needed to communicate the battle's political outcomes to an illiterate population. The tapestry designers did not show data on the number of soldiers or create detailed graphs of the battle plan. Instead, they crafted a story line that unfolds in vivid colors. A viewer can feel the pain of the men and the horses. The effect is memorable. The designers of the Bayeux tapestry knew the importance of communicating with interest, emotion, and fact.

A presenter today does not have to stitch a tapestry or engage an illiterate audience. Typically, a presenter collects the data, does the analysis, and develops a well-thought-out recommendation. Nevertheless, the public is disgruntled and will not listen, and the boss makes a politically driven decision that runs counter to the analysis.

How can a presenter make the audience understand the inherent logic? The lessons from the ancient tapestry advise the tactic of communicating with—not presenting to—the audience.

Advice on successful communication and presentation skills is readily available; the focus here, however, is on applying insights from neuroscience to understand how to make a presentation brain-friendly. Before a discussion of the five elements of an effective presentation, consider two fundamental brain principles that establish a background.

A detail from the 70-meter-long Bayeux Tapestry shows Odo, William the Great's half-brother, cheering his troops in the Battle of Hastings, 1066.

Reward and Threat

The brain has a reward center, the *nucleus accumbens*, and a threat center, the amygdala. Activating the reward center is preferable in most situations that involve informing or persuading. In contrast, activating the threat center causes people to behave emotionally, illogically, and even to lash out.

Several conditions activate either the reward or the threat center—particularly control, certainty, connection, and clout:

- The perception of control activates the reward center. Conversely, the perception of a loss of control activates the threat center.
- The same applies to certainty, a reward, and uncertainty, a threat.
- Connection is a sense of relatedness to others, a reward; the sense of disconnection from others creates a threat.
- Clout is a feeling of status, a reward, or of the loss of status, a threat.

The skillful use of these conditions can have a positive or a detrimental impact on a presentation.

Photo: Institute of Physics

Skillful delivery and use of materials are key to effective communication; scientist Maggie Aderin-Pocock taps these techniques in a lecture on space travel at an Institute of Physics program in London.

Cognitive Load

The brain has an extensive memory capacity in its long-term storage. In contrast, working memory, which includes the executive control function in the prefrontal cortex, is powerful but much more limited. This part of the brain contains logic and reasoning, and helps a person think through a problem.

Research shows that working memory holds only four to seven items of information at a time. Moreover, working memory is an energy hog in the brain and quickly tires. Because of this, a person often feels fatigued after extensive focus—for example, after a packed day of Transportation Research Board (TRB) Annual Meeting committee meetings, sessions, or training. Making skillful use of this limited brain energy is important for both a communicator and the audience.

Five Elements

Mindful of this background, a communicator should consider five elements when creating a presentation, whether for a nontechnical audience or a technical audience:

1. Clear purpose,
2. Knowledge of the audience,
3. Structured content,
4. Powerful materials, and
5. Skillful delivery.

Clear Purpose

The creators of the tapestry knew their goal: Communicate the history and the political outcome of the Battle of Hastings to citizens. Today's communicator should have similar clarity, whether informing a group, seeking specific action, persuading to a viewpoint, guiding a decision, or simply listening.

Be clear about the purpose of the presentation. This may seem obvious but is an often underappreciated step, missed frequently. The meeting ends, and the participants are left wondering, "What was the point?"

Before walking in the door, a presenter should know the purpose and state it up front. What is the ideal outcome? What does success look like? What is the "ask"? State the purpose up front. This reassures the audience and confirms expectations. Ask for confirmation from the audience or from key players that they understand and agree with the expressed purpose.

Neuroscience tip: Clarity of purpose creates certainty for the audience. Asking for confirmation of the purpose creates a perceived sense of control. Both certainty and control activate the brain's reward center—this makes for a good start to the presentation.

In addition, clarity of purpose reduces the cognitive load. The audience does not need to use precious brain energy to figure out the point. Make it easy—tell them. Preserve their brain power for more important tasks.

Know the Audience

The citizens of 11th-century France were illiterate, poor, and spent their days eking out a living. To care about a distant battle and its outcome, they needed to be engaged and intrigued. The tapestry creators knew that a story would capture their attention.

Photo: TEDx San Diego

A successful communicator considers the audience, as well as the purpose and content of the presentation.

Analytical and scientific work focuses on facts, methodology, and analysis. For an important meeting, particularly involving a nontechnical audience, however, a communicator should make the effort to understand the audience and its needs. Create a connection. Apply the following practical tips:

◆ *What's in it for me?* Each audience member is asking, "What's in it for me?" A communicator should consider this perspective and answer the question. Some audiences already have opted in, as at a public meeting, a community association event, or a TRB session—the audience has chosen to be there. Why did they take time to walk in the door? Know what's in it for them when preparing the program.

◆ *Character sketch.* Create a character sketch of the decision maker or of the group. The more a presenter knows about the audience's interests and motivations, the better the presentation can be tailored, with examples added to create a connection and to appeal to the reward center. Consider the following factors:

- The group's interests, concerns, and history;
- The political climate and the career trajectory and risk profile of the decision maker; and
- The consequences of the decisions: Are credibility, embarrassment, power, or an election at stake?

◆ *Cultivate a connection in advance.* The messenger matters. People respond more readily to someone they like and who is similar to them. A communicator should learn about the group and its concerns and reflect that understanding in the presentation. The audience will respond.

Of course, the presenter sometimes may not be the most welcome person at a meeting—for example, when representing a project opposed by the community. When the "high-powered consultant" credential is not viable, a presenter may be able to find a respected community leader to accompany or to make introductions. Persuasion is a social, not a logical, act.

Neuroscience tip: The brain is designed for personal connection. When a person feels part of an in-group, the reward center is activated; empathy and collaboration are enabled. The greater the connection with the audience and decision makers, the more likely they are to listen.

When a communicator comes across as representing the "out-group" and exhibits little understanding of the audience, an audience member's brain registers distrust and alarm. As a result, each member of the audience has to overcome this resistance before even starting to listen.

The brain's threat center is highly sensitive to anything that jeopardizes clout or status. If the decision that is sought puts the decision maker in a dilemma, the decision maker's threat center is activated. The communicator should find a way to reframe the recommendation to build status.

A presenter only armed with data comes across as tone deaf. Decision makers shake their heads and say, "They just don't get it." That assessment is correct, unless the presenter knows as much about the people as about the topic.

Content Structure

Benjamin Franklin said, "I have already made this paper too long, for which I must crave pardon, not having now time to make it shorter." Ben was right—whittling a topic down to its essence takes time and effort. For example, a briefing to the Secretary or Deputy Secretary of Transportation is allotted only one half-hour, often less. In such constraints, be crystal clear on the ask, know the what's-in-it-for-me, and have a concise, organized structure—these are essentials. Following are the basics for an organizing structure.

Opening

Research shows that analytically inclined and highly engaged people respond positively to facts and data. People who are less engaged respond to emotion-based information. Nonetheless, all people need an initial reason to pay attention; a compelling opening that connects at an emotional level accomplishes this most effectively.

Yet 95 percent of TRB sessions open with the statement, "Thank you for the opportunity to be here. I'm honored to be with my colleagues today."

This is polite but boring. An opening subliminally tells the audience whether this presentation is the same ol' thing or something worthy of their brain's energy.

A communicator should be thoughtful about the first sentences. Try a quotation, an attention-getting statistic, or a story that connects the topic with the interests of an audience wondering "What's in it for me?"

For example, several years ago, a TRB session on the state of the U.S. DOT Intelligent Transportation Systems (ITS) program highlighted advances since the first ITS Strategic Plan. The presentation opened: "The year is 1992. The Washington Redskins just won the Super Bowl, and 'Achy Breaky Heart' was a Billboard hit. And the first ITS Strategic Plan was just released."

Within seconds, the predominantly hometown crowd of Redskins fans was hooked, and music hummed in their heads. But what was most important was that their attention was focused on the presentation. Create an interesting, attention-getting opening that connects with the audience and captures their attention early, and they will be more likely to stay focused on the presentation.

The One Thing

What is the one thing that the audience should remember? Can that one thing be explained easily and simply to anyone? If not, try again. A presenter should be clear about what the audience should remember. State the one thing, repeat it, repeat it, and repeat it. Repetition is a key way of telling the brain to store the information into memory.

Neuroscience tip: Information has to compete for space in the working memory, which can hold only four items of active information at once. A presenter should be clear about what an audience member's brain should store, by stating the one thing clearly and succinctly to place it into short-term memory and reinforcing it frequently enough to embed in the long-term storage—a process known as long-term potentiation.

Use of Time

Research confirms that people remember the first and last points they hear. Use those prime-time slots for the one thing and for the conclusions, which may be the same as the one thing. Time and again, a TRB presentation starts with a detailed explanation of data collection, methodology, and analysis. But before the results can be explained, the speaker says, "I am out of time and will flip quickly through the last slides." Methodology, data collection, and analysis are not likely to be the most important points for a nontechnical audience—the conclusions will.

Key Points

A clear organizing structure gives the audience a road map for the presentation and creates a sense of certainty, activating a sense of reward. After a compelling opening that highlights the one thing, state the presentation's structure, including three to five key points.

A presenter should think about how to commu-

Image: Library of Congress Prints and Photographs Division

Benjamin Franklin, speaking to lords in council in London's Whitehall Chapel, recognized the importance of brevity in communications.

Photo: U.S. Department of Agriculture

U.S. Agriculture Secretary Tom Vilsack answers audience questions at a community meeting. Connecting with listeners on a personal level often helps a speaker gain trust.

Photo: Kevin Krecl, Flickr

Michael Arrington of TechCrunch poses a question to the Disrupt SF 2014 conference audience.

nicate each point effectively. Not everyone consumes information in the same way, complicating the presenter's task. Highly motivated people will listen to facts and analysis, but others need examples, a story, or an analogy.

The best option is to provide both for each point—state the point succinctly and include a fact-based statement and an analogy. This approach increases the likelihood that each point will be memorable from the analogy or story and will have credibility through the facts.

Closing

Questions do not have to wait until the end. The presenter can use questions throughout to engage interest and to track the audience's understanding. If the questions are deferred to the end, the presenter should leave time after the questions for a summary and a memorable closing. The last words the audience hears should be a compelling comment from the presenter that reiterates the what's-in-it-for-me and the one thing.

Powerful Materials

Like the color and artistry of the Bayeux tapestry, the design of presentation slides makes a difference in the attention and retention levels of the audience. A communicator should pay careful attention to the following elements.

Visual Images

PowerPoint or Keynote slides do not constitute a script. Slides should not display complete sentences or texts. Text-filled slides serve no one—the audience least of all. PowerPoint is a powerful tool for visual communication. For retention, replace text with images.

Words that convey visual metaphors also can be powerful. For example, in a recent presentation, U.S Transportation Secretary Anthony Foxx discussed moving 14 billion tons of freight and likened the amount to a "small mountain of freight"—an excellent use of visual language. Marrying the words to an image of a small mountain makes a memorable point.

Neuroscience tip: The brain's language center activates when a person is reading or listening to speech. The language center, however, does not multitask and cannot focus on reading and listening simultaneously, only on one task or the other. Filling the screen with text invites the audience to switch from listening to reading the text. Should the audience be listening or reading? They can do only one.

Neuroscience tip: Images activate the visual center in the brain. The visual center and the language center work well together. When both are active, memory is heightened. Highly skilled presenters therefore use images that visually reinforce the spoken points.

Charts and Graphs

Not everyone can read a graph or chart quickly. Do not make the audience feel lost. Instead, design a chart or graph that communicates one key point. For example, allow the graph to become background

Photo: Kris Krug, Flickr

Diagnostics for All cofounder Hayat Sindi uses image-heavy PowerPoints—as well as a physical model—to describe new point-of-care diagnostic tools microfabricated from paper.

and highlight the key point in the foreground. Clearly and visually identify the point for the audience to grasp—they should not have to work to figure it out.

Bullet Slides

Do not use slides with bulleted points. If bullet slides are necessary, make them interesting—but not by changing the bullet from a black dot to a check mark. At a minimum, use color for the key words. The PowerPoint SmartArt tool offers a handy and simple way to convert bullets into colorful graphics.

Handouts

A PowerPoint deck should not serve as the handout for the presentation. An effective visual presentation loses its effectiveness as a slide-by-slide handout. Instead, design a companion handout that includes more detailed information for the analytically oriented, plus references, website addresses, complete graphs and charts, and other details. A handout should be a value-added complement to the program, providing additional relevant information and improving retention.

Skilled Delivery

Communication is a two-way process. The communicator is not presenting to an audience but communicating with them. Even in a formal presentation, as at a TRB Annual Meeting session, a speaker can communicate interest through eye contact and engagement. Think of the presentation as a one-on-one conversation, with one in the front, one in the back, one on the right and one on the left.

Engage the audience throughout the program. Ask for input by raised hands responding to questions. Attendees who are actively engaged pay attention and are not distracted. Multitasking decreases the accuracy of each of the multiple tasks by 20 to 50 percent. A multitasking audience therefore absorbs even less of what is being communicated.

In contrast, learning and retention soar with active engagement. The more the communicator invites the audience to consider and apply the points to their own situations, the more learning takes place.

Neuroscience tip: No matter how skilled the presenter, the audience will forget most of what was said. Studies show that retention improves dramatically with interaction and follow-up reminders. Optimally, allow for interaction every 10 minutes or so. Raising a hand, responding to questions, or sharing an observation with a neighbor or with the speaker enhances an audience member's learning and retention.

Photo: Rispon Photography

U.S. Transportation Secretary Anthony Foxx—shown here at the 2015 TRB Annual Meeting—uses vivid language and effective imagery when he speaks.

For follow-up, e-mail a summary to participants a few days after the program, as a reinforcement. For example, after a community association meeting, e-mail a summary to the organizers to share in the community newsletter or website. The follow-up may include the main points and a summary of the input for the attendees.

Neuroscience tip: Working memory captures information in the moment, but the information is not embedded in long-term memory until later. Memory consolidation happens best during periods of deep sleep. Consequently, follow-up reminders work best when delivered the next day or a few days later.

Effort and Time

Embroidery may not be needed for a TRB presentation or for a city council briefing, but the communication lessons from an 11th-century fabric version of a PowerPoint deck still apply: Be clear about the purpose, know the audience, organize the content, develop powerful materials, and skillfully deliver the information.

Presenters invest time in understanding the material but generally spend less time in understanding the audience and the audience's needs. Developing a brain-friendly program requires effort and time, but a presenter owes it to the audience to make that effort. What is all that research and analysis for, if the audience does not understand and apply it?

By the way, the French won the Battle of Hastings. *Vive la France!*

Innovative Inspection Devices Help Extend Timber Bridge Life Spans

How Local Engineers Can Use State-of-the-Art Technology to Address Deterioration and Save Money

ERICA LARSEN AND RENAE KUEHL

Larsen is Senior Marketing Communications Specialist, and Kuehl is Senior Associate–Traffic Safety Engineer, with SRF Consulting Group, Minneapolis, Minnesota.

Editor's note: *This article is adapted from the technical summary, "Timber Bridge Life Spans Extended with Innovative Inspection Devices," published by the Minnesota Department of Transportation Research Services and Library in February 2015. The technical summary is available at www.lrrb.org/media/reports/201501TS.pdf.*

Common in rural areas, timber bridges are an important component of the U.S. highway system. More than 48,000 bridges in the United States contain structural timber in the superstructure or substructure, according to the National Bridge Inventory (NBI) of December 2012. Approximately 2,000 of these timber bridges are located in Minnesota; many of these were built in the 1950s and 1960s and now may be experiencing some level of deterioration.

Problem

Although praised as environmentally friendly in comparison with other bridge types, wooden bridges are prone to deterioration caused by moisture in the wood, as well as by fungi, insects, and mechanical damage. This damage often occurs within the wood, not on the surface, making the deterioration difficult to detect.

A timber cap abutment has collapsed onto a timber piling as a result of decay and bearing loads.

Traditional inspection techniques—such as visual inspection, sounding with a hammer, and coring—often miss early-stage or internal damage in timber bridges. Although providing general findings on the bridge's condition, traditional inspection methods do not supply engineers with accurate information for making confident and informed decisions about corrective measures to extend a bridge's service life safely. Engineers need to assess the load ratings and to plan for replacement or repairs. A research project therefore was initiated to identify inspection techniques that would enable local engineers to address deterioration and extend timber bridge life, saving agencies the costs of detours and bridge replacements.

Solution

Research Objectives

The project developed a comprehensive research and evaluation program to address the evaluation and inspection of timber bridges. Several organizations collaborated on the project, including the Natural Resources Research Institute at the University of Minnesota–Duluth; the State Aid and Bridge offices of the Minnesota Department of Transportation (DOT); the Local Road Research Board; the Iowa Highway Research Board; the Bridge Engineering Center at Iowa State University; the U.S. Department of Agriculture's Forest Products Laboratory in Madison, Wisconsin; and HDR, Inc.

The project sought to achieve the following primary goals:

- Identify state-of-the-art nondestructive evaluation (NDE) techniques and equipment for inspecting timber bridges,
- Develop inspection protocols and procedures for entering the information into Minnesota's Structure Information Management System (SIMS),
- Develop an inspection manual for timber bridges, and
- Train local and state bridge safety inspectors and engineers in each Minnesota DOT district.

A long horizontal split provides an opportunity for moisture to pass through the timber deck and enter the abutment cap, leading to substantial decay.

Scope and Tasks Performed

Researchers first reviewed NDE techniques and technologies for timber bridges and developed a list of equipment. The best methods found for determining deterioration included measuring the moisture in the wood, the velocity of a stress wave across the wood, and the wood's resistance to drilling.

The researchers developed protocols for using the most promising equipment, as well as new forms for reporting data on timber bridges in Minnesota's SIMS. Researchers performed an economic assessment of the proposed protocols, recommended inspection equipment, and developed a short course on timber bridges for local inspectors and engineers. The course was presented to more than 140 participants in Minnesota and Iowa. Finally, researchers described techniques for using inspection tools in the *Timber Bridge Inspection Manual*, which supplements Minnesota DOT's *Bridge Inspection Field Manual*.

Findings and Recommendations

After receiving feedback from Minnesota county engineers and the Minnesota DOT Bridge Office, researchers recommended the following equipment for timber bridge inspection:

- **Moisture meter.** Timber generally will not decay if the moisture content is less than 20 percent; as the moisture content increases, decay becomes more likely and more serious. Moisture meters effectively measure the levels of moisture in timber bridges.
- **Stress wave timer.** This instrument identifies decay by measuring stress wave propagation across the grain in wood members. Stress waves typically travel more slowly through deteriorated timber than through high-quality timber.
- **Resistance microdrill.** This instrument measures the wood's resistance to a drill bit with a small diameter—approximately three millimeters—to identify decay, voids, or termite damage.

The complete timber bridge inspection kit, including more general equipment, such as an inspection hammer and basic safety equipment, ranges in cost from $8,800 to $13,300, primarily depending on the model of microdrill. Less expensive models present data on a paper printout, which some bridge safety inspectors and engineers prefer, but other models collect data electronically for transmission via Bluetooth, or wireless connection.

Application

Several counties have purchased inspection equipment, and Minnesota DOT has purchased three complete sets—each with a different type of microdrill—for counties' use. The Natural Resources Research Institute at the University of Minnesota–Duluth is managing this equipment for counties for two years, while Minnesota DOT collects feedback.

A pin-style moisture meter is used to determine the moisture content of timber elements.

A resistance microdrill is the preferred drilling inspection technique for timber bridge elements.

The Minnesota DOT Bridge Office is creating a portal on its website on the topic of timber bridge inspection, which will include information from this research, along with training materials, videos, the inspection manual, case studies, and a link to request a loan of the Minnesota DOT equipment.[1] Minnesota DOT's refresher sessions in bridge training in each district every spring will incorporate the information from the project. The investigators are working with the Minnesota Local Technical Assistance Program to offer the timber bridge short course annually.[2]

[1] www.dot.state.mn.us/bridge/inspection.html.
[2] www.mnltap.umn.edu/.

Benefits

The recommended methods of timber bridge inspection offer several key benefits.

First, the inspection tools produce definitive and clear results, providing reliable data for engineers in decision making about the repair or replacement of a bridge. The methods allow engineers to understand fully the condition of each bridge and to optimize bridge maintenance plans, deferring noncritical repairs.

Second, an economic assessment found that the NDE techniques could extend the service life of timber bridges by 10 years or more and could improve the safety and reliability of Minnesota's bridges.

Finally, the proper inspection equipment can provide the information needed to identify and implement specific actions to save money by reducing replacement costs—as well as the user costs related to detours,

Economic analysis suggests that in nearly all cases, the extended service life and the reduction in truck detours justify the costs of the inspection tools and techniques. Researchers are conducting a follow-up project to investigate cost-effective timber bridge repair techniques. Results from this study are forthcoming.

For more information, please contact Technical Liaison David Conkel, Minnesota Department of Transportation, Dave.Conkel@state.mn.us.

Resources

Accelerator, March–April 2015, www.dot.state.mn.us/research/accelerator/Accelerator-March2015_WEB.pdf.

Demonstration videos of inspection techniques. https://www.youtube.com/watch?v=opT2N053ToQ&feature=youtu.be.

Development and Integration of Advanced Timber Bridge Inspection Techniques for NBIS, Final Report. www.dot.state.mn.us/research/TS/2015/201501.pdf.

Timber Bridge Life Spans Extended with Innovative Inspection Devices: Technical Summary. Minnesota Department of Transportation Research Services and Library, February 2015. www.lrrb.org/media/reports/201501TS.pdf.

Editor's Note: Appreciation is expressed to Stephen F. Maher and G. P. Jayaprakash, Transportation Research Board, for their efforts in developing this article.

Suggestions for Research Pays Off topics are welcome. Contact G. P. Jayaprakash, Transportation Research Board, Keck 488, 500 Fifth Street, NW, Washington, DC 20001 (202-334-2956; gjayaprakash@nas.edu).

CALENDAR

TRB Meetings

January 2016

9 TransportationCamp DC 2016
Arlington, Virginia

10–14 TRB 95th Annual Meeting
Washington, D.C.
For information, visit www.trb.org/AnnualMeeting/Annual Meeting.aspx

21–22 Shifting International Trade Routes Workshop
Tampa, Florida

April

3–5 Lifesavers Conference
Long Beach, California

13–16 World Steel Bridge Symposium*
Orlando, Florida

14–15 Ferry Safety and Technology Conference
New York, New York

22–28 World Tunnel Congress
San Francisco, California

25–27 International Conference on Winter Maintenance and Surface Transportation Weather
Colorado

May

1–4 6th Conference on Innovations in Travel Modeling
Denver, Colorado

1–4 North American Travel Monitoring Exposition and Conference (NATMEC): Improving Traffic Data Collection, Analysis, and Use
Miami, Florida

4–6 15th International Conference on Managed Lanes
Miami, Florida

17–19 Road Safety on Five Continents*
Rio de Janeiro, Brazil

June

TBD Use of Scenario Planning in Transportation Planning
Portland, Oregon

14–16 International Symposia on Enhancing Highway Performance: 7th International Symposium on Highway Capacity and Quality of Service and 3rd International Symposium on Freeway and Tollway Operations*
Berlin, Germany

21–23 From Sail to Satellite: Delivering Solutions for Tomorrow's Marine Transportation Systems
Washington, D.C.

26–30 8th International Conference on Bridge Maintenance, Safety and Management*
Foz do Iguaçu, Brazil

26–29 American Society of Civil Engineers International Conference on Transportation and Development*
Houston, Texas

July

TBD Transportation-Related Environmental Analysis, Ecology, and Historic and Archeological Preservation Summer Conference
Salt Lake City, Utah

TBD Resource Conservation and Recovery Summer Conference
Asheville, North Carolina

11–12 11th National Conference on Transportation Asset Management
Minneapolis, Minnesota

16–18 International Conference on Transportation Infrastructure and Materials
Xi'an, China

25–27 GeoChina 2016 International Conference*
Shandong, China

Additional information on TRB meetings, including calls for abstracts, meeting registration, and hotel reservations, is available at www.TRB.org/calendar. To reach the TRB staff contacts, telephone 202-334-2934, fax 202-334-2003, or e-mail TRBMeetings@nas.edu.

*TRB is cosponsor of the meeting.

Hyun-A Park

Spy Pond Partners, LLC

Hyun-A Park began her career with the Massachusetts Division of Capital Planning and Operations—the agency that oversees the state's building facilities—working to improve its network-level decision making. She joined Cambridge Systematics in the 1990s as an associate and a few years later became a vice president and head of the asset management business unit.

After participating in the Central Artery–Tunnel Project (the "Big Dig") in Boston, Park discovered the opportunities in transportation research through TRB and the U.S. Department of Transportation (DOT). "It was exciting to be in the transportation industry, where funds were available to research ways to improve business practices that would benefit the industry as a whole rather than just one organization," comments Park. "The value of broad impact was very appealing to me."

"I get to sit at the table with peers and customers and to have a dialogue on issues that keep transportation leaders awake at night."

Since then, Park has worked with many organizations at the local, state, and federal levels. In 2006, she cofounded Spy Pond Partners, LLC, a management consulting firm that helps transportation and infrastructure management organizations make the best use of their resources. As the firm's president, Park is responsible for business development, strategic planning, and organizational development.

Park coauthored the *AASHTO Transportation Asset Management Guide: A Focus on Implementation*, published in 2013 by the American Association of State Highway and Transportation Officials (AASHTO) and U.S. DOT. The guide describes transportation asset management (TAM) as a planned approach for the effective operation, maintenance, and enhancement of physical assets throughout their life cycle, with a focus on best practices for resource allocation and utilization. "I've loved seeing the growing importance of TAM over the past 20 years," Park muses. "It is gratifying to see the research products that I contributed to used by transportation agencies as a key resource."

Park has spearheaded a variety of TAM projects, from a comprehensive web portal for TAM resources to a multipart asset management webinar series. She has produced peer exchanges on asset management for the Federal Highway Administration and AASHTO. At the Asset Management and Maintenance peer exchange in 2013, topics included the relationship between asset management and maintenance, TAM plans and the Moving Ahead for Progress in the 21st Century Act (MAP-21), TAM plans and risk management, and TAM and financial plans. Park also is developing MAP-21 asset management plans for the state transportation agencies of Connecticut, Maryland, New Mexico, Rhode Island, and Virginia.

"It has taken time and many research efforts to build the momentum for the energy that exists around TAM today," Park observes. "This has made these resources available to Congress in creating the MAP-21 TAM-related requirements."

Park has served as principal investigator or team member for many National Cooperative Highway Research Program projects, from working with state DOTs to advance performance management practices to developing a guide for effective handling of workforce issues. "On the business front, TRB has been a forum for me to get a sense of current issues for transportation agencies, as well as pressing needs," Park comments. "I get to sit at the table with peers and customers and to have a dialogue on issues that keep transportation leaders awake at night."

Park joined the Standing Committee on Management and Productivity in 1996. Two years later, she became a member of the Standing Committee on Strategic Management and served as its chair from 2005 to 2011. She then became chair of the Management and Leadership Section in 2011 and chair of the Policy and Organization Group in 2014. She is a member of the Technical Activities Council and a friend of the Standing Committee on Transportation Asset Management.

"My involvement with TRB has been one of the highlights of my career. It has added tremendous value to my business progress and to my personal growth as well," she notes. "My advice to younger professionals is to engage in TRB and find a mentor who guides you in the richness of experiences that TRB has to offer. Kathy Stein, past chair of the Strategic Management Committee, provided this guidance to me when I was first involved in TRB. The plethora of opportunities can be overwhelming, so making good choices on the best options for you is an important step. Staying abreast of research activities enables young professionals to look at day-to-day problems from different perspectives—making it easier to get greater insights for the work you are doing."

Mark Robinson

DBi Services

In his more than 20 years of transportation experience, Mark Robinson has worked directly with transportation agencies in designing, implementing, managing, and evaluating performance-based contracts and in applying innovations to transportation maintenance, operations, construction, and safety. Robinson is senior vice president at DBi Services, managing its Asset Management Business Unit and supporting company-wide growth strategy. In his operations role, he leads a team of frontline managers and field staff, covering 23 large, performance-based maintenance programs across North America, with annual revenue of $130 million. In his strategy role, he assists other company leaders and managers to enter new markets, seeks innovative deals and partnerships, and develops and implements new initiatives.

"Whether we are talking about advanced materials for patching potholes, or new equipment and techniques to let us get maintenance done faster and safer, research plays a key role in supporting advances in the field."

"The neat thing about maintenance and operations is that the decisions you make now will have an immediate impact on the traveling public," Robinson observes. "This makes it an ideal environment for applied research—we are continuously looking for and trying new ways to solve the challenges of an aging infrastructure."

Before he joined DBi in 2014, Robinson spent 19 years at SAIC, now called Leidos. He joined SAIC in 1995 as a traffic engineer and moved up through the organization to become vice president and director of transportation solutions in 2008. He collected and disseminated guidance on best practices, managed staff activities, led business growth and strategy, and oversaw a variety of programs, including an integrated logistics services contract with the Transportation Security Administration, a Federal Highway Administration (FHWA) American Traffic Safety Services Association Work Zone Safety grant, performance specifications and contracting for FHWA's Highways for LIFE program, and transportation asset management programs for the District of Columbia Department of Transportation, and many FHWA task order contract vehicles.

Robinson appreciates the emphasis on results that is characteristic of performance-based maintenance and operations, and muses that challenges and obstacles should be viewed not as roadblocks but as opportunities for exercising professional judgment, innovation, and research results. "We constantly are focused on solutions, and so we are always hungry for the latest research," he notes. "Whether we are talking about advanced materials for patching potholes, or new equipment and techniques for faster and safer maintenance, research plays a key role in supporting advances in the field."

A certified Project Management Professional and a registered professional engineer in Ontario, Canada, Robinson received a bachelor's degree, master's degree, and Ph.D. in civil engineering from Queen's University in Ontario. He played on the 1992 National Championship football team at Queen's and was inducted into the university's Hall of Fame in 2010. He credits his experience with college football for some aspects of his management philosophy: "You win and lose as a team. Play the position that you're meant to play and do the same for your employees. Be flexible and have a sense of humor. Don't celebrate until you have won the game."

Robinson observes that a lasting outcome from his engineering education is the ability to solve problems. He places a major emphasis on communication and collaboration, on encouraging diverse perspectives, and on solutions rather than problems, noting that technicians and managers should be able to solve the majority of the problems they encounter and should seek the advice of a supervisor for the rest. "Make action plans and hold yourself to them. The best idea has no impact if it isn't implemented," he comments.

Robinson joined the Standing Committee on Maintenance and Operations Management in 2006. In 2015, he became its chair and, as chair, a member of the Maintenance and Preservation Section. He served on the Standing Committee on Safety Management from 2007 to 2010. He also is a member of the Project Management Institute and a recipient of FHWA's Partnership in Excellence Award.

Robinson has authored or coauthored many research papers and has made many presentations at professional conferences, including "Long-Term Effects of Maintenance Programs," presented at the DBi Infrastructure Management Symposium; "Performance Contracting for Construction—It's Not Just for Maintenance," presented to the International Road Federation in Washington, D.C.; and "Performance Contracting for Construction: A Framework for Implementation," presented at the TRB Annual Meeting.

EMERGING TRENDS IN FREIGHT DATA—In October, researchers gathered for the Commodity Flow Survey (CFS) Workshop at the Keck Center in Washington, D.C. Ken Allen, H-E-B Stores (retired); Jose Holguin-Veras, Rensselaer Polytechnic Institute; Cavan Capps, U.S. Census Bureau; and Michael D. Meyer, WSP–Parsons Brinckerhoff, discussed major supply chain trends and the future of the CFS.

COOPERATIVE RESEARCH PROGRAMS NEWS

Guide for Bridge Preservation Actions

Many transportation agencies are experienced in bridge preservation. The short- and long-term performance of specific actions for bridge preservation has not been identified, measured, evaluated, or documented, however; lacking information about the quantified effectiveness of a given action, many practitioners must rely on judgment or common sense.

The University of Colorado at Boulder has received a $300,000, 27-month contract [National Cooperative Highway Research Program (NCHRP) Project 14-36, FY 2011] to develop a bridge preservation guide for the American Association of State Highway and Transportation Officials that includes a catalog of bridge element preservation actions and the criteria and selection methodology for these actions, with associated costs and benefits for use in life-cycle cost analysis.

For more information, contact Waseem Dekelbab, TRB, 202-334-1409, or wdekelbab@nas.edu.

Transit Asset Condition and Service Quality

To support transit investment prioritization, Spy Pond Partners, LLC, has received a $350,000, 18-month contract [Transit Cooperative Research Program (TCRP) Project E-11, FY 2015] to provide evidence-based guidance to transit decision makers on the relationship between asset condition and transit service quality. The guidance aims to incorporate all asset classifications and the condition scale, as specified in the *Asset Management Guide*, to account for characteristics of transit service quality, and to be useful to transit agencies of varying sizes and modes.

For more information, contact Dianne S. Schwager, TRB, 202-334-2969, or dschwager@nas.edu.

Public–Private Partnership Resource

WSP–Parsons Brinckerhoff has received a $150,000, 12-month contract (TCRP Project G-15, FY 2014) to prepare a resource for public transportation agencies to understand, evaluate, initiate, plan, and implement small and medium-sized public–private partnership (P3) initiatives. The project will define the different types of small and medium-sized P3 initiatives, identify the risks and benefits, assist agencies in identifying and screening opportunities for P3 initiatives, address the roles and responsibilities of public and private participants, and examine funding and financing options for P3 initiatives.

For more information, contact Dianne S. Schwager, TRB, 202-334-2969, or dschwager@nas.edu.

Knowledge Management for Strategic Transit Workforce Development

ICF Incorporated has received a $300,000, 18-month contract (TCRP Project F-23, FY 2015) to develop a resource for transit agencies on knowledge management to protect institutional knowledge and support strategic workforce development. The project will address the knowledge management needs of transit agencies of different sizes and modes, as well as various transit functions and organizational levels. Best practices, methods, and tools will assist transit agencies in addressing such challenges as high rates of turnover, retirements, difficulty in finding skilled candidates for positions, and rapidly evolving technology.

The project also will identify barriers to effective knowledge management and ways to overcome the barriers, will specify implementation tactics, and will compile a national catalogue of workforce development and knowledge management programs and resources.

For more information, contact Dianne S. Schwager, TRB, 202-334-2969, or dschwager@nas.edu.

Photo: Dallas Area Rapid Transit

A TCRP project will assist agencies in strategic workforce development.

Research to Improve Snow Removal

To compile a synthesis of best practices in snow and ice control for the Illinois Department of Transportation (DOT), researchers at Bradley University surveyed snow-removal professionals, reviewed the literature, and collected operations data on plowing conditions. Field testing was conducted during 11 Illinois snowstorms in 2012, 2013, and 2014.

According to the report, the most effective data for understanding plow and blade behavior were collected from the condition of the plow and from video of the plowing operation. Researchers deployed finite element models for the underbody scraper and for a front-mounted Alaskan plow, to simulate plow behavior under various loads and environmental forces.

Snowplow operators should be alert and should have a thorough understanding of the snow removal equipment, the report emphasizes. Stresses to the front-body plow mechanism and underbody scraper on the average snow-removal vehicle do not exceed 10,000 psi, according to the findings; however, concrete pavements cause higher amounts of stress on plows than do asphalt pavements.

Researchers also found that using an underbody scraper simultaneously with a front-body plow creates a cleaner driving lane more quickly and more effectively, and that this method is best at ice removal from ramps. Tests also showed that a hydraulic blade-saver mechanism reduced stresses on the snowplow and on the carrier structure in dry runs on asphalt and concrete pavement, as well as on soil on concrete pavement.

To see the full report, visit https://apps.ict.illinois.edu/projects/getfile.asp?id=3692.

Photo: Washington State DOT

Snowplow operators should have a thorough understanding of their vehicles and equipment. A Washington State DOT employee replaces a broken shear pin on a snowblower.

Photo: Rutgers University

The BEAST's 120-ft steel I-beams rest on support towers affixed to rail carts.

Accelerated Testing Lab Extends Bridge Life

A new accelerated testing facility for full-scale bridges at the Rutgers University Center for Advanced Infrastructure and Transportation (CAIT) allows researchers to induce, measure, and accelerate the deterioration of bridge decks and superstructures. The Bridge Evaluation and Accelerated Structural Testing lab—or the BEAST—can measure the stresses on bridges caused by environmental factors, traffic loads, and chemical deicing treatments.

The BEAST is a large chamber that encloses the bridge test section and a loading device that moves up to 60,000 lbs of loading at a speed of 20 mph for 24 hours. The device consists of two parallel steel I-beams—120 feet long and 7 feet tall—that rest on support towers affixed to rail carts. The chamber also replicates freeze–thaw conditions with temperature fluctuations from 0° to 104°F and applies a salt brine similar to that used in deicing. The conditions mimic 15 years of seasonal changes to a bridge test section in six months, according to Rutgers.

CAIT worked with Applied Research Associates to engineer and construct the BEAST facility. The center has completed research projects for the Federal Highway Administration's Long-Term Bridge Performance Program.

For more information on the BEAST, contact Ali Maher at mmaher@rci.rutgers.edu.

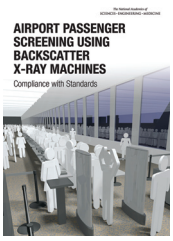
INTERNATIONAL RESEARCH NEWS

World Economy Improves, but Road Deaths Rise

Improved road safety often follows economic declines and high unemployment, according to a report from the International Transport Forum (ITF) of the Organisation for Economic Co-Operation and Development,. Research on the relationship between economic performance and road safety shows that unemployment levels correlate inversely with the number of road crash fatalities and injuries—when unemployment is high, the reductions in road deaths often are most pronounced among the younger age groups.

The ITF analysis identifies three factors behind increased road safety during economic downturns: reduced growth in traffic or a decline in traffic volumes; a disproportionate reduction in travel among high-risk age groups, such as younger travelers; and reduced disposable income, which may be associated with cautious driving behaviors such as not driving after drinking, or driving at fuel-saving lower speeds, or making fewer discretionary trips.

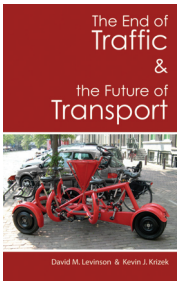
To see the full report, visit http://www.internationaltransportforum.org/Pub/pdf/15IRTADEconomicTimes.pdf.



Airport Passenger Screening Using Backscatter X-Ray Machines: Compliance with Standards

National Academies of Sciences, Engineering, and Medicine. National Academies Press, 2015; 148 pp.; $69; 978-0-309-37133-9.

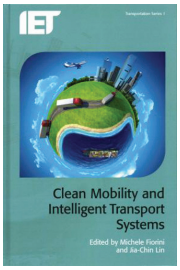
Released as a prepublication available for preorder or free download, this report reviews findings from previous studies, as well as current processes used by the Department of Homeland Security and equipment manufacturers to estimate the radiation exposures when screening air travelers with backscatter X-ray advanced imaging systems.



The End of Traffic and the Future of Transport

David M. Levinson and Kevin J. Krizek. E-book, $8.99. Available on Kindle Editions and at the iBookstore. Visit http://davidlevinson.org/the-end-of-traffic-and-the-future-of-transport.

This volume proposes that traffic, in its present form, is ending. The authors discuss the large-scale trends shaping the transportation landscape—such as electrification, automation, the sharing economy, and big data—and suggest strategies for the future transportation needs and priorities of communities.



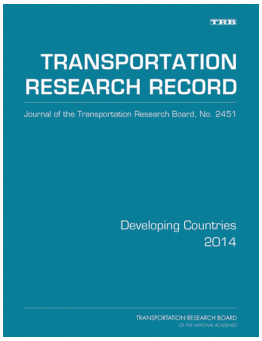
Clean Mobility and Intelligent Transport Systems

Edited by Michele Fiorini and Jia-Chin Lin. Institution of Engineering and Technology, 2015; 456 pp.; $145; 978-1-849-19895-0.

This overview presents the current topics in intelligent transportation systems and clean mobility, from the green cars initiative to cooperative collision warning for vehicles to multisensor maritime surveillance and more.

The titles in this section are not TRB publications. To order, contact the publisher listed.

TRB PUBLICATIONS



Developing Countries 2014
Transportation Research Record 2451

Papers in this volume summarize transportation workers' perspective on indigenous transportation and climate change adaptation; automobility in Brazil, Russia, India, and China; social welfare maximization; and more.

2014; 64 pp.; TRB affiliates, $38.25; nonaffiliates, $51. Subscriber categories: planning and forecasting; public transportation; environment.

Socioeconomic, Health, and Human Factors
Transportation Research Record 2452

The evolving connections of transit, agglomeration, and growth of high-technology business clusters; travel behavior of the poor after welfare reform; rural communities and transportation equity; and other topics are addressed.

2014; 123 pp.; TRB affiliates, $48.75; nonaffiliates, $65. Subscriber categories: society; economics; policy.

Planning 2014
Transportation Research Record 2453

This volume presents findings on such topics as future transportation demand in the United States, transportation project evaluation and decision making, and peak vehicle miles traveled and postpeak consequences.

2014; 177 pp.; TRB affiliates, $60; nonaffiliates, $80. Subscriber category: planning and forecasting.

Energy, Climate Change, and Alternative Fuels 2014
Transportation Research Record 2454

Authors explore consumer choice of E85 denatured ethanol fuel, charging behavior and its impacts on electric vehicle miles traveled, a user equilibrium–based location model of rapid charging stations for electric vehicles, and more.

2014; 106 pp.; TRB affiliates, $48.75; nonaffiliates, $65. Subscriber categories: energy; environment.

Pavement Management 2014, Volumes 1–3
Transportation Research Record 2455, 2456, and 2457

These volumes explore topics including the safety impacts of skid resistance in decision-making processes for pavement management, the flexural capacity of full-depth and two-lift concrete slabs with recycled aggregates, a sensitivity analysis of field-to-laboratory subgrade conversion factors, and a surface drainage evaluation for rigid pavements.

2014; Vol. 1, 97 pp.; TRB affiliates, $47.25; nonaffiliates, $63. Vol. 2, 177 pp.; TRB affiliates, $60; nonaffiliates, $80. Vol. 3, 150 pp.; TRB affiliates, $56.25; nonaffiliates, $75. Subscriber category: pavements.

Visibility; Work Zone Traffic Controls; Highway–Rail Grade Crossings 2014
Transportation Research Record 2458

The papers in this volume evaluate human

TRB PUBLICATIONS *(continued)*

perceptions of vehicle turning intention, a method for road lighting audits and safety screenings at urban intersections, lane bias issues in work zone travel time measurement and reporting, and more.

2014; 117 pp.; TRB affiliates, $48.75; nonaffiliates, $65. Subscriber categories: operations and traffic management; safety and human factors; railroads.

Critical Infrastructure, Emergency Evacuation, and Logistics of Disaster Recovery 2014
Transportation Research Record 2459

Research is presented on ways to plan postdisaster operations in a highway network, an approach for assessing climate change vulnerabilities in transportation infrastructure, a simulation study of evacuation routes and traffic management strategies, and other topics.

2014; 132 pp.; TRB affiliates, $53.25; nonaffiliates, $71. Subscriber categories: security and emergencies; operations and traffic management.

Data Systems and Asset Management
Transportation Research Record 2460

In this volume, which includes the 2014 Thomas B. Deen Distinguished Lecture by Joseph L. Schofer, papers address such topics as the value proposition for transportation projects, an automated road travel survey, and traffic collision record mapping.

2014; 185 pp.; TRB affiliates, $60; nonaffiliates, $80. Subscriber categories: data and information technology; planning and forecasting.

Highway Capacity and Quality of Service 2014
Transportation Research Record 2461

Scenario selection and probability adjustment for reliability and active traffic management analysis, estimation of the mean critical gap, and capacity estimation for weaving segments are among the subjects examined in this volume.

2014; 144 pp.; TRB affiliates, $53.25; nonaffiliates, $71. Subscriber categories: operations and traffic management; planning and forecasting.

Soil Mechanics 2014
Transportation Research Record 2462

Findings are presented on such topics as instrumenting and testing full-scale test piles for evaluating setup phenomenon, analyzing stress distribution in a layered system, and seismic performance of geosynthetic-encased stone columns.

2014; 135 pp.; TRB affiliates, $53.25; nonaffiliates, $71. Subscriber categories: geotechnology; bridges and other structures; pavements.

Traffic Control Devices 2014
Transportation Research Record 2463

Addressed in this volume are safety and operational impacts of optional flashing yellow arrow delay, traffic sign recognition using sparse representations and active contour models, pedestrian crossing speed, and more.

2014; 69 pp.; TRB affiliates, $44.25; nonaffiliates, $59. Subscriber categories: operations and traffic management; safety and human factors; pedestrians and bicyclists.

Pedestrians 2014
Transportation Research Record 2464

The long-term impact of the California safe routes to school program, a planning-level model for assessing pedestrian safety, and walking behaviors by trip purposes are among the subjects explored in this volume.

2014; 153 pp.; TRB affiliates, $56.25; nonaffiliates, $75. Subscriber categories: pedestrians and bicyclists; safety and human factors.

Safety Management; School Transportation; Young Drivers 2014
Transportation Research Record 2465

Authors present research on practices to reward safe and environmentally sustainable driving, the safety effects of Missouri's strategic highway safety plan, child pedestrian and bicycle crashes, and more.

2014; 78 pp.; TRB affiliates, $45.75; nonaffiliates, $61. Subscriber category: safety and human factors.

Median Cross-Section Design for Rural Divided Highways
NCHRP Report 794

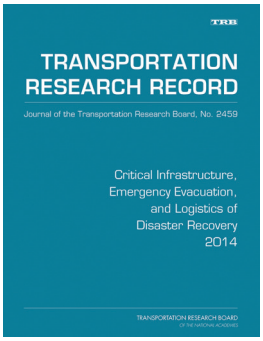
This volume offers guidelines for designing typical median cross sections on rural freeways and divided highways.

2014; 119 pp.; TRB affiliates, $45.75; nonaffiliates, $61. Subscriber categories: design; safety and human factors.

Design Methods for In-Stream Flow Control Structures
NCHRP Report 795

Design guidelines are presented for in-stream flow control structures used to limit lateral migration and reduce bank erosion.

2014; 94 pp.; TRB affiliates, $43.50; nonaffiliates, $58. Subscriber category: hydraulics and hydrology.



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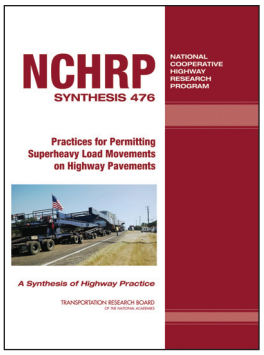
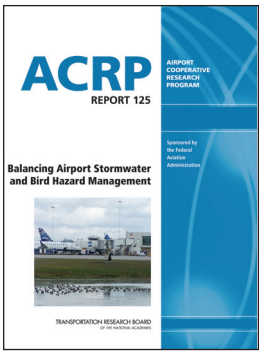


Practices for Permitting Superheavy Load Movements on Highway Pavements
NCHRP Synthesis 476

This synthesis documents the practices followed in issuing permits for overweight and superheavy commercial vehicles, also known as superloads.

2015; 303 pp.; TRB affiliates, $34.50; nonaffiliates, $46. Subscriber categories: highways; policy; vehicles.



Methods and Practices on Reduction and Elimination of Asphalt Mix Segregation
NCHRP Synthesis 477

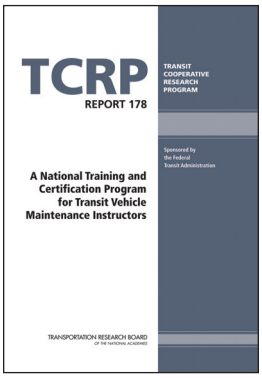
Offered in this synthesis is guidance on reducing or eliminating segregation during aggregate production, mix design, asphalt mix production, mix transport and transfer, and placement.

2015; 116 pp.; TRB affiliates, $48; nonaffiliates, $64. Subscriber categories: highways; materials.

Balancing Airport Stormwater and Bird Hazard Management
ACRP Report 125

Assistance is provided for airports to identify and evaluate stormwater management and bird mitigation practices. A risk evaluation tool is included on a CD-ROM that accompanies the print edition of the report.

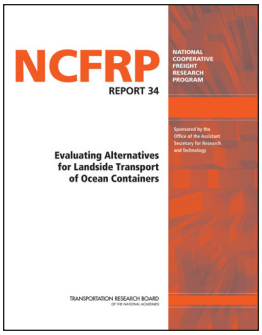
2015; 56 pp.; TRB affiliates, $44.25; nonaffiliates, $59. Subscriber categories: aviation; environment.



A Guidebook for Increasing Diverse and Small Business Participation in Airport Business Opportunities
ACRP Report 126

This report compiles industry best practices and other measures for airports to attract and enhance participation in their contract opportunities.

2015; 106 pp.; TRB affiliates, $45.75; nonaffiliates, $61. Subscriber categories: aviation; administration and management.



A Guidebook for Mitigating Disruptive WiFi Interference at Airports
ACRP Report 127

The guidebook provides practical assistance for improving wi-fi performance in airports by enhancing the ability of airport authorities to identify when radio frequency interference is occurring and then how to eliminate, reduce, or minimize its impact.

2015; 109 pp.; TRB affiliates, $45.75; nonaffiliates, $61. Subscriber categories: aviation; data and information technology.

Practices in Preserving and Developing Public-Use Seaplane Bases
ACRP Synthesis 61

This synthesis reviews and presents information on planning, design considerations, permits, regulatory requirements, and facility and service needs of public-use seaplane bases throughout the United States.

2015; 99 pp.; TRB affiliates, $43.50; nonaffiliates, $58. Subscriber categories: aviation; terminal and facilities.

Cell Phone Lots at Airports
ACRP Synthesis 62

This volume presents information about airport cell phone lots—lots that allow free, temporary parking—to help airports determine if the benefits outweigh the operating and maintenance costs and any foregone revenues.

2015; 75 pp.; TRB affiliates, $38.25; nonaffiliates, $51. Subscriber categories: aviation; terminals and facilities.

Quantifying Transit's Impact on GHG Emissions and Energy Use—The Land Use Component
TCRP Report 178

This report explores the relationships between transit and land use patterns and their contribution to compact development and to the potential reductions in greenhouse gas (GHG) emissions. The report is accompanied by an Excel-based calculator tool.

2015; 173 pp.; TRB affiliates, $18.75; nonaffiliates, $25. Subscriber categories: public transportation; energy; environment.

Practices for Utility Coordination in Transit Projects
TCRP Synthesis 118

This synthesis summarizes utility coordination practices—specifically, issues that arise during typical phases of project development and delivery—in the planning, design, and construction of infrastructure facilities.

2015; 66 pp.; TRB affiliates, $15; nonaffiliates, $20. Subscriber categories: public transportation; terminals and facilities.

Evaluating Alternatives for Landside Transport of Ocean Containers
NCFRP Report 34

This report explores a method for evaluating alternatives to diesel trucks for ocean container transport to or from deep-water ocean ports and inland destinations within 100 miles.

2015; 172 pp.; TRB affiliates, $53.25; nonaffiliates, $71. Subscriber categories: freight transportation; operations and traffic management; terminals and facilities.

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FEATURES are timely articles of interest to transportation professionals, including administrators, planners, researchers, and practitioners in government, academia, and industry. Articles are encouraged on innovations and state-of-the-art practices pertaining to transportation research and development in all modes (highways and bridges, public transit, aviation, rail, marine, and others, such as pipelines, bicycles, pedestrians, etc.) and in all subject areas (planning and administration, design, materials and construction, facility maintenance, traffic control, safety, security, logistics, geology, law, environmental concerns, energy, etc.). Manuscripts should be no longer than 3,000 words (12 double-spaced, typed pages). Authors also should provide charts or tables and high-quality photographic images with corresponding captions (see Submission Requirements). Prospective authors are encouraged to submit a summary or outline of a proposed article for preliminary review.

RESEARCH PAYS OFF highlights research projects, studies, demonstrations, and improved methods or processes that provide innovative, cost-effective solutions to important transportation-related problems in all modes, whether they pertain to improved transport of people and goods or provision of better facilities and equipment that permits such transport. Articles should describe cases in which the application of project findings has resulted in benefits to transportation agencies or to the public, or in which substantial benefits are expected. Articles (approximately 750 to 1,000 words) should delineate the problem, research, and benefits, and be accompanied by one or two illustrations that may improve a reader's understanding of the article.

NEWS BRIEFS are short (100- to 750-word) items of interest and usually are not attributed to an author. They may be either text or photographs or a combination of both. Line drawings, charts, or tables may be used where appropriate. Articles may be related to construction, administration, planning, design, operations, maintenance, research, legal matters, or applications of special interest. Articles involving brand names or names of manufacturers may be determined to be inappropriate; however, no endorsement by TRB is implied when such information appears. Foreign news articles should describe projects or methods that have universal instead of local application.

POINT OF VIEW is an occasional series of authored opinions on current transportation issues. Articles (1,000 to 2,000 words) may be submitted with appropriate, high-quality illustrations, and are subject to review and editing.

BOOKSHELF announces publications in the transportation field. Abstracts (100 to 200 words) should include title, author, publisher, address at which publication may be obtained, number of pages, price, and ISBN. Publishers are invited to submit copies of new publications for announcement.

LETTERS provide readers with the opportunity to comment on the information and views expressed in published articles, TRB activities, or transportation matters in general. All letters must be signed and contain constructive comments. Letters may be edited for style and space considerations.

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◆ All manuscripts should be supplied in 12-point type, double-spaced, in Microsoft Word, on a CD or as an e-mail attachment.

◆ Submit original artwork if possible. Glossy, high-quality black-and-white photographs, color photographs, and slides are acceptable. Digital continuous-tone images must be submitted as TIFF or JPEG files and must be at least 3 in. by 5 in. with a resolution of 300 dpi. A caption should be supplied for each graphic element.

◆ Use the units of measurement from the research described and provide conversions in parentheses, as appropriate. The International System of Units (SI), the updated version of the metric system, is preferred. In the text, the SI units should be followed, when appropriate, by the U.S. customary equivalent units in parentheses. In figures and tables, the base unit conversions should be provided in a footnote.

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