

TR NEWS

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NOVEMBER–DECEMBER 2014

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The Nine Leaders Who Built the Transportation Research Board

Suzanne B. Schneider

The advent of TRB's tenth Executive Director in February 2015 offers an occasion to review the history of the nine men who led the Board from its beginnings in 1920 to the present. Engineers all, they have served as spokesmen and champions for what transportation research can accomplish and have facilitated the dialogue, coordination, fundraising, study, and dissemination needed for the research enterprise to thrive.

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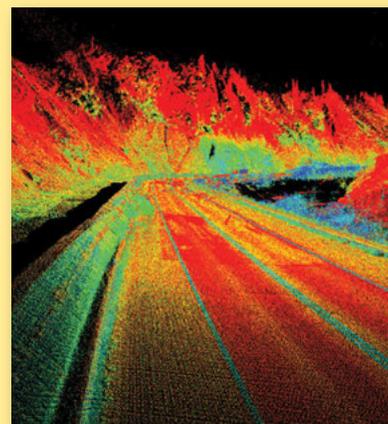
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COVER: Point cloud from a LiDAR scan image of a roadway and terrain in Denali National Park, Alaska. Imaging technologies are revolutionizing many areas of transportation practice; articles in this issue highlight several other historic turning points for transportation research and practice. (Image: Alaska Department of Transportation and Public Facilities)

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 2014 Annual Report* is included in this issue as a special insert, between pages 24 and 25.

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COMING NEXT ISSUE



Amphibious excavator constructing a pilot channel to increase flow through the debris dam after the March 22, 2014, landslide—the deadliest in U.S. history—near Oso in northwestern Washington State.

With the Panama Canal celebrating its centennial in 2014 and scheduled to open new locks in 2016, a feature article in the next issue looks at the legacy and future of the canal and the probable effects the expansion will have on U.S. harbor infrastructure and supply chains. Also featured is a report on the 2014 state partnership visits by TRB senior program officers, highlighting research needs and applications, particularly model efforts by state agencies to leverage new technology. Other features describe Louisiana's strategy to “right-size” the state highway system, working with local governments; the response to the deadly Oso mudslide in March 2014 on Washington State Route 530, including recovery efforts and preventive measures; the effects of sustainability practices on airport operations and maintenance; and improving transportation options for veterans, military service members, and their families.

Caretakers and Change Makers

The Nine Leaders Who Built the Transportation Research Board

SUZANNE B. SCHNEIDER



The author retired as Associate Executive Director of TRB in September 2013 after 27 years in the Executive Office, guiding program oversight activities, report review, publications, and communications. She worked closely with the Board's eighth and ninth Executive Directors.

If you have ever visited the offices of the Transportation Research Board (TRB) in the National Academies' Keck Center in Washington, D.C., you may recall seeing row upon row of photographs of the Board's Executive Committee Chairs—78 individuals who have served in that role from 1920 to 2014. On a wall around the corner from the Executive Committee Chair gallery is a smaller group of portraits—eight of the nine men who have served as the Board's Executive Directors since its founding 94 years ago.



W. K. Hatt,
Executive Director
from 1921 to 1924.



Charles M. Upham,
Executive Director
from 1924 to 1928.

Shaping the Institution

These nine individuals—engineers all—have shared a strong commitment to TRB and its mission, and each has contributed to shaping the institution. Four of these men, three in the Board's first decade, could be described as “caretakers”—they provided leadership for a relatively short period of four or fewer years and then returned to the careers they had interrupted.

In contrast, the other five served 10 years or more as Executive Director, capping their careers with their tenures, and their accomplishments were vital to the building of TRB. Three of these “change makers” rose through the ranks at the Board, while the other two came from outside.

The stories of these nine men, individually and collectively, help tell the story of TRB—how it came into being, what gave it staying power, and how the profound changes in transportation, society, and technology have contributed to its growth and evolution into the institution it is today. Telling some of this rich story now is timely, with the advent of a tenth Executive Director in 2015.

Initial Caretakers

The story of TRB's creation has been told many times before. In a special issue of *TR News* marking the 75th anniversary of TRB, L. G. (Gary) Byrd vividly recounted the background, organizations, and individuals involved in establishing the National Advisory Board on Highway Research, as it was known at its founding on November 11, 1920, to provide a mechanism for the exchange of information and research results about highway technology:

The founding fathers were early giants in the highway community—leaders in the National Research Council, professional societies, state



PHOTO: LIBRARY OF CONGRESS PRINTS AND PHOTOGRAPHS DIVISION

Thomas H. MacDonald, Chief of the Bureau of Public Roads, in 1939; nearly two decades earlier he had helped found the National Advisory Board on Highway Research.

highway departments, the Bureau of Public Roads, academia, and industry. (1, p. 7)

The founders included Anson Marston, Dean and Director of the Engineering Department at Iowa State College; Thomas H. MacDonald, a former student of Marston's and Chief of the U.S. Bureau of Public Roads—the predecessor of the Federal Highway Administration; and several prominent individuals from state highway agencies, academia, the American Society of Civil Engineers, and the American Association of State Highway Officials (AASHO)—the predecessor to the American Association of State Highway and Transportation Officials (AASHTO).

Flinn: Up and Running

The National Research Council (NRC), established in 1916 as the operating arm of the nonprofit National Academy of Sciences, became the institutional home of the new board. Its first director, referred to as Interim Executive Director, was Alfred D. Flinn, Vice Chairman of the Board's Executive Committee and Vice Chairman of the NRC Division of Engineering. Through his NRC role, Flinn was able to make the organizational and financial arrangements necessary to get the new board up and running. During his brief tenure, the Board's office was located in the Engineering Societies Building in New York City.

Hatt: Setting Firsts

In July 1921, William K. Hatt was appointed Executive Director. Professor of Civil Engineering and Director of Testing Laboratories at Purdue University, Hatt requested a leave of absence from the university to take on this new role.

Under his leadership, the Board held its first two annual meetings, the first in January 1922 at the Engineering Societies Building. Attendance grew rapidly, from 30 participants at first to 273 registrants by 1924.

During Hatt's tenure, the Board organized the first six technical committees, and the initial staff focused on a survey of highway research. Hatt is credited with suggesting the creation of a highway research information service—later accomplished under one of his successors. The Bureau of Public Roads provided the bulk of the funding for the Board.

Upham: Making Contacts

When Hatt returned to Purdue in 1924, Charles M. Upham, former Chief Engineer of the North Carolina State Highway Department, succeeded him. Upham, who served through 1927, focused on establishing relationships with the state highway agencies and with

universities. Under his tenure, the Board appointed “contact men” from the states and universities— assembling a network of 45 state and 121 university representatives by the close of 1924.

The Board gained a new name, the Highway Research Board (HRB), in 1925, after a vote by the Executive Committee. Upham resigned in 1928 to become Engineer–Director of the American Road Builders Association, the predecessor of the American Road and Transportation Builders Association.

Crum Takes the Helm

Building on the work of the three caretakers who preceded him, “idea man” Roy W. Crum took over as Executive Director in 1928; this first change maker as HRB director served 23 years, until his death in 1951. A graduate of Anson Marston’s engineering program at Iowa State, Crum had served on the faculty, as well as at the Iowa Engineering Experiment Station and at the Iowa State Highway Commission.

During his tenure as the Board’s Executive Director—the longest yet—Crum focused on building HRB’s capabilities and its reputation in fulfilling its core missions: identifying national highway research needs, correlating research efforts to enhance efficiency and avoid unnecessary duplication, and disseminating the results of highway research.

In his first annual report to the Board’s Executive Committee, Crum summarized these key elements of HRB’s mission and noted:

In a broad sense, the object of this institution is to make itself helpful in any way possible in the solution of the many problems that confront the builders and the users of the highways. . . . We hope as time goes on to broaden the scope and influence of the Board. (2, p. 40)

Information and Cooperation

Under Crum’s leadership, the Board’s program, technical studies, and staff expanded. Byrd notes that one of Crum’s first acts was to request funding for a highway research information clearinghouse (1, p. 12); in 1931 the *Highway Research Abstracts* newsletter series was initiated. This laid the groundwork for what became the Highway Research Information Service in the 1960s and later the multimodal, international Transportation Research Information Services (TRIS) and Transportation Research Information Documentation (TRID). For many years, Fred

Burggraf, who joined the Board in 1929 and became Research Engineer in 1931, handled the *Abstracts* series.

Other highlights of Crum’s tenure included the following:

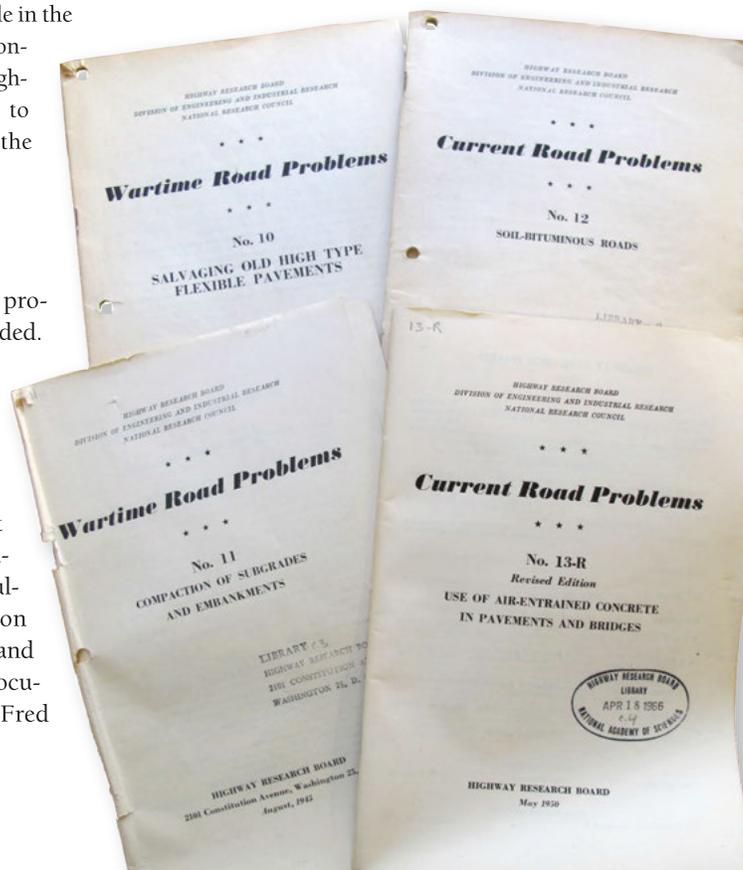
- ◆ Reorganization of the committees into six areas of research—Administration and Finance, Transportation, Highway Design, Materials and Construction, Maintenance, and Traffic;
- ◆ Cooperation with AASHTO in conducting and maintaining a highway research census, *Highway Research, 1920–1940*, enumerating approximately 1,300 projects;
- ◆ Initiation of a cooperative project with the Bureau of Public Roads on highway safety research;
- ◆ Establishment of a joint committee with the American Road Builders Association on the development of equipment for constructing stabilized roads;
- ◆ Initiation of fees for member organizations;
- ◆ Creation of the Highway Research Correlation Service in 1945, the basis for much of today’s core program, with the support of the Bureau of Public Roads and AASHTO—41 states provided funds for the initial year of the service, which launched the continuing program of staff field visits to state and other research agencies;
- ◆ Publication of wartime bulletins addressing transportation issues specific to World War II; after the war, these evolved into the *Current Road Problems* series; and



Roy W. Crum,
Executive Director
from 1928 to 1951.



Fred Burggraf,
Executive Director
from 1951 to 1964.



During World War II, the Highway Research Board published a series of bulletins focusing on transportation related to the war effort; after the war, the publications became the *Current Road Problems* series.

W. N. Carey (*left*) worked with Burggraf (*right*) and A. C. Benkelman (*center*) on the AASHO Road Test. Benkelman developed the Benkelman beam or deflector beam, a nondestructive, portable tester for pavements.



◆ Publication of the first *Highway Capacity Manual* in 1949—apparently HRB lacked sufficient funds to publish the first edition, because the Government Printing Office handled the publication and sale.

Three Heritages

Crum's emphasis was on building a strong organization and partnerships with the states, federal government, and industry. In a tribute after Crum's death in 1951, MacDonald identified "three heritages" from the HRB Executive Director (2, p. 69):

◆ An organization grown from nine committees and 81 members to 80 committees and 758 members,

After stepping down as Executive Director in 1966, D. Grant Mickle (*center*) returned to chair the HRB Executive Committee in 1970. Alan M. Voorhees, 1972 Executive Committee Chair, is at left, and 1971 Chair Charles E. Shumate at right.



◆ A five-foot-high shelf of the finest in highway research publications, and

◆ The concept that highway research is a continuing, unfolding process and that new participants should be encouraged to share in the activity year by year.

Burggraf: Extending the Vision

Burggraf, who succeeded Crum, served as HRB Executive Director from 1951 until 1964. A graduate of George Washington University, Burggraf had worked at the National Bureau of Standards and the Illinois Division of Highways. He joined the HRB staff in 1928 and left in 1932 for a position at the Calcium Chloride Association. He rejoined the Board in 1940 as Research Engineer, was named Assistant Director in 1941, and was promoted to Associate Director in 1945.

Major developments during Burggraf's tenure in the 1950s included the initiation of an important series of controlled road tests of pavement performance, administered by HRB. Burggraf himself had participated in the first such test, the Bates Road Test, while he was a research engineer with the Illinois highway department.

The road test projects—culminating in the \$27 million AASHO Road Test in 1955—expanded HRB's role and staff. William N. Carey, Jr., who had joined HRB in 1946 and later became Executive Assistant to the Director, served as Project Engineer on the Western Association of State Highway Officials (WASHO) Road Test and then as Chief Engineer on the AASHO Road Test.

Growth and Expansion

Areas for research also were expanding—among the emerging topics were metropolitan area traffic and transportation planning, highway law, urban passenger transportation, highway taxes, and tolling. The passage of the Federal-Aid Highway Act of 1956, which established the Highway Trust Fund and set in motion the construction of the nation's vast network of Interstate highways, produced new challenges.

Growth was evident during Burggraf's tenure—committee membership nearly doubled from 655 in 1951 to 1,255 in 1963, and Annual Meeting attendance almost tripled—from 850 to 2,443. The demand for lecture and committee rooms at the Annual Meeting led to a shift in location in 1956 to the Sheraton Park Hotel—now the Marriott Wardman Park Hotel—and a few years later to expansion to the nearby Shoreham Hotel—now the Omni Shoreham.

Cooperative Research

A staff-authored report published in 1959, *Highway Research in the United States: Needs, Expenditures, and Applications*, made the case that research was not keeping pace with the states' needs. The report laid the groundwork for a new program, the National Cooperative Highway Research Program (NCHRP), established in 1962 through a three-party agreement among NRC, the Bureau of Public Roads, and AASHTO, and administered by HRB.

Approximately \$3 million was provided to the new program of problem-solving, contract research on topics selected by the state agencies and guided by expert panels. The success of this model led to significant growth in the size of the Board's staff and volunteer base and in the range of subject matter addressed, as well as to a series of similar cooperative programs of research administered by the Board for other transport modes.

Other accomplishments during Burggraf's directorship included establishment of the Highway Research Information Service (HRIS), a clearinghouse for highway research results; growth in publications, specialty conferences, and requests for information; and creation of an industry category of membership, recognizing that highway industry representatives accounted for almost one-third of committee membership and Annual Meeting registrations. An Industry Dinner in 1961 attracted 100 highway industry leaders, and approximately 25 industries became affiliates at a fee of \$1,000.

Mickle: Expanding Outreach

D. Grant Mickle became Executive Director when Burggraf retired in 1964. A civil engineer, Mickle had worked for the Massachusetts Department of Public Works, the Michigan Department of State Highways, and the City of Detroit. He had directed the traffic engineering division of the Automotive Safety Foundation from 1943 until 1961, when he was named the first Deputy Federal Highway Administrator.

During his nearly three years as HRB Executive Director, Mickle focused on expanding financial support and industry outreach, as well as on public information activities. In a report to the Executive Committee, he noted that a survey of industry leaders provided "some cogent and illuminating answers" to help "increase our service to the Board's present industrial members and hopefully to attract other industries to join with us in a common effort to achieve the finest possible highway transportation system" (2, p. 83). During Mickle's tenure, the Executive Committee also authorized creation of a Special Committee on International Activities to foster international research exchange and coordination.

Carey: Moving to Multimodal

Mickle resigned in 1966 to return to the Automotive Safety Foundation as Vice President; a few years later, in 1970, he chaired the HRB Executive Committee as President of the Highway Users Federation for Safety and Mobility. Succeeding Mickle as Executive Director was longtime HRB staff member Carey.

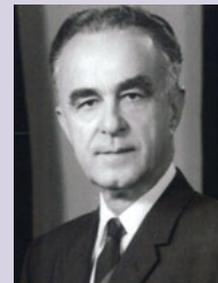
A civil engineering graduate of the University of Minnesota, Carey had worked in cement research and on airport construction before joining the Board in 1946. After service as Executive Assistant to the Director, Project Engineer for the WASHO Road Test, and Chief Engineer for Research on the AASHTO Road Test, he became HRB Assistant Director in 1962 and Deputy Executive Director in 1964.

New Scope

Early in Carey's tenure, a Special Committee on Long-Range Planning, appointed during Mickle's term, reported its findings and recommendations to the Executive Committee. The Executive Committee approved a new statement of purpose and scope for the Board, which was subsequently approved by the Division of Engineering and the NRC Governing Board:

Purpose—The purpose of the Board is to advance knowledge concerning the nature and performance of transportation systems, through the stimulation of research and dissemination of information derived therefrom.

Scope—The Board will give attention to all factors pertinent to the understanding, devising,



D. Grant Mickle,
Executive Director
from 1964 to 1966.



W. N. Carey, Jr.,
Executive Director
from 1966 to 1980.

Carey (center), shown conferring at an HRB Annual Meeting, helped guide HRB through its transition to a multimodal organization.



Archive Photo



Thomas B. Deen,
Executive Director
from 1980 to 1994.

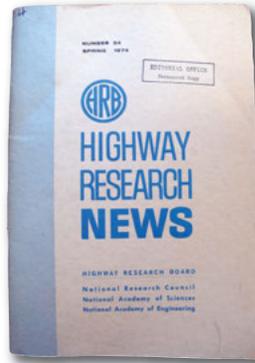
and functioning of highway and urban transportation systems and their interrelationships with other aspects of total transportation. It will concern itself with the planning, design, construction, operation, maintenance, and safety of facilities and their components; the economics, financing, and administration of the systems; and their interactions with the physical, economic, legal, and social environment they are designed to serve. (2, p. 89)

As Byrd noted, the new statement made clear that “the interests of HRB committees and sponsors were extending beyond highway transportation, and it signaled the Board’s intention to ultimately become a multimodal organization” (1, p. 18). With his background and reputation in the highway field, Carey was well positioned to lead this charge.

Filling a Gap

In a spring 1974 *HRB News Brief*, Carey noted that the Long-Range Planning Committee had reported that “in the field of transportation outside of highways, there is no organization that performs the same functions as the Highway Research Board.” Further, the committee had recommended that the Board attempt to fill this gap by changing its name to the Transportation Research Board and broadening its scope accordingly. Because of the concerns of highway sponsors, however, the change was delayed until funding from nonhighway transportation sources could be assured.

Carey cited a “major step forward”: the Urban Mass Transportation Administration (UMTA)—now the Federal Transit Administration—recently had



In a 1974 edition of *HR News*, Carey wrote about the decision to change HRB’s name—and mission—to the Transportation Research Board.

signed on as a financial sponsor, enabling the appointment of a staff transit specialist, the establishment of relevant committees, and the coverage of transit research in HRB programs, publications, and information services. In addition, support from UMTA and several other federal DOT agencies had allowed the expansion of the Board’s computer-based information services to include maritime, railroad, and urban mass transportation.

Broadened Constituency

The transformation of HRB into TRB was propelled by the growing recognition among state highway agencies—and HRB committees—that their missions were becoming multimodal, as well as by internal developments at NRC. Almost half of the state highway departments already had evolved into or become parts of state departments of transportation, and in 1973, AASHO changed its name and its constitution to reflect that change.

That same year, NRC reorganized into four divisions, with HRB assigned to the new Commission on Sociotechnical Systems. Discussions explored the creation of a new transportation research division within the commission, including HRB along with separate maritime and air boards. The HRB Executive Committee and state and federal sponsors, however, expressed concerns about such a segregation of transportation activities and unanimously recommended a new name and expanded scope for the Board. In March 1974, NRC approved the change of name to the Transportation Research Board and



Archive Photo

Under Deen’s tenure, the National Research Council elevated TRB to a major division; the Board also broadened its sources of financial support.

broadened the scope to include highway, rail, air, marine, and urban mass transportation activities.

During the remaining years of Carey's tenure, the focus was on consolidating the Board's new responsibilities; adding new sponsors, committees, and staff; and reaching out to the significantly broadened constituency.

Deen: Upping the Ante

When Thomas B. Deen was appointed Carey's successor in 1980, TRB was 60 years old, with an established mission, a respected parent organization and staff, engaged sponsors, and a large and growing body of volunteers who contributed to and relied on its functions and services. Deen was an outsider, president of the internationally known transportation consulting firm, Alan M. Voorhees Associates.

That Deen would relinquish a prestigious leadership position to take on the directorship of TRB as the capstone to an already distinguished career was a testimony to the stature that TRB had gained in the field. Deen has written engagingly about that decision in an article, "The Transportation Research Board at 90: Everyone Loves It, but No One Can Explain Why" (3).

A civil engineering graduate of the University of Kentucky, Deen had pursued advanced studies at the University of Chicago and at Yale University's Bureau of Highway Traffic. Before joining Voorhees Associates, he directed the Nashville Area Transportation Study and served as Director of Planning for the National Capital Transportation Agency, which developed the initial plans for the Washington, D.C., Metrorail system.

Early in his tenure, Deen implemented a set of measures to restore fiscal discipline during a period when rampant inflation was threatening the sustainability of TRB programs. He also worked aggressively to bring in new financial sponsors, as well as to maintain support from existing sponsors. Within NRC, Deen strove to gain increased respect from the Academies' leadership and support for TRB programs.

Introducing Policy Studies

These efforts paid off in 1982 with the elevation of TRB from a unit operating within a division into one of the major program divisions of NRC. As part of this move, TRB—like the other NRC program divisions—would be required to conduct policy studies. The TRB Executive Committee created two subcommittees to oversee these new responsibilities—a Subcommittee for NRC Oversight, to provide liaison between TRB and the NRC Governing Board; and to monitor the policy study process, a Subcommittee on Policy Review—later expanded in scope as the Sub-

committee on Planning and Policy Review.

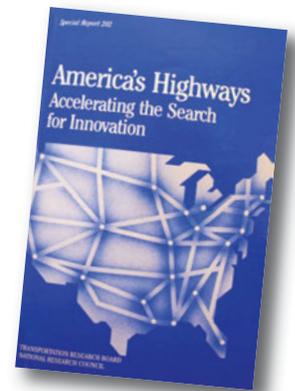
TRB's entry into the policy study arena required organizational changes and new hires and challenged volunteers, sponsors, and staff to see the Board's mission in a new light. Some believed that the conduct of studies on complex, often controversial, national transportation policy issues would alienate sponsors concerned about whether the outcome of a study might be prejudicial to their interests. As the program developed, however, such fears were put to rest; the move into policy studies helped attract new TRB sponsors and contributors.

From the first five policy studies mandated by Congress in 1982, the Board has conducted more than 130 on a variety of topics in response to requests from Congress, federal or state agencies, or the Executive Committee. An independent committee, appointed in accordance with rigorous NRC procedures, carries out each study. The Board's policy study work has enhanced its stature and influence within the national transportation community.

Strategic Research

In 1982, Deen recommended a proposal, adopted by the Executive Committee, that TRB initiate a strategic study to assess the need for fundamental highway research in areas with the potential for yielding breakthroughs. The 1984 report, *America's Highways: Accelerating the Search for Innovation*, led to the establishment of the first Strategic Highway Research Program (SHRP)—a \$150 million, 5-year program of highly focused research that yielded cost-effective innovations in areas including asphalt materials, pavement performance, concrete bridge protection, and snow and ice control. The U.S. Congress funded the program, which was housed within NRC.

Another strategic study recommended the creation of a cooperative research program for transit, modeled on NCHRP. The Transit Cooperative



Deen's proposal for a highly focused research program—outlined in Special Report 202, *America's Highways: Accelerating the Search for Innovation*—led to the historic and productive first Strategic Highway Research Program.

The first SHRP, like SHRP 2, relied on close collaboration with the American Association of State Highway and Transportation Officials and with the U.S. Department of Transportation.

ARCHIVE PHOTO





**Robert E. Skinner, Jr.,
Executive Director
from 1994 to 2015.**

Research Program (TCRP) was established in 1992, toward the end of Deen's tenure. Several other similarly structured cooperative research programs followed. Under Deen's leadership, TRB also undertook the Innovations Deserving Exploratory Analysis (IDEA) programs, which support research into promising but unproved innovations for highways, transportation safety, transit, and more.

With his strong service orientation, Deen also initiated a strategic planning process that engaged members of the Executive Committee, other volunteer leaders, sponsors, committee members, and staff in a structured assessment of TRB's mission, goals, services, constituencies, and resources and in the identification of emerging challenges and opportunities. The strategic planning process, with many later refinements, continues and has led to many beneficial actions and activities.

Enhancements and Advancements

Beginning in 1988, Executive Committee members were engaged by another Deen invention—special policy discussion sessions during the semiannual meetings. Nicknamed “red meat” sessions, the discussions have afforded the opportunity to explore an emerging issue of choice with guest speakers and colleagues. The popularity of these sessions continues; some have led to TRB studies, conferences, and other activities.

The size and scope of TRB programs grew significantly during Deen's 14-year tenure. The Board's annual budget increased from \$9 million to \$35 million, and attendance at the Annual Meeting rose from 4,000 to 7,000. New sponsors came on board—including federal agencies and industry associations; committee and conference activities flourished; and

Skinner delivers his first Executive Director's report to the TRB Executive Committee in January 1994, flanked by Executive Committee Vice Chair Lillian C. Borrone and Chair Joseph M. Sussman. The size and scope of the TRB Annual Meeting expanded under Skinner's tenure—attendance grew from 7,000 to 12,300.



ARCHIVE PHOTO

the publications output surged. TRB accomplished this growth while enhancing its ties to its veteran partners—the state and federal transportation agencies and transportation research institutions.

Skinner: Building for the Future

Robert E. Skinner, Jr., became Executive Director following Deen's retirement in 1994. Skinner joined TRB in 1983 in the new division conducting the first round of congressionally mandated policy studies. He served as study director for the studies on geometric design standards for highway resurfacing, restoration, and rehabilitation projects and on the effects of twin trailer trucks.

In 1986, he was appointed Director of the Studies and Information Services Division, supervising the conduct of more than 30 policy studies, and overseeing the management of TRB's information services, library, and synthesis reports unit. Skinner earned a bachelor's degree in civil engineering from the University of Virginia and a master of science degree in civil engineering from the Massachusetts Institute of Technology. Before joining TRB, he was a Vice President at PRC Voorhees, directing planning and research studies for local, state, and federal agencies.

Strengthening and Sustaining

The size and scope of TRB continued to grow during Skinner's tenure—the annual budget rose from \$35 million to \$113 million, and Annual Meeting attendance climbed from 7,000 to 12,300. Under Skinner's leadership, TRB strengthened the multimodal and multidisciplinary range of its programs, inaugurated major communications initiatives, fostered international research partnerships and coordination, and



Skinner was interviewed in 1995 by reporter Sylvia Chase for ABC's *Prime Time Live*. Skinner worked to promote transportation research and to raise the profile of TRB.

worked proactively to enhance the diversity of the Board's committees, programs, and staff.

In a period of constrained federal and state agency budgets, Skinner guided a TRB-wide effort to achieve cost efficiencies and raise additional revenue, while avoiding the need to cut vital services. He maintained strong relationships with longtime state and federal DOT sponsors, nurtured new relationships, and earned the admiration of National Academies' leadership for his effective management of the NRC's longest-continuing unit.

Portfolio of Achievements

Highlights of these and other accomplishments during Skinner's 21-year tenure as Executive Director include the following:

- ◆ Creation of the Airport Cooperative Research Program in 2005, with funding by the Federal Aviation Administration. This applied research program, modeled on NCHRP and TCRP, addresses problems shared by airport operating agencies. Reauthorized in 2012, the program has produced more than 250 reports in a variety of series and was funded at approximately \$15.0 million in Fiscal Year 2014. Several smaller cooperative research programs—in freight, rail, and hazardous materials transportation—also were initiated during Skinner's tenure.

- ◆ Establishment of a second Strategic Highway Research Program (SHRP 2), authorized by Congress in 2005, to address some of the most pressing needs relating to the nation's highway system. Funded at more than \$230 million and managed by TRB, the program includes the largest-ever naturalistic driving study, along with research focused on renewal, travel time reliability, and ways to speed the delivery of

projects that can increase highway capacity. With the program's expected completion in 2015, additional work is focusing on ways to ensure timely implementation of the research results.

- ◆ Continuing strong support of TRB by state DOT sponsors, as contributors to the Board's core programs and to NCHRP, as participants on committees and panels, and as users and proponents of TRB products and services. In 2013, almost 800 state DOT employees were members of TRB standing committees, and some 1,550 were serving on panels of the Cooperative Research Programs.

- ◆ Initiation of the free, weekly *Transportation Research E-Newsletter*, which reports on transportation research and research-related events within TRB and beyond; the popular webinar series, which disseminates information on TRB reports, Annual Meeting sessions, and topics requested by TRB committees; a redesigned website; and a variety of social media activities. More than 50,000 subscribe to the e-newsletter worldwide.

- ◆ Signed agreements with prominent international organizations to coordinate research, cosponsor activities, and explore partnerships. In a multiyear project, TRB is partnering with the European Union to conduct a series of four conferences on transportation research issues of common interest. Professionals from several other countries have worked at TRB as loan staff for SHRP 2 and other programs. In 2011, TRIS records were combined with those of the International Transport Research Documentation to launch the TRID database of more than 1 million records available free on the web.

- ◆ Steadily increasing participation by women and members of minority groups in TRB committee activities and leadership, on staff, and in other roles.

In 2011, the Texas A&M Transportation Institute (TTI) awarded Skinner the Director's Research Champion Award; (left to right:) Dennis Christiansen of TTI, Skinner, Dianne Skinner, Herbert Richardson of TTI, and John Horsley of AASHTO.



Photo: TTI

With Skinner's leadership, staff and volunteers built on efforts begun during Deen's directorship to enhance diversity in all aspects of the Board's work. Of the 21 TRB Executive Committee chairs from 1995 to 2014, seven have been women and two have been African Americans (one also a woman). Recent initiatives that support this continuing goal include the TRB Minority Student Fellows Program and the Young Members Council.

- ◆ Continued growth in Annual Meeting attendance and paper submissions; initiation of a commercial exhibit at the meeting; and inauguration of web and electronic meeting apps. To accommodate growth, the Annual Meeting has moved to a new venue, the Washington, D.C., Convention Center, starting in January 2015.

- ◆ A reorganization of the Technical Activities Council in 2004 added the volunteer leaders of each of the modal groups—public transportation, rail, freight systems, aviation, and marine. Recently a state DOT representative and a representative of the Young Members Council were added. The Marine Board, transferred to TRB from another NRC division in 1999, has made significant contributions to TRB's portfolio—for example, an upswing in marine-related policy study requests from a variety of sponsors, some new to TRB.

Skinner will retire, after serving more than 20 years as Executive Director, at the end of January 2015.

Making a Difference

The nine men who led the Board from its beginnings in 1920 to the present have been at the center of the

transportation research enterprise in the United States and beyond. Caretakers and change makers alike, they shared a vision of the difference that research can make. But as Skinner has observed in an article, "Ten Theses About Transportation Research," research is a means, not an end; the ultimate goal is innovation (4).

The implementation of better, more cost-effective materials and processes can enhance people's mobility, increase safety, benefit the economy, and improve the quality of life. But transportation rarely makes the headlines, and research is even less glamorous.

Effectively, and each in his own way, these nine individuals were spokesmen and champions for what transportation research can accomplish—and facilitators of the dialogue, coordination, fundraising, study, and dissemination needed to make good things happen. We celebrate their successes and look forward to the contributions that Neil Pedersen will make as TRB's tenth director in addressing this continuing, vital challenge.

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Pedersen Named TRB Executive Director

After a national search, Neil J. Pedersen, former Administrator of the Maryland State Highway Administration (SHA) and past Chair of the TRB Executive Committee, was selected as the 10th Executive Director of TRB, effective February 1, 2015. Pedersen has served as Deputy Director of the second Strategic Highway Research Program (SHRP 2) since 2012.

TRB's new staff leader has more than 38 years of experience in the transportation profession. For 29 years, he held management and leadership positions at the Maryland Department of Transportation's SHA, including chief executive officer for more than eight years. A native of Massachusetts, Pedersen earned bachelor's degrees in civil engineering and urban studies from Bucknell University and a master's degree in civil engineering from Northwestern University. He began his career as a consultant in transportation planning, working first for R. H. Pratt Associates and then for JHK and Associates. He managed projects ranging from travel demand forecasting to transit alternatives analyses and toll road feasibility studies.

In December 1982, he joined Maryland SHA as Deputy Director of the Office of Planning and Preliminary Engineering; in 1984, he was promoted to office director. In July 2000, he was appointed Deputy Administrator for Planning and Engineering, with responsibility for SHA's planning, environmental, engineering, and real estate activities. In January 2003, he was named Administrator, serving as principal adviser to the Governor and the Secretary of Transportation on highway-related matters and providing strategic leadership to an agency of 3,200 employees who plan, design, construct, maintain, and operate Maryland's 5,200-mile state highway network and 2,500 bridges.

Pedersen also exercised oversight for Maryland's highway safety and motor carrier programs, and he led the delivery of the state's two megaprojects—the Woodrow Wilson Bridge and the Intercounty Connector. Throughout his tenure, Pedersen remained technically engaged in the science and art of planning and engineering while providing highly effective management and leadership, often in a politically charged context.

For the American Association of State Highway and Transportation Officials (AASHTO), Pedersen chaired the Task Force on Context-Sensitive Solutions and served as Vice Chair of the Standing Committee on Highways and of the Subcommittee on Asset Management. He also was a member of AASHTO's Standing Committee on Research and the Standing Committee on Planning.

Before joining the TRB staff, Pedersen was active as a TRB vol-

unteer for more than 30 years, serving on a variety of committees and panels. He is a past chair of the Technical Activities Council and of the SHRP 2 Technical Coordinating Committee for Capacity Research. He also served as a member of the Executive Committee's Subcommittee on Planning and Policy Review and on the National Cooperative Highway Research Program Project Panel on Research for the AASHTO Standing Committee on Highways. In addition, he is an Emeritus Member of the TRB Statewide Multimodal Transportation Planning Committee.

Among his honors, Pedersen has received the George S. Bartlett Award (2006), the Road Gang's Lester P. Lamm Award (2005), the Planner of the Year Award from the Maryland Chapter of the American Planning Association (1997), AASHTO's Intermodal Award (1994), and the Community Service Award of the Institute of Transportation Engineers' Baltimore–Washington Chapter (1992).

Pedersen will work closely with Robert E. Skinner, Jr., who is retiring at the end of January after more than 30 years of service to the National Academies.

“Neil has taken on virtually every volunteer leadership role TRB has to offer, with great success, and as a TRB staff member has helped move SHRP 2 products from research into practice,” Skinner commented. “I will be leaving TRB in good hands.”

“The Academies' Presidents—Ralph Cicerone, Dan Mote, and Victor Dzau—join me in congratulating Neil on his new position and in thanking Bob Skinner for his outstanding service to the National Research

Council,” said Bruce B. Darling, Executive Officer of the National Academy of Sciences (NAS) and National Research Council (NRC) and chair of the search committee. “We look forward to Neil's leadership on critical transportation issues for the nation and for the profession.”

TRB Executive Committee Chair Kirk Steudle noted that the members of the search committee “interviewed extraordinary candidates” and “concluded that Neil is the best choice to take TRB forward.” In addition to Steudle, members of the search committee included Deborah H. Butler, former Chair of the TRB Executive Committee and current member; Susan Hanson (NAS), Executive Committee member and Chair of the Subcommittee for NRC Oversight; Jeff Paniati, Executive Director of the Federal Highway Administration; Mike Walton (NAE), past TRB Executive Committee Chair and former SNO Chair; Bud Wright, AASHTO Executive Director; Audrey Mosley, NAS and NRC General Counsel; Peter Blair, Executive Director of the NRC Division on Engineering and Physical Sciences; and Gregory Symmes, Executive Director of the NRC Division on Earth and Life Studies.



Neil J. Pedersen



Commercial Aviation Soars into Its Second Century

Aerial Views of a Rapidly Developing History—and Outlook

JOHN FISCHER, GREG CASTO, AND GEORGE HAMLIN

Fischer is a consultant in Annapolis, Maryland, and an emeritus member of the TRB Aviation Economics and Forecasting Committee. Casto is President, AvAirPros, Naples, Florida. Both are members of the TRB History Committee. Hamlin is President, Hamlin Transportation Consulting, Fairfax, Virginia, and is the author of the Skyliners series of pictorial airline histories.

On January 1, 1914, a two-seat Benoist XIV airplane took off on a 21-mile trip to Tampa, Florida, carrying pilot Tony Jannus and one passenger, who paid \$400—equivalent to more than \$9,000 today—to be the first passenger on the 23-minute flight. This was the start of commercial airline service in the United States.

The St. Petersburg–Tampa Airboat Line offered several round-trips daily for some time afterward. Speaking before the crowd of 6,000 who had assembled to watch the first flight, Percival Fansler, creator of the Airboat line, declared, “What was impossible yesterday is an accomplishment of today, while tomorrow heralds the unbelievable” (1).

The onlookers probably could not have envisioned today’s highly developed international airline industry. According to the Federal Aviation Admin-

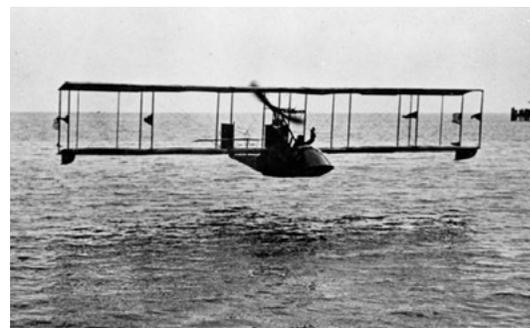


PHOTO: STATE ARCHIVES OF FLORIDA, FLORIDA MEMORY

Pilot Tony Jannus lands in Tampa, Florida, after a successful flight of his two-seater seaplane, January 1, 1914.

(Photo, top of page:) An Air France Airbus at Miami International Airport. Commercial aviation has grown from its beginnings in Florida a century ago into a highly developed international industry.

istration (FAA), U.S. airlines carried 739.3 million passengers in 2013 for 834.1 billion revenue passenger miles (RPMs)—that is, one paying passenger traveling 1 mile—and more than 1 trillion available seat miles (ASMs)—that is, one seat traveling 1 mile (2, p. 42). If the FAA's forecasts are accurate, these numbers will increase to 1.15 billion passengers, 1.47 trillion RPMs, and 1.75 trillion ASMs by 2034.

Dramatic Growth

From its first days, the airline industry grew by fits and starts through the 1920s as aircraft technology improved and the necessary infrastructure of airports, air traffic control, and the rules of the air were created, often without coordination. Airline service grew dramatically in the next decade, with the introduction in 1933 of new aircraft such as the Boeing 247 (see photograph, below). The arrival of the Douglas DC-3 slightly later in the decade, however, proved a watershed moment—the DC-3 was the first aircraft widely viewed as capable of producing a profit for its operators solely by carrying passengers.

Airline industry growth took a break during World War II but benefited from the technologies introduced during the war, as well as from the number of aircraft produced and the infrastructure created to support the military. Growth accelerated once again.

The introduction of jet aircraft, notably the Boeing 707, into commercial service in the 1950s began to shrink the world in a new way. In the preceding half-century, improvements in new aircraft of many types, improved infrastructure, dramatic technological advances, and new business practices resulting in part from economic deregulation made air travel cheaper and more available worldwide.



PHOTO COURTESY OF GEORGE HAMLIN

Boeing 247 next to a Boeing 767.



PHOTO: WIKIMEDIA COMMONS

The Douglas DC-3—the first airplane capable of producing a profit as a commercial aircraft—prepares for takeoff in 1940.



IMAGE: JAMES VAUGHAN

Superhighways of the Sky

Flying between almost any two major cities in the world in one day is now possible. This would have been unimaginable from the perspective of January 1, 1914. As Microsoft founder Bill Gates observed in a 1999 *Time* magazine article, “The Wright Brothers created one of the greatest cultural forces since the development of writing, for their invention effectively became the first World Wide Web of that era, bringing people, languages, ideas, and values together. It also ushered in an age of globalization, as the world's flight paths became the superhighways of an emerging international economy. Those superhighways of the sky not only revolutionized international business, they also opened up isolated countries, carried the cause of democracy around the world, and broke down every kind of political barrier. And they set travelers on a path that would eventually lead beyond the earth's atmosphere” (3).

Eyewitness Observations

A more entertaining and perhaps more enlightening approach to the past 100 years is to move from a chronological history to insights directly from industry leaders and observers:

◆ “You cannot get one nickel for commercial flying,” claimed Inglis M. Uppercu, founder of Aero-marine West Indies Airways, the first American airline to last more than a few months, in 1923.

◆ A June 1929 issue of *Airports Magazine* published excerpts from a paper on the Architectural Treatment of the Modern Airport, presented by architect Francis Keally at the First Annual Airport Convention. “Aviation is the great transportation method of the future. We must look at it that way...to avoid

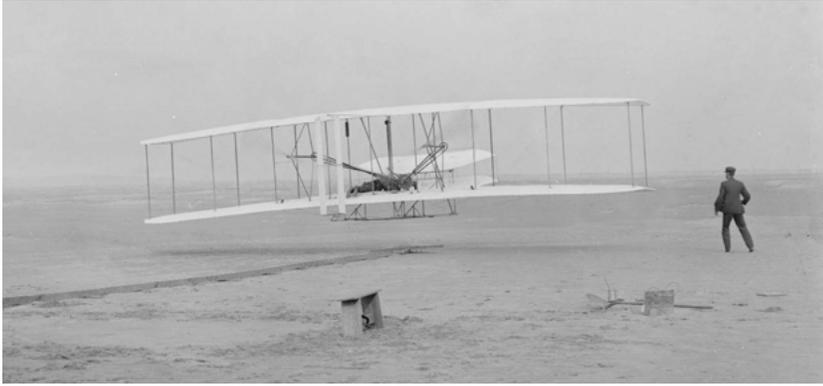
In the 1950s, the first-class lounge of a Boeing 707 was a fashionable way for the “jet set” to travel.



PHOTOS: ARTHUR S. SIEGEL, OFFICE OF WAR INFORMATION, FARM SECURITY ADMINISTRATION

Commercial aviation derived benefits from the war efforts in the 1940s. (Above and below:) Michigan Air National Guard operations at the airport in Wayne County, Michigan—now Detroit Metropolitan Wayne County Airport; parts of the original runway remain as taxiways.





Wilbur Wright runs alongside the airplane piloted by his brother Orville at the world's first flight in Kitty Hawk, North Carolina, in 1903, launching "one of the greatest cultural forces since the development of writing."

The control tower of Dulles International Airport under construction in 1962. Dulles was described in contemporary news articles as the "Gateway to the Jet Age."



PHOTO: WARREN K. LEFFLER, LIBRARY OF CONGRESS PRINTS AND PHOTOGRAPHS DIVISION

mistakes in the planning of airports," Keally advised. "It may well be that the activities of the airport will become so important that an entire community will develop around it."

◆ A 1930 advertisement by Curtiss-Wright Airports Corporation, with the headline, "The Airport....Key That Opens the Sky Lanes to Commerce," stated: "The pioneering has been done. Oceans have been crossed...continents have been spanned. The air mail is an accepted fact...transcontinental air-rail lines run on regular schedule....Air transportation has proved itself. All that remains is to amplify, to extend, to make readily available....But the ship that takes the sky must always be able to come down....in safety. Aviation can grow no faster than the airports the country provides."

◆ "Not looking far enough ahead is one of the errors we've been making through the history of commercial aviation," observed Federal Aviation Administrator Elwood (Pete) Quesada in an August 15, 1960, *Time* article on Dulles Airport, described as the "Gateway to the Jet Age."

◆ Commenting on the introduction of the jet aircraft, Pan American World Airways founder Juan Trippe enthused, "This is the most important aviation development since Lindbergh's flight. In one fell swoop, we have shrunken the earth."

◆ "Deregulation will be the greatest thing to happen to the airlines since the jet engine," opined Richard Ferris, CEO of United Airlines, in 1976.

◆ "I really don't know one plane from the other," admitted Alfred Kahn, Chairman of the Civil Aeronautics Board, in 1977. "To me, they are just marginal costs with wings."

◆ "The worst sort of business is one that grows rapidly, requires significant capital to engender the growth, and then earns little or no money," wrote Warren Buffett, in his annual letter to Berkshire Hathaway shareholders in 2008. He continued: "Think airlines. Here a durable competitive advantage has proven elusive ever since the days of the Wright Brothers. Indeed, if a farsighted capitalist had been present at Kitty Hawk, he would have done his successors a huge favor by shooting Orville down."

Future Visions

A *USA Today* article on commercial aviation's centennial asked several prominent industry leaders for their insights on the future (4). Following are two responses:

◆ "I have no doubt that during my lifetime we will be able to fly from London to Sydney in under 2 hours, with minimal environmental impact. The awe-inspiring views of our beautiful planet below and zero-gravity passenger fun will bring a whole new meaning to in-flight entertainment," said Sir Richard Branson, president of Virgin Atlantic Airways.

◆ Ben Baldanza, CEO of Spirit Airlines, observed: "Google's 'put me there' technology implemented into its maps software renders all airlines obsolete."

When TRB was formed out of its predecessor Highway Research Board in 1974, aviation research became part of the expanded mission. Aviation has grown into a vibrant component of TRB, with nine standing committees pursuing a range of research subjects, many closely tracking airline industry issues. TRB's aviation work has expanded substantially with the creation of the Airport Cooperative Research Program in 2005. Whatever the next 100 years may bring in aviation, TRB will have a part in it.

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Indo-HCM— India's Highway Capacity Manual Project

*Developing a National Guide
to Address Unique Traffic
Conditions*

KAYITHA RAVINDER,
SENATHIPATHI VELMURUGAN, AND
SUBHAMAY GANGOPADHYAY

The U.S. *Highway Capacity Manual* (HCM), developed by the Transportation Research Board and first published in 1950, is the most quoted and consulted manual worldwide on the traffic capacity of highways. The HCM has undergone significant improvements, with major restructuring and revised new editions in 1965, 1985, 2000, and 2010.

The HCM methods, however, often require adjustment for application in other countries. National manuals have evolved to meet roadway design and traffic control practices. For example, according to the HCM 2000, the maximum flow rate on a multilane highway is 2,200 passenger car units (PCUs) per hour per lane (1); other nations have adjusted this threshold:

Ravinder is Principal Scientist, Transportation Planning Division; Velmurugan is Senior Principal Scientist and Head of the Traffic Engineering and Safety Division; and Gangopadhyay is Director, Council of Scientific and Industrial Research—Central Road Research Institute, New Delhi, India.

The Mumbai–Pune expressway viewed from Rajmachi point in Khandala, India. The Central Road Research Institute is collaborating with academic institutions to develop an Indian Highway Capacity Manual.

PHOTO: WIKIMEDIA COMMONS

Example of traffic heterogeneity in India.



PHOTO: CSIR-CRRI

Traffic on the Sir Leo Hielscher Bridges on Australia's Gateway Motorway, near Brisbane. Each nation interprets highway capacity guidelines in ways unique to its traffic characteristics. The Australian method follows the U.S. *Highway Capacity Manual* with modifications to determine ideal traffic flows.

◆ The Danish HCM, which has modified the HCM 2000 to meet conditions in Denmark, has published adjustment factors that steeply reduce capacity when conditions become less than ideal; the Danish HCM estimates that the capacity under ideal conditions on a four-lane highway is 2,300 PCUs per hour per lane.

◆ Similarly, Finland and Norway have made minor modifications to the HCM 2000 to meet local conditions and roadway capacities; the Finnish and Norwegian methods have established a maximum capacity of 2,000 PCUs per hour per lane for multi-lane highways.

◆ The Australian method for analyzing roadway capacity basically has followed the HCM 2000 with modifications for specific problems. Under ideal conditions, the average minimum headway is 1.8 seconds and the maximum flow is 2,000 vehicles per hour per lane.

◆ The Indonesian HCM determined the capacity of multilane highways as 2,300 light vehicles per hour per lane.

◆ In China, field data were used to calibrate and validate a highway simulation model developed in Sweden. The results revealed lower free-flow speeds and a marginally lower roadway capacity of 2,100 passenger car equivalents per lane on a four-lane divided carriageway under Chinese conditions.

In addition, Yang and Zhang conducted an extensive field survey of traffic flow on multilane highways in Beijing, developed an empirical model, and established an average roadway capacity per hour per lane per direction on four-lane divided carriageways as 2,104 PCUs; on six-lane facilities, 1,973 PCUs; and on eight lanes, 1,848 PCUs (2). This finding is unlike the HCM results obtained in many developed countries, which assume that the average capacity per lane is equal on different highways and that highway capacity is proportionate to the number of lanes on divided carriageways.



PHOTO: CENTRALIAK, FLICKR

India's Research Endeavor

In India, the Central Road Research Institute (CRRI) of the Council of Scientific and Industrial Research (CSIR) has undertaken a national study to develop the Indian Highway Capacity Manual (Indo-HCM). Several of the nation's most respected academic institutes are collaborating with CSIR on the Indo-HCM, including the Indian Institute of Technology in Roorkee, the Indian Institute of Technology in Bombay, the Indian Institute of Technology in Guwahati, the School of Planning and Architecture in Delhi, the Sardar Vallabhai Patel National Institute of Technol-

ogy in Surat, the Indian Institute of Engineering Science and Technology in Shibpur, and Anna University in Chennai.

The main hypotheses of the project are that Indian traffic characteristics are fundamentally different from those in developed countries and that driver behavior is vastly different from that in developing economies such as China and Indonesia. The development of an HCM that directly addresses the unique traffic conditions in India therefore was a necessity.

In 2012, under its 12th five-year plan, the Planning Commission of the Indian government provided funding to CSIR-CRRI for the development of the Indo-HCM. The five-year project started in April 2012 and is scheduled to conclude in March 2017.

Project Scope

The project is addressing each of the various categories of Indian roads: expressways, national highways, state highways, major district or county roads, other district roads, and urban roads. The principal goal is to study the nationwide characteristics of road traffic and to develop a manual for determining the roadway capacity and level of service (LOS) for varying types of interurban and urban roads, including controlled and uncontrolled intersections and pedestrian facilities.

To accomplish this goal, the project is analyzing the characteristics of traffic heterogeneity (see photo, top of page 18) to identify appropriate distributions of the variables that influence traffic flow and to examine these characteristics through an extensive collection and analysis of field data. Related studies are examining straight and midblock roadway sections and uncontrolled intersections, including the range of geometries and operating conditions. The capacity and LOS guidelines for controlled intersections in urban areas are being studied separately.

Preceding Research Efforts

Most of the models apply to homogeneous traffic conditions and therefore are not applicable to the heterogeneous traffic that characterizes Indian roads. The Road User Cost Study (RUCS) of 1982 was the first major research effort to address this issue (3), followed by the Updated RUCS of 1992 and another in 2001 (4).

The 1990 Indian Roads Congress (IRC) suggested a tentative design service volume of 40,000 PCUs for a four-lane divided carriageway in plain terrain; this is significantly lower than in most of the developing countries and necessitated supporting research. Several studies in the past two decades have aimed to assess the capacity on varying widths of carriageways, including single-lane, intermediate-lane, two-



PHOTO: INDRANEEL BHOWMICK, FLICKR

lane bidirectional, and four- to eight-lane divided carriageways on different terrains (4–7).

The research efforts, however, have been piecemeal, and the results did not constitute what was needed—an Indo-HCM. Development of the manual therefore became a goal in itself.

Study Methodology

The methodology for the development of the Indo-HCM is unique, because the research is analyzing the characteristics of heterogeneous traffic flow and identifying appropriate distributions of the various traffic variables influencing the traffic stream. The task is to examine the traffic flow characteristics and vehicular interactions occurring on the different typologies of road sections.

The study has deployed traditional macroscopic modeling, along with microscopic simulation modeling, regarded as one of the most effective analytical tools for estimating the capacity of Indian highways (7). Once validated, these models can be applied to study the traffic-flow characteristics of a range of associated variables, generating more acceptable results for assessing the effectiveness of traffic management measures.

The outputs derived from the appropriate traffic flow simulation models would be used to construct fundamental diagrams of flow, making possible an estimate of the capacity of a facility. To ensure uniformity of analysis, the 1st National-Level Workshop, January 18–19, 2013, in Surat, formulated and standardized a methodology, which all of the participating academic institutions have adopted.

The Indo-HCM study comprises nine work packages (WPs). In addition, annual project review workshops examine progress in each WP; the second review workshop was held at Anna University, Chennai, March 28–30, 2014.

India's vast road network comprises expressways, rural roads, and city streets.

Many Indian roads have nonstandard lane widths—and some drivers disregard lane markings altogether. Capacity estimates in India must consider the carriageway width.



PHOTO: ESTHER DRYDM, FLICKR

Work Packages

WP-1: Roadway Capacity Estimation of Two-Lane, Intermediate, and Single-Lane Carriageways

The categories of normal, undivided roadway sections in India are the following:

- ◆ Single-lane roads, 3.5 m to 3.75 m wide;
- ◆ Intermediate-lane roads, 5.5 m to 6.0 m wide; and
- ◆ Two-lane roads with earthen or paved shoulders, 7.0 m to 7.5 m wide.

Although roads in India are categorized by lane width, as noted above, many roads have nonstandard widths and do not conform to any discrete number of lanes. The carriageway width, therefore, is the main consideration. This also applies to the analysis of the operational features, because road users seldom obey lane markings.

As noted earlier, the interurban roads are categorized as expressways, national highways, state highways, major district or county roads, other district roads, and urban roads. The roadway capacities are being studied in the context of the engineering features. The roads in the study are located on the typ-



PHOTO: MEENA KASHI, FLICKR

The bus rapid transit system Janmarg opened in Ahmedabad, India, in 2009. Analyses of urban roadway capacity need to account for the full variety of modes.

ical interurban corridors in the vicinity of Delhi, Mumbai, Kolkata, Chennai, Surat, Dehradun, Guwahati, and other cities to achieve a balanced geographical distribution representing plain, rolling, and hilly terrains.

WP-2: Roadway Capacity Estimation of Multilane Intercity Highways

In addition to the factors examined in WP-1, lateral clearance, median width, number of lanes, auxiliary lanes, and shoulder width and type are being considered on the test sections. If necessary, adjustment factors may be derived from the collected data.

WP-3: Roadway Capacity Estimation of Interurban and Urban Expressways

In addition to the factors listed under WP-2, the adequacy of ramp provision, weaving sections, and merge–diverge sections are being examined in relation to expressway capacity. The expressway test sections were selected according to availability in the vicinity of the study cities.

WP-4: Urban Roadway Capacity Estimation for Arterials, Subarterials, and Collectors

Test sections in the cities of Delhi, Mumbai, Kolkata, Chennai, Surat, Dehradun, and Guwahati were chosen for determining the capacity of urban roads classified as arterial, subarterial, and collector streets. The PCU vehicle type is assumed to be unaffected by the volume and composition of the traffic.

The presence of slow-moving vehicles in the traffic stream impedes the free flow of traffic. Attempts have been made to determine dynamic PCU values for different types of vehicles operating on different categories of roadway in India, both urban and interurban.

The PCU for a vehicle type changes with the many factors that influence the behavior of vehicles in the traffic stream. Therefore, the following equation was proposed for estimating the PCU from field data (5).

$$PCU_i = \frac{V_c / V_i}{A_c / A_i}$$

where

- V_c = speed of a car,
- V_i = speed of a vehicle type i or clearing speed for an intersection,
- A_c = projected rectangular area of a car (length by width), and
- A_i = projected rectangular area of vehicle type i on the road (length by width).

The applicability of the equation for determining the number of PCUs for varying types of carriageways is being studied. If the formulation proves acceptable for traffic on different types of carriageways, refinements may be finalized for interurban and urban roads.

WP-5: Capacity Estimation of Controlled Intersections

Intersections are critical nodal points in any road network and often are the causes of traffic delays; therefore separate studies of intersections are imperative, to determine the LOS and capacity norms under different operating conditions. The two broad categories of uncontrolled and controlled or signalized intersections are being studied in detail in and around the selected cities.

Signalized intersections are found on Indian urban roads of varying widths, including undivided and divided carriageways; therefore, the following factors are being considered:

- ◆ Roadway: number of intersecting legs; approach width, gradient, and curvature; safe stopping sight distance; intersection sight distance; and channelization;
- ◆ Traffic: volume and composition; directional flow, straight and turning; peak and nonpeak flow; parking regulations in the vicinity; location of bus stops nearby; and pedestrians;
- ◆ Environmental: weather and other environmental influences on the intersection's operation; and
- ◆ Control conditions: speed limit; prohibitions on overtaking; and availability of traffic control devices such as signs, islands, markings, and the like.

A detailed analysis of roundabouts is being carried out independently with the same parameters.

WP-6: Capacity Estimation of Uncontrolled Intersections

The scope of this package is confined to the factors applicable to the range of major uncontrolled intersections on interurban roads serving a sizable portion of suburban and exurban traffic.

WP-7: Capacity Estimation of Pedestrian Facility

LOS describes the operating conditions or suitability of a mode of travel in the transportation system. The LOS of varying types of roads is based primarily on speed, travel time, and intersection delay. The calculation of pedestrian LOS, however, is complex, because it represents the operating condition of pedestrian facilities and the level of comfort that



PHOTO: CHRIS CONWAY, HILARY OSHEROFF, FLICKR

pedestrians experience in using the facilities. Pedestrian LOS must be studied for a variety of facility types.

WP-8: Gap Acceptance Studies

Driver behavior at typical conflict points is being studied to understand the movements of crossing vehicles at major uncontrolled intersections; video recordings are being conducted at vantage positions. The photograph below illustrates the field setup of a camera deployed to capture video data at a typical uncontrolled intersection in Delhi for a study of the gap acceptance by different types of vehicles.

Many factors affect the capacity estimation of signalized intersections in India, from turning traffic and sight distance to speed limits and prohibitions on overtaking.

Video camera installation at an uncontrolled intersection in Delhi.



PHOTO: CSIR-CRRI

Inbuilt high-mast arrangement for collecting video data in Chennai.



Photo: CSIR-CRRI

WP-9: Development of Reliability as a Performance Measure

Travel time reliability (TTR) is increasingly recognized as an important performance measure for mobility. The WP is focusing on the development of TTR as a surrogate performance measure for expressways and multilane highways. The photograph above shows a gantry arrangement for collecting video data in Chennai.

Project Deliverables

The project calls for tangible annual outputs. A state-of-the-art report was prepared at the end of 2013 highlighting the salient aspects of nationwide characteristics of highway traffic, operation, and control and reviewing the hierarchical functioning of interurban and urban roads. The report for 2013–2014 addresses the generation and updating of the traffic database and traffic flow characteristics for Indian roads.

The remaining project reports are as follows:

- ◆ Development of speed-density-volume relationships for a range of roadway and traffic conditions is scheduled for delivery the third year (2014–2015).

- ◆ Procedures for determining the operational efficiencies of different categories of Indian roads, including intersections, with evaluations of the various combinations of geometry and operating conditions, are planned for the 2015–2016 report.

- ◆ Guidelines for roadway capacity and LOS estimation for different categories of roads and intersections, including pedestrian facilities, is targeted for 2016–2017. The report also will revise several codes of the Indian Roads Congress, as well as the evolving guidelines for expressways.

The final manual is expected to serve as a practical tool for engineers and planners. The volume will mitigate the traffic and infrastructure problems by developing, calibrating, and validating models for conditions prevailing on the varying road widths on plain and on rolling and hilly terrains.

Acknowledgments

The authors thank their CSIR-CRRI colleagues who are involved in the Indo-HCM project for extending their support during the conceptual development of the study. The authors also thank the regional coordinators associated with this project.

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Implementing Modern Roundabouts in the United States

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Modern roundabouts have emerged officially in nearly all of the 50 states. The United States has joined many other countries in the widespread implementation of an intersection alternative that has significant safety and operational benefits. These safety benefits have led to the implementation of modern roundabouts in numerous states and have established the roundabout as a viable intersection alternative in rural and urban environments. The reduction in injury and fatal crashes at roundabout intersections, consistently between 76 and 90 percent, is unprecedented (1).

Implementation Snapshot

Some agencies have implemented roundabouts at a faster pace than others. A snapshot of several agencies that have contributed to the roundabout movement in the United States shows the diversity of the implementations:

- ◆ The Maryland State Highway Administration was a pioneer in the adoption of modern roundabouts, with widespread implementation on state highways.
- ◆ The City of Carmel, Indiana, continues to outpace other cities, with more than 60 roundabouts—

nearly one for every 1,000 citizens.

- ◆ A regional partnership on the Western Slope of Colorado has involved consistent collaboration between local agencies, the Colorado Department of Transportation (DOT), and the Federal Highway Administration (FHWA) for nearly 20 years. As a result, a majority of the interchange ramp terminals on a 120-mile stretch of Interstate 70 were constructed as roundabouts, and several more are under consideration.

- ◆ The Wisconsin state roadway system was the first to reach 150 roundabouts, and 120 more are planned. Wisconsin DOT published its first roundabout policy, the *Wisconsin Roundabout Guide*, in early 2004 and has completed five updates.¹

- ◆ The Lummi Nation in Washington State has installed a rural roundabout and has embraced the safety benefits of the design.

- ◆ Georgia DOT accelerated its roundabouts program with nearly 150 modern roundabouts planned for construction in the next 7 years. Georgia DOT also was the first state agency to construct a mini-roundabout.

¹ <http://dot.wi.gov/safety/motorist/roaddesign/roundabouts/docs/guide-wisdotrab.pdf>.

Roundabout at Interstate 70 Edwards Access Road near Eagle, Colorado. Studies and guidance from TRB, state departments of transportation, and the Federal Highway Administration have supported the growth of roundabouts in the United States.



PHOTO COURTESY OF HILLARY ISEBRANDS, FHWA



PHOTO COURTESY OF HILARY ISBRANDS, FHWA

Roundabout in Clearwater Beach, Florida.

Persistent Interest

Countless agencies and champions inside and outside those agencies have supported the research and implementation of roundabouts since the early 1990s. Implementation was sparse at first, with only a few roundabouts in Maryland and Colorado. The early success and interest in roundabouts, however, led to a National Cooperative Highway Research Program (NCHRP) Synthesis project, with findings published in 1998 as NCHRP Synthesis 264, *Modern Roundabout Practice in the United States*.²

At the same time, the Insurance Institute of Highway Safety invested in studies on the safety benefits of roundabouts and funded the first statistical before-and-after safety analysis of modern roundabouts in the United States. The report offered an initial glimpse at safety data for the roundabouts in the United States, confirming that the results were consistent with international experience.

² http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_264.pdf.

Persistent interest followed this early research and in 2000 FHWA published *Roundabouts: An Informational Guide*.³ The FHWA guide relied heavily on international expertise and experience to assemble practical information for U.S. planners and engineers considering a roundabout.

Two needs became apparent: first, to develop a U.S.-based capacity model to be integrated into the *Highway Capacity Manual*, and second, to substantiate the earlier safety research with more data. The Transportation Research Board (TRB) spearheaded the first comprehensive roundabout research project in the United States through NCHRP Project 3-65, *Roundabouts in the United States*, which updated the FHWA guide. The findings appear in NCHRP Report 672, *Roundabouts: An Informational Report, Second Edition*, released in 2010.⁴ Figure 1 (below) shows a timeline of modern roundabout implementation and breakthroughs.

Fostering Growth

State DOTs—including Kansas, Wisconsin, New York, and Washington State—fostered the growth of modern roundabout design by publishing guidance. FHWA continued to support the consideration and construction of modern roundabouts, and in 2008 the FHWA Office of Safety elevated modern roundabouts to the status of a proven safety countermeasure. Roundabouts still are touted as one of the safest designs for intersections.

Recent efforts to support performance-based design solutions have attracted attention to roundabouts. Several state DOTs, including Minnesota and California, have adopted intersection control evaluation policies, setting the stage for performance-based designs. Historically, transportation agencies only con-

³ www.fhwa.dot.gov/publications/research/safety/00068/.

⁴ http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_672.pdf.

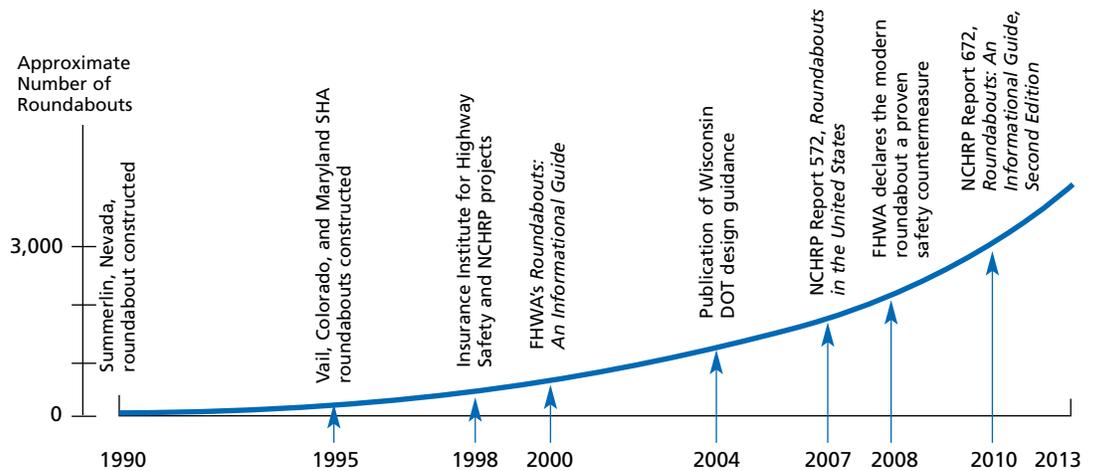


FIGURE 1 Timeline of roundabouts implementation in the United States.

sidered all-way stops, signals, grade separation, or short-term improvements to address safety and operational intersection problems. With a more proactive analysis of design alternatives, roundabouts are being considered early in the project development process and are found to provide short- and long-term benefits that previously were not considered.

With the overwhelmingly favorable safety record of roundabouts in reducing injury and fatal crashes across the world, all transportation agencies should be considering the design as a viable intersection alternative. Efforts will continue to develop and provide guidance and technical assistance to encourage the consideration of roundabouts.

Active Projects

In July 2014, TRB published NCHRP Report 772, *Evaluating the Performance of Corridors with Roundabouts*.⁵ Meanwhile, several national roundabout evaluation and research projects are advancing knowledge on the issues of pedestrian accessibility, freight movements, and the calibration of capacity models. Active projects include the following:

- ◆ NCHRP Project 3-78b, Guidelines for the Application of Crossing Solutions at Roundabouts and Channelized Turn Lanes to Assist Pedestrians with Vision Disabilities⁶;

- ◆ NCHRP Project 3-110, Estimating the Life-Cycle Cost of Intersection Designs⁷;

- ◆ NCHRP Project 17-70, Roundabout Crash Prediction Method for the *Highway Safety Manual*⁸;

- ◆ NCHRP Project 20-05, Topic 46-02, Roundabout Design, Operations, and Safety Practices⁹;

⁵ <http://www.trb.org/Main/Blurbs/171016.aspx>.

⁶ <http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3389>.

⁷ <http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3392>.

⁸ <http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3663>.

⁹ <http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3791>.



Roundabout at Eby Creek, US-6, Eagle, Colorado.

PHOTO COURTESY OF HILARY ISBRANDS, FHWA



PHOTO: DAN BURTON, PEDESTRIAN AND BICYCLE INFORMATION CENTER

- ◆ The FHWA Research and Technology project, Field and Safety Evaluation of Mini-Roundabouts¹⁰; and

- ◆ The FHWA Office of Safety project, Accelerating Roundabout Implementation in the United States: Evaluations to Address Key Issues, including

- The effectiveness of rectangular rapid flash beacons,
- Reassessment of capacity analysis,
- Environmental characteristics,
- Forensic safety evaluation,
- Trucks and freight considerations (e.g., truck incidents and maneuvering),
- Optimizing crosswalks placement and geometry, and
- Human factors assessment.

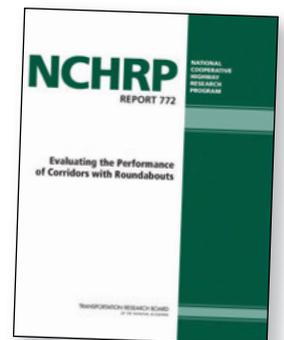
Residential area roundabout in Brighton, Michigan. NCHRP researchers are studying the accessibility of roundabouts to pedestrians.

Continuous improvement of roundabout design for all users is a priority within the profession and is supported by many agencies and stakeholder groups. The United States has come a long way in the acceptance of modern roundabouts, but the opportunities are countless for agencies to consider and construct roundabouts. The TRB Roundabouts Committee conducts conferences and sponsors webinars to promote research and technology transfer; the committee's information resource center is located at www.trb.org/ANB75/ANB75.aspx.

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1. NCHRP Report 572: *Roundabouts in the United States*. Transportation Research Board of the National Academies, Washington, D.C., 2007. www.trb.org/Main/Blurbs/158299.aspx.

¹⁰ www.fhwa.dot.gov/research/tfhrc/projects/projectsdb/projectdetails.cfm?projectid=fhwa-proj-10-0066



NCHRP Report 772, *Evaluating the Performance of Corridors with Roundabouts*, is available from the TRB Bookstore at <https://www.mytrb.org/Store/Product.aspx?ID=7229> or can be viewed online at www.trb.org/Publications/Blurbs/171016.aspx.

Active Traffic Management Strategies for Arterials

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Active traffic management (ATM) is the timely adaptation of a roadway facility's configuration and controls to maintain optimal productivity in response to—or in anticipation of—variations in demand, incidents, and weather. A recent synthesis project surveyed and assessed ATM strategies that go beyond traffic-actuated, responsive, and adaptive signal control. The findings were published in National Cooperative Highway Research Program (NCHRP) Synthesis 447, *Active Traffic Management for Arterials* in July 2013.

The synthesis provides an overview of the state of the practice associated with designing, implementing, and operating ATM on arterials. The synthesis focused on strategies to manage traffic and congestion actively on arterials; situations and operating conditions in which ATM strategies have been deployed on arterials; and the system and technology requirements for implementing the strategies. Also highlighted are the institutional issues associated with implementation; the operations and maintenance requirements; and the benefits and costs of ATM on arterials.

The Federal Highway Administration (FHWA) is sponsoring pilot projects to apply integrated corridor

management strategies for arterials and freeways (1). Because of the limited experience in U.S. applications, however, these were not included in the survey.

Approach

A literature search and interviews with agency staff were conducted to assess the state of ATM practice on arterial streets in the United States. Agencies were selected for interviews after a screening survey that was broadcast to members of the Institute of Transportation Engineers (ITE) Traffic Engineers Council, the ITE Public Agency Council, the Association of American State Highway and Transportation Officials (AASHTO) Subcommittee on Traffic Engineering, the Transportation Research Board (TRB) ATM Joint Subcommittee, and the TRB Signal Systems Committee.

Members of these groups who indicated that their agency had a high level of experience with one or more ATM strategies on arterials were chosen for follow-up telephone interviews. Case studies on the implementation of specific ATM strategies on arterials were developed from additional follow-up calls. The synthesis was not a complete inventory of agencies and ATM installations in the United States but

Reversible lanes provide more capacity in anticipation of regular changes in demand, such as rush hour. An NCHRP Synthesis project surveyed active traffic management strategies that respond to changing traffic conditions in real time.



PHOTO: MATT JOHNSON, FLICKR



A bus queue jump signal gives buses priority at an intersection near Montlake Bridge in Seattle, Washington.

presented a selective investigation into lessons learned from the implementation of ATM strategies on arterial streets.

ATM on Arterials

ATM strategies identified in the survey were grouped according to the method or tactic used—for example,

- ◆ Monitoring arterial performance;
- ◆ Dynamic signal control, such as special plans, signal priority, and queue jump;
- ◆ Dynamic geometric control, such as reversible lanes, dynamic turn prohibitions, and dynamic turn lanes; and
- ◆ Traveler information.

Monitoring Arterial Performance

Conventional and advanced arterial monitoring relies on technologies that count traffic volumes or measure performance at specific spots of the facility and on technologies that measure performance over the length of the facility (2).

◆ **Spot measurement technologies** include inductive loop detectors, magnetometers, radar detectors, and video cameras. These devices detect a vehicle's presence; the information can be used to count traffic volumes and to estimate spot speeds over the limited detection ranges of the devices.

◆ **Probe technologies** that measure arterial performance over the length of the facility include blue-tooth detectors, wi-fi detectors, cell phones, toll tags and other Global Positioning System (GPS) tracking devices, and license plate readers. These devices identify vehicles at different points on the facility and measure the elapsed time from point to point or track the position of GPS units within the vehicles over a broad geographic area.

Dynamic Signal Controls

Dynamic signal controls employ the following approaches to improve the responsiveness of signal timing to conditions evolving in the field (3):

◆ **Traffic-actuated control.** The signal can lengthen or shorten green times or skip phases within a limited range of maximum and minimum values determined from anticipated ranges of traffic demand. Limits may differ by the time of day.

◆ **Traffic-responsive control.** The signal can select from a wider range of possible timing plans, determined from demand patterns observed in the field, with slightly greater flexibility.

◆ **Traffic-adaptive control.** The signal operates with the greatest flexibility in responding to—and sometimes anticipating—microscopic changes in traffic patterns (4).

◆ **Specialized timing plans.** Agencies develop specialized signal timing plans for special events, including major sporting events.

Inductive loop detectors and other spot measurement devices count traffic volumes and speeds at specific areas along a route.



When a Portland, Oregon, light rail train is detected approaching an intersection, a special signal alerts motorists and other travelers and the green signal accommodates the train.



PHOTO: KIRKELSON & ASSOCIATES

◆ **Signal priority.** Signal priority works within the established signal control plan to improve operations for certain vehicles, such as transit vehicles. Typically when a vehicle with signal priority is detected, the green time is extended or the green phase begins earlier, to accommodate the vehicle.

◆ **Queue jump.** Separate signals display a green light to the transit lanes before a green light for the other lanes.

Dynamic Geometric Configuration

Arterial geometric configuration tactics include dynamic lane assignments, dynamic turn restrictions, and reversible lanes.

◆ **Dynamic lane assignments.** With dynamic lane assignment, for example, an approach that has heavy left-turn movements in the morning peak period can operate with dual left-turn lanes. After the peak, when the left-turn demand has abated, the second left-turn lane can become a through movement. These lane assignment changes usually are implemented with changeable overhead signs (5).

◆ **Dynamic turn restrictions.** When necessary, certain turning movements can be restricted to improve the safety and operation of an intersection. Instead of restricting right turns for the entire day, for example, a dynamic “No Right Turn on Red” sign can illuminate during the left-turn phase, improving safety without impacting intersection operations more than necessary.

◆ **Reversible lanes.** With reversible lanes, an agency can increase the arterial capacity in the peak direction by changing the directional flow within certain lanes. Reversible lanes usually are designated with overhead signs and special pavement markings (6).

Traveler Information

Disseminating information about arterial travel to the public can shift demand to other hours, other routes, and other modes of travel to balance congestion on the street network. Dynamic message signs, web pages, and mobile device messages are the primary ways that agencies are distributing data about traffic on arterials.

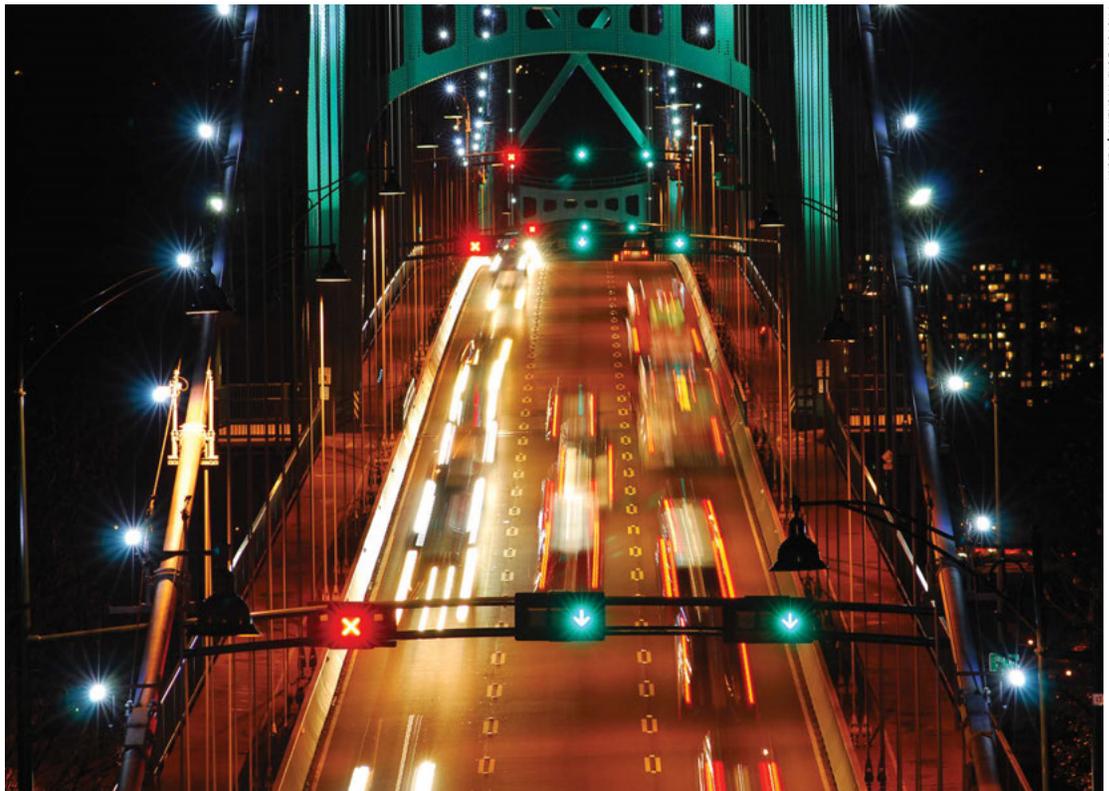


PHOTO: GORD MCKENNA, FLICKR

Lion's Gate Bridge in Vancouver, British Columbia, Canada. Dynamic signs designate lane directions and other information, such as turn restrictions.

Literature Search and Interviews

The literature review and agency interviews indicated that ATM strategies have been deployed successfully on arterials that had the following characteristics:

- ◆ Recurring and nonrecurring traffic congestion, coupled with limited options for improving capacity;
- ◆ An operating agency with the maintenance and operations resources to implement and fine-tune the ATM application; and
- ◆ The active participation and coordination of multiple divisions within an agency and of other agencies in the ATM application.

The literature review and interviews found that few ATM strategies had matured enough to be finally determined as unsuccessful. Nonetheless, in the case of reversible lanes—a mature ATM strategy—the literature identified situations in which the strategy was retired because it was no longer needed or in which the costs outweighed the benefits. In addition, some agencies have determined that when travel demands increase, reversible lanes can impose delays in the reverse direction.

System and Technology Requirements

The literature review and agency interviews found that system and technology requirements associated with implementing the tactics vary:

- ◆ **Continuous real-time monitoring** of arterial performance requires permanent detectors in the field and moderate-capacity communications between the field and the central office. Data stored in the central office can be used for engineering studies, as well as for real-time control.
- ◆ **Dynamic signal control** requires sophisticated software at the control center, in the field, or both.
- ◆ **Dynamic geometric control**—such as dynamic turn lanes and prohibitions—requires sophisticated software in the field and in the control center, plus specialized display hardware in the field.
- ◆ **Dynamic traveler information**, depending on the technology selected, may require specialized display hardware in the field, with communications between the central office and the field, or it may require cell phone and website technology.

Associated Concerns

The agency interviews revealed institutional issues, operations and maintenance requirements, and the benefits and costs associated with implementing these strategies:

- ◆ Institutional issues were among the greatest

PHOTO: SEATTLE DOT



challenges to implementing ATM on arterials;

- ◆ Budgeting for the operations and maintenance costs of ATM on arterials was a necessary task, but the interviewees did not provide information on the costs separately from other agency costs; and
- ◆ All considered ATM on arterials a positive benefit to the public but were not prepared to quantify the benefits with computations or measurements. Most considered the implementation of their ATM application to be in the developmental phase and not sufficiently mature for a formal evaluation.

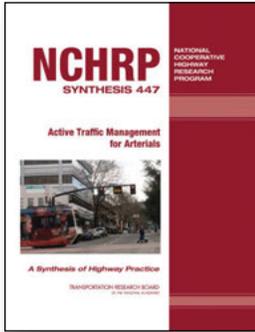
The literature review identified measures related to monitoring arterial performance, dynamic signal control, reversible lanes, dynamic turn prohibitions, and traveler information. Instances of agencies implementing dynamic turn lanes were less common in the literature and in practice. Dynamic parking management—also a relatively recent innovation—is only beginning to be documented in the literature and implemented in pilot programs.

Although the literature and technologies are available to support arterial performance monitoring, the 2012 National Traffic Signal Report Card of the National Transportation Operations Coalition shows that public agencies give themselves a failing grade in monitoring arterial performance (7). The report suggests that the problem may be a lack of resources, although the coalition did not query agencies about the reasons for the low self-assessment. Future research is needed to understand the obstacles.

Requirements for Success

The dominant theme that emerged from the case examples was that the major requirements for a successful ATM implementation on arterial streets were much the same as for any major investment project by the agency:

Many agencies that have implemented ATM have emphasized the need for sufficient infrastructure to accommodate the new ATM technologies.



NCHRP Synthesis 447, *Active Traffic Management for Arterials*, is available from the TRB Bookstore at <https://www.mytrb.org/Store/Product.aspx?ID=5795> or can be viewed online at www.trb.org/Publications/Blurbs/169212.aspx.

- ◆ Build political support,
- ◆ Line up funding,
- ◆ Identify and engage stakeholders within and across agencies,
 - ◆ Hire the appropriate technological expertise if not available in house, and
 - ◆ Plan out and design the proposed investment in detail:
 - Conduct an inventory of the infrastructure necessary to support the new technology,
 - Recognize that technology is not perfect and account for this in planning for ATM, and
 - Consider the effect of the project on ongoing maintenance costs, recognizing that underestimating is easy.

Each of the agencies interviewed identified at least one—and often more—of these points as lessons learned in implementing ATM on their streets.

Challenges to Address

According to the interviews, the major difference between the challenges of conventional capacity improvements and ATM investments appears to be the degree to which ATM requires the involvement of multiple stakeholders and the use of new and possibly unfamiliar technologies. These stand out as major challenges to ATM project implementation.

Many interviewees noted that predicting and monitoring the benefits of ATM implementation can be key to securing and continuing political and stakeholder support, yet few agencies had conducted formal before-and-after studies. Most interviewees were unable to identify the performance measures most appropriate for measuring the costs and benefits of ATM installations; in most cases, this was because they were still refining the ATM installations and were not yet ready to consider formal performance measures.

The interviewees generally were unable to respond to requests for quantitative information on the benefits of their ATM installations. In part, this was because U.S. ATM installations are evolving and have not yet achieved a steady state in which a formal before-and-after analysis is appropriate.

In the interviews, most ATM measures appeared to be far enough along in technological development for agencies to use the technical expertise available in-house or from contractors to plan, design, construct, and operate most ATM measures. Measures for dynamic turn lanes, however, lagged in technological development. The agencies implementing dynamic turn lanes had to develop on their own some of the software and hardware systems for implementing the measures.

Research Needs

The synthesis identified the following knowledge gaps:

1. Lack of consensus on the appropriate measures of effectiveness and the appropriate analysis methods for evaluating ATM investments and
2. Lack of sufficient expertise in the hardware, software, and operation of dynamic turn lanes in coordination with traffic signals.

Research is needed, therefore, to develop analytical tools for predicting how different ATM investments can affect travel time reliability and delay in an arterial system, either alone or integrated with a freeway.

The Reliability projects of the second Strategic Highway Research Program have developed performance measures and analysis methods for predicting travel time reliability (8). This information, recently developed and not yet fully disseminated, should benefit the community of agencies implementing or considering the implementation of ATM measures on their arterials.

Additional research is needed to determine the conditions under which these active traffic management strategies can best be applied to arterial roadways. Additional information on applications would allow agencies to determine which ATM strategies will best improve their arterial operations.

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Adopting Geospatial Technologies Key to Digital 3-D Revolution in Transportation

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Point cloud from mobile LiDAR data obtained for slope stability assessment on the Parks Highway near Denali National Park, Alaska.

The geospatial industry has undergone many technological advances in the past half century, from Global Positioning System (GPS) satellites to Internet applications to airborne and mobile LiDAR or light-detecting and ranging technology. Fertile ground for the digital revolution, the geospatial industry is transitioning from 2-D, paper-based mapping and plans to 3-D digital models. The transition affects transportation engineering in highway design with computer-assisted design and in highway construction with 3-D model-based design and automated machine guidance; transportation agencies in North America and worldwide are adopting these techniques.

In the rest of this decade, U.S. transportation agencies will be shifting standard operating procedures from paper maps and plans—the preferred medium since the days of the Roman Empire—to 3-D digital applications. The change under way in the industry is far-reaching and historic.

But change of this magnitude does not occur eas-

ily, particularly for large organizations that do not have a history of data sharing and that are being asked to do more with reduced resources. Yet doing more with fewer resources is a key reason for embracing the changes—geospatial technology can increase productivity significantly and can empower fewer workers to deliver the same or higher levels of service. The moves to mobile and cloud computing are examples of this opportunity.

Mapping the State of the Art

Recognizing the rapid pace of change in the geospatial industry, the Transportation Research Board (TRB) in 2010 initiated development of a synthesis report to summarize the state of the art and provide transportation agencies with a practical resource of applied research and lessons learned. The findings were published in 2013 as National Cooperative Highway Research Program (NCHRP) Synthesis 446, *Use of Advanced Geospatial Data, Tools, Technologies, and Information in Department of Transportation Projects*.¹

IMAGE: ALASKA DOT & PF

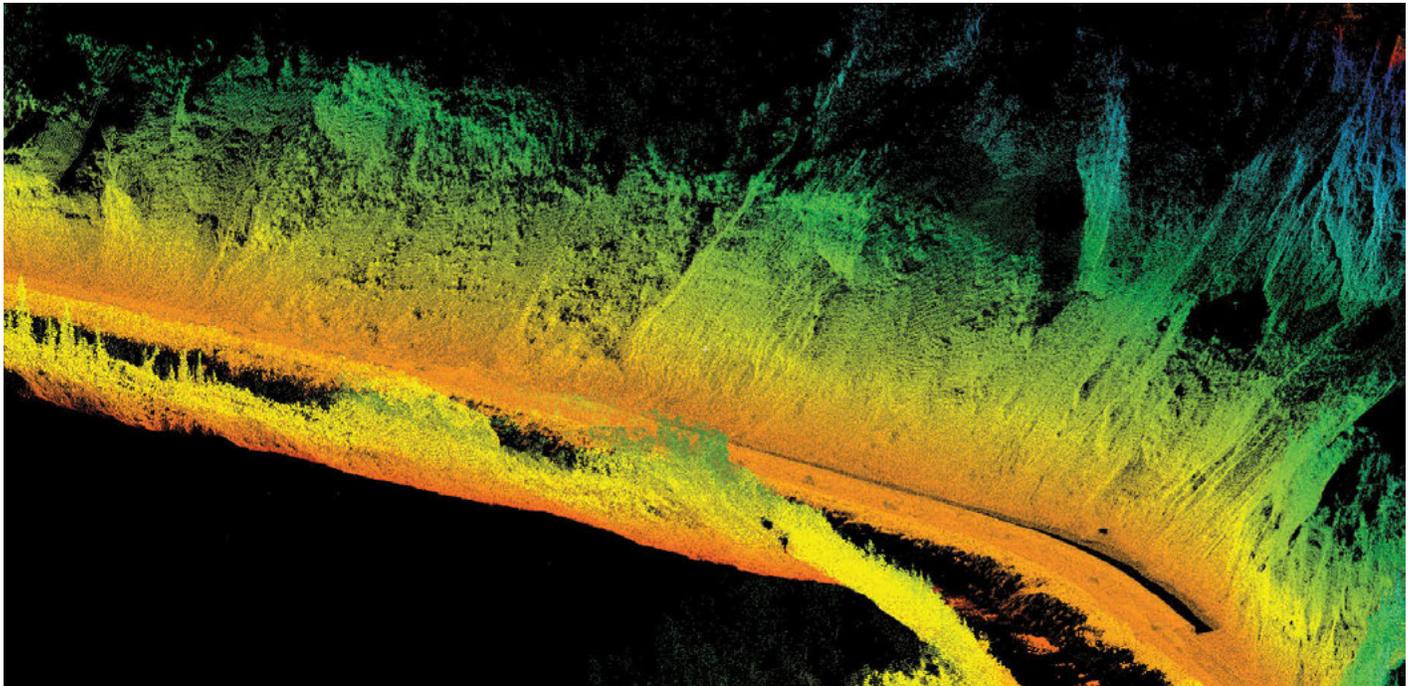
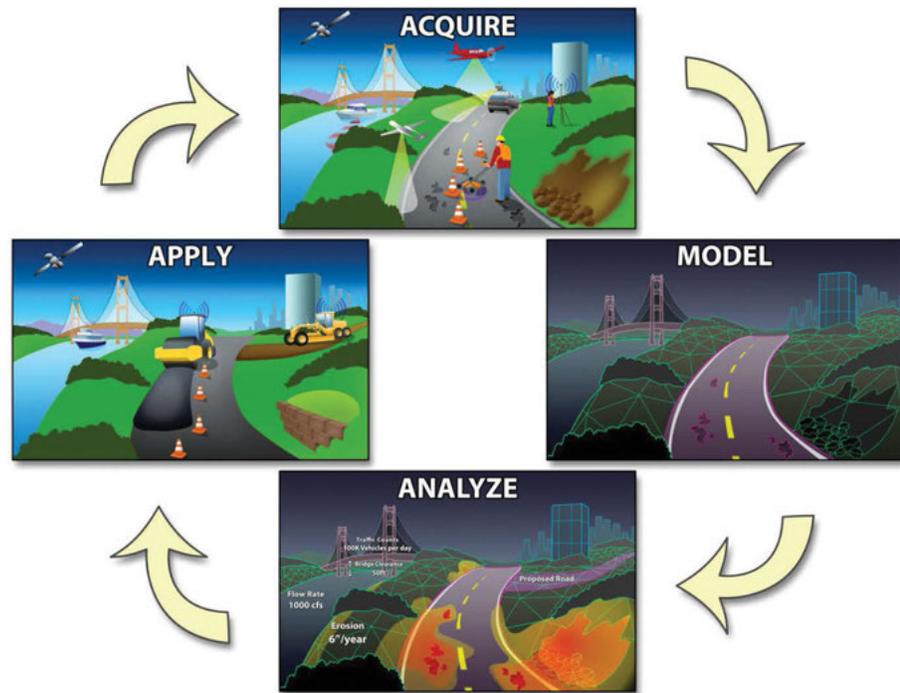


FIGURE 1 Geospatial tools applied across various phases of infrastructure life cycle. [Note: Labels in Analyze image (clockwise from right): Proposed road; erosion, 6 in. per year; flow rate, 1,000 cubic feet per second; bridge clearance, 50 feet; traffic counts, 100,000 vehicles per day.]



The synthesis team gathered data primarily through an international literature search and two online survey questionnaires, one sent to each U.S. and Canadian department of transportation (DOT) and the second to a group of vendors and service providers. The team developed a graphic (Figure 1, above) to emphasize the importance of geospatial data, tools, and technologies across the life cycle of a transportation infrastructure asset.

Global navigation satellite systems (GNSS) are now the norm in the acquisition of data, and airborne and mobile LiDAR—along with other remote sensing techniques—are documenting the as-found conditions in 3-D with unprecedented accuracy and resolution. This is the foundation of the 3-D revolution.

The data are transformed into 3-D models to inform decision makers visually and to support scientific, what-if analyses and virtual construction that can include time and cost—an expanded capability that some have termed 5-D. For the first time, transportation agencies can link the office to the field, as technologies such as automated machine guidance can make use of 3-D models to construct a project more efficiently.

In addition to a discussion of the strengths and weaknesses of the technology applications, the synthesis investigates related organizational and human factors. These cannot be ignored, because in most cases the greatest challenge is not the technology but the business process reengineering that is required to take

full advantage of the new systems. As noted earlier, change does not come easily in large organizations.

Assembling Resources

The results of the literature review are presented as an actively linked and geographically searchable reference to online publications that document the use of geospatial information and technologies in transportation applications. Information from pilot studies, individual technology analyses, and in-depth comparisons was evaluated for relevance and synthesized into a cohesive body of work, from historical uses to the state of the practice.

The resource covers such technologies as photography, remote sensing, LiDAR, GNSS, automated machine guidance, ground-penetrating radar, unmanned vehicles, traditional surveying methods, geographic information systems, and more. Several tables assemble data sources, such as clearinghouses, conferences, journals, and online magazines; evaluate the level of relevance; and specify the web addresses, providing an interactive facet to the synthesis.

In addition to synthesizing the body of knowledge on geospatial data tools and information in transportation, the publication assists DOTs and other agencies in considering and applying such techniques as geospatial enablement and the effective management of data quality.

Learning from Users

Nearly all of the state DOTs, plus Puerto Rico, the District of Columbia, and the Province of Alberta,

¹ www.trb.org/Main/Blurbs/169202.aspx.

responded to the online questionnaires. Among the key findings were that most DOTs regularly use geospatial technologies and are realizing benefits in terms of increased safety, productivity, and reliability.

Many state DOTs are actively researching new ways to use the technologies. The technologies most frequently used are GPS, transportation geographic information systems, and videologging. Many DOTs are transitioning to 3-D workflows, investigating centralized data access, and developing standards and specifications for these new technologies. For example, California DOT has developed mobile LiDAR specifications, and TRB has published guidelines in NCHRP Report 748, *Use of Mobile LiDAR in Transportation Applications*.

Although many state DOTs see the possibilities and benefits of the technologies, they face several challenges. Survey respondents indicated that the top three factors holding back the adoption of new technologies are cost, inertia, and technical expertise. In interviews, service providers stated that the top three factors that enable DOTs to introduce new technologies successfully are early adoption, an internal champion, and a keen interest in safety.

Most of the research and investigations by state DOTs are only published internally. These publications and experiences, however—even if the results were not as planned—could be helpful to other agencies. Many respondents favored establishment of a centralized website to disseminate this information in a timely way.

Mobile LiDAR Guidelines

NCHRP Report 748, *Guidelines for the Use of Mobile LiDAR in Transportation Applications*, released in 2013, addresses one of the most important 3-D geospatial technologies for transportation agencies in the next five to 10 years.² The project incorporated findings from an extensive international literature search and from online questionnaires on the state of the art. The report emphasizes the value of provid-

² www.trb.org/Main/Blurbs/169111.aspx.

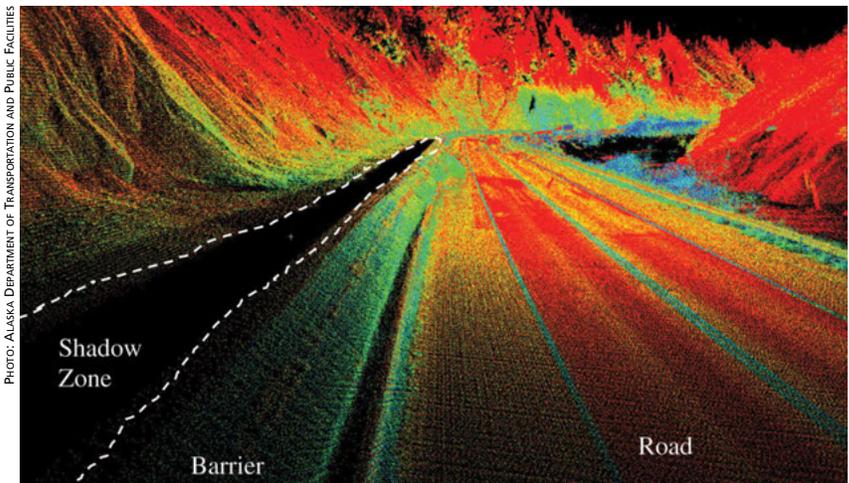


PHOTO: ALASKA DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

ing senior management with a detailed analysis about when and where to use this transformative technology.

The guidelines are not prescriptive but focus on desired outcomes, not on hardware and software or on geomatic specifications. The report includes an in-depth discussion of the technology and workflows for readers with a technical background. A web-based version of the guidelines is available, along with a variety of informative materials and resources including interactive, e-learning courses.³

One of the key findings is that every division in a transportation agency can benefit from knowledge about the as-found, 3-D field condition of the agency's assets. To maximize the benefits of mobile LiDAR, transportation agencies can develop a centralized data management strategy so that all divisions have access to the information and understand the limitations. This will require a paradigm shift in the way that transportation agencies manage data.

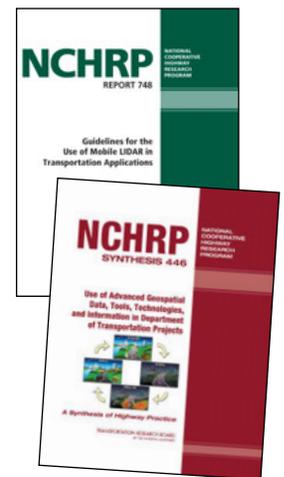
Transformational Technology

U.S. transportation agencies are being forced to do more with less. A major technology transformation now under way promises significant increases in productivity by empowering staff with accurate and timely information about field conditions in an easy-to-understand, 3-D visual environment. In many ways, the challenge is not the new technology but the organizational change that needs to occur to take advantage of the technology.

The digital versions of the two TRB reports are valuable, user-friendly resources. With the technology changing quickly, no standard textbooks are available. NCHRP Synthesis 446 and NCHRP Report 748 present the state of the art, with built-in flexibility to accommodate periodic updates.

³ <http://learnmobilelidar.com/>.

Obstructions can create shadows in the point cloud of a mobile LiDAR scan; the acceptable quantity and location of data gaps need to be considered.



NCHRP Synthesis 446 and NCHRP Report 748 are available from the TRB Bookstore at www.trb.org/Finance/Bookstore.aspx or can be viewed online at www.trb.org/Main/Blurbs/169202.aspx and www.trb.org/Main/Blurbs/169111.aspx, respectively.



PHOTO: U.S. ARMY CORPS OF ENGINEERS

Contractors use a ground-penetrating radar device on the Gavins Point Dam spillway in South Dakota.

Smart Growth and Urban Goods Movement

EDWARD McCORMACK, ANNE GOODCHILD, AND ALON BASSOK

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The quest to design cities that support a good quality of life, with vibrant, livable spaces, has provoked discussion about the role of transportation in urban environments. Much of the discussion has focused on passenger travel, land use, and the importance of nonmotorized transport under the theme of smart growth.

Smart-growth design generally includes compact development with moderate to modestly high density, a mixture of land uses, and a range of feasible transportation options that promote and facilitate nonautomobile modes of travel, such as transit, bicycles, and walking (1). Although freight movement is essential to a thriving economy, the planning and development for smart growth has often ignored the role of goods movement. A National Cooperative Freight Research Program (NCFRP) project explored the interaction between smart growth and urban goods movement; NCFRP Report 24 describes the implications of this relationship on transportation modeling and freight planning.

Principles and Conflicts

In the past 15 years, the urban planning and transportation literature has targeted smart growth, growth management, and urban center concepts as

potentially beneficial urban strategies. Table 1 (page 35) summarizes the principles of smart growth.

Few comprehensive studies have documented the impacts of these principles on goods movement—the movement of products, including waste removal and package delivery, throughout the urban area. In developed economies, people and businesses rely on this trade of goods and services, but conflicts arise with other urban activities. In most urban regions, space is scarce, and the competition for roadway space and parking is intense. Many urban regions were established before motorized transport, and their infrastructures are not well designed for the larger vehicles associated with goods movement.

More knowledge is needed about the activities and effective management of urban goods movement. Analyses have focused on reducing the number of vehicles required to move goods; reducing the monetary, environmental, and time costs; and restructuring goods-movement systems; the analyses, however, have not considered land use.

Research Gaps

◆ *Parking and loading.* The demand for adequate loading space significantly influences driver satisfaction. Research findings, however, have not iden-



A delivery truck blocks a bike lane in Chicago, Illinois. Smart-growth design that accounts for urban goods movement can prevent conflicts between modes in cities.

TABLE 1 Principles of Smart Growth (1)

Principle	Intent
Create a range of housing opportunities and choices.	Provide good-quality housing for people of all income levels.
Create walkable neighborhoods.	Create desirable places to live, work, learn, worship, and play.
Encourage community and stakeholder collaboration.	Create great places to live, work, and play in accord with how and where the community wants to grow.
Foster distinctive, attractive communities with a strong sense of place.	Encourage communities to craft a vision and set standards for development and construction that respond to community values of architectural beauty and distinctiveness and that expand choices for housing and transportation.
Make development decisions predictable, fair, and cost-effective.	Involve the private sector to ensure successful implementation.
Mix land uses.	Integrate mixed land uses into communities to improve livability.
Preserve open space, farmland, natural beauty, and critical environmental areas.	Bolster local economies, preserve the environment, improve quality of life, and guide new growth.
Provide a variety of transportation choices.	Increase choices in housing, shopping, communities, and transportation.
Strengthen and direct development toward existing communities.	Use available infrastructure and resources; conserve open space and natural resources on the urban fringe.
Take advantage of compact building design.	Pursue alternatives to conventional, land-consuming development.

tified the appropriate balance between the need for adequate parking for goods movement and the other uses of road space. The research also does not consider the impact of regulations on mobility and goods movement.

◆ *Bicycle and pedestrian facilities.* Smart growth emphasizes design that fosters nonmotorized mobility and multimodal environments. These designs include sidewalks along roadways, a well-connected bicycle network, and narrower streets that encourage slower speeds and are perceived as pedestrian friendly (2, 3). Little research has focused on the relationship between these types of street designs and urban goods movement.

◆ *Land use mix.* Smart growth seeks to intersperse land uses of different types. This integrated land use design is intended to reduce travel distances and to make nonmotorized and multimodal travel more attractive. To some extent, proximate residential, retail, office, and industrial spaces may also reduce the needs for goods movement, but this effect has not been studied. In addition, the literature on the relationship between land use patterns and truck-trip generation is sparse.

◆ *Logistics studies.* Logistics, operations research, and industrial engineering include topics related to smart growth and the movement of freight vehicles. Research can explore time and size restrictions, vehicle choice, and warehouse locations.

Learning from Stakeholders

What do experts know about the relationship between smart-growth principles and goods movement? Six focus groups were conducted in 2011, three in Seattle, Washington, and three in Philadelphia, Pennsylvania, convening freight stakeholders with expertise and experience in daily operations. The three groups in each metropolitan area com-

More research is needed on the relationship between land use patterns and truck-trip generation.

PHOTO: AAA FOUNDATION FOR TRAFFIC SAFETY



City restrictions limiting the hours for deliveries can result in heavy-duty trucks sharing the road with day traffic.



PHOTO: AAA FOUNDATION FOR TRAFFIC SAFETY

prised (a) truck drivers, (b) logistics managers, and (c) planners, public officials, and developers. The findings highlighted research gaps (Table 2, below).

Several areas of conflict were common to all of the focus groups. Despite a clear tension between truck drivers, who want additional parking and loading, and planners, who must balance that request with other competing interests, no research has examined or developed an optimal balance of parking space and time regulations.

Moreover, noise ordinances and other restric-

tions, such as specific delivery-time windows, may have the unintended consequence of causing truck congestion by not allowing deliveries to be spaced throughout the day. When multiple trucks must deliver during the same time window, with limited parking accommodation, drivers must vie for the same parking locations at the loading dock. The lack of parking forces drivers to double-park, circle the block, idle while waiting, or use hand trucks to deliver goods from a parking location farther away.

The potential for conflicts between trucks and

TABLE 2 Key Areas and Examples of Gaps

Research Area	Example of Gap	Focus Group Support
Access, parking, and loading zones	<ul style="list-style-type: none"> • What is the appropriate amount of parking or size and number of loading zones to dedicate to goods-movement vehicles? • Can time-of-day changes relieve demand for space? • What is the optimal balance of parking space and time regulations? 	There is a tension between truck drivers, who need additional parking and loading space, and planners, who must balance that need with competing interests.
Road channelization, bicycle, and pedestrian facilities	<ul style="list-style-type: none"> • Does the number of clashes between goods-movement vehicles and non-motorized modes increase when these vehicles coexist more frequently? • What tools or configurations are appropriate to reduce modal conflicts? 	The potential for conflicts between trucks and nonmotorized modes is a primary concern for urban goods movement in smart-growth environments.
Land use mix	<ul style="list-style-type: none"> • How do the environmental benefits of passenger-trip reductions associated with mixed use balance against the environmental costs of time restrictions on goods-movement vehicles to reduce their impacts on residences and other businesses? • Can vehicle sizes be changed? • What incentives encourage freight-trip consolidation? 	How can trip reduction and associated environmental gains fostered by mixed-use development be balanced with the lifestyle conflicts of differing uses in close proximity? Some methods of achieving these types of gains—including off-hours deliveries or larger, more efficient vehicles—have specific impacts, for example, on air quality or noise levels, that are undesirable in mixed-use environments.
Logistics	<ul style="list-style-type: none"> • Does density affect truck-trip generation? • Do mixed land uses change truck-trip generation rates? 	Because of the risks associated with innovative distribution methods, research is needed to illustrate the benefits and to identify ways to remove some of the barriers, for example, by offering government subsidies.

nonmotorized modes also was a common theme. Although the conflicts are a primary concern for urban goods movement in smart-growth environments, the literature addressing the problem is scarce.

Another area of tension is that mixed-use development fosters trip reductions for environmental gains; the differing uses in close proximity, however, create lifestyle conflicts. Other methods of achieving these gains—such as off-hours deliveries or larger, more efficient vehicles—can have undesirable effects on air quality and noise levels.

Additional research is needed on the benefits of these innovative distribution methods and on ways to remove some of the barriers. Efforts to manage the transportation system through real-time information and metered access offer promising solutions for reducing congestion, its costs, and its environmental impacts.

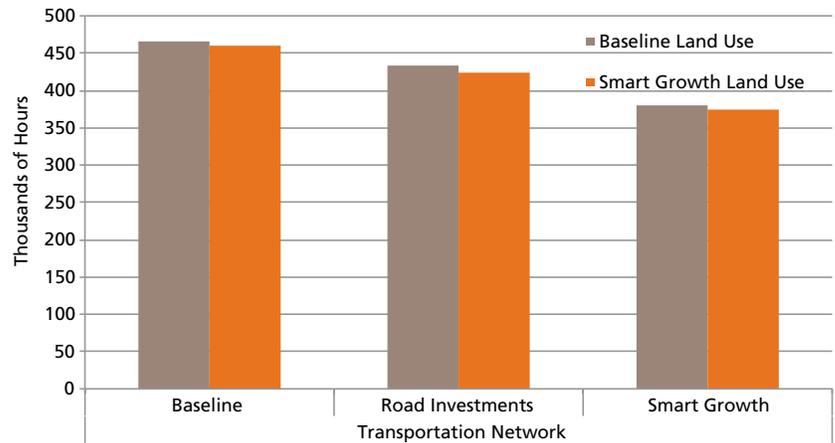
Forecasting Models

Urban transportation forecasting models that account for some aspects of freight are relatively common in large urban areas. A survey for TRB Special Report 288, *Metropolitan Travel Forecasting: Current Practice and Future Direction*, found that many municipal planning organizations were using travel models but noted, “The treatment of commercial and freight travel is one area in which most travel-forecasting models need substantial improvement. The development of better models is hampered by a lack of data on truck and commercial vehicle travel both within and beyond the metropolitan area” (4).

A few planning efforts have tried to incorporate the effects of smart growth into passenger-oriented, four-step travel-demand models, typically by post- or preprocessing (5–7). The adjustments include reducing the scale of modeling zones to integrate nonmotorized modes, incorporating pricing rules, altering the model’s car ownership levels to account for constrained parking with smart growth, and increasing the use of transit.

To explore the relationship between land use development and freight movements under smart growth, researchers conducted a series of model runs with the analytical tools at the Puget Sound Regional Council (PSRC). These included a blend of state-of-the-art modeling tools, as well as more traditional analytical tools familiar to other metropolitan planning organizations and local jurisdictions. In this way, others could replicate the analysis for policies in their own regions.

The results of six model runs suggested that a smart-growth land use configuration not only offers benefits for passenger travel, but also provides ben-



efits from—and for—goods movement (Figure 1, above). The largest benefits can be realized when a smart-growth land use scenario is coupled with commensurate investments in transit and nonmotorized transportation.

For trucking and shipping firms, more compact development and less congestion reduced total travel distances and hours on the road, as well as costs. Secondary benefits related to total travel included emissions reductions and potential economic gains from a more efficient and productive goods-movement system.

Modeling Results

The modeling results consistently showed that, in comparison with roadway investments, smart-growth improvements to transit and nonmotorized transportation infrastructure produced greater benefits to trucks. With limited financial resources, these investments could be selected instead of capacity enhancements, because roadway facilities, even when designed to accommodate freight movements, generally have far greater benefits to passenger vehicles and may reduce the benefits to freight, as the modeling results showed. To accommodate freight, strategies that remove other vehicles from the roadway, that maintain or preserve the current system, or that add strategic capacity for a specific purpose should be preferred over general roadway expansion.

Greater attention should be given to freight planning for local streets. The modeling results indicated that truck miles of travel remain unchanged on local facilities regardless of the land use or transportation-investment scenario. Trucks will continue to leave their warehouses and use local streets to connect to the main parts of the transportation system; many trucks also will continue to make pickups and deliveries on local streets—for example, for waste management or parcel delivery.

Land use planning also should consider locating

FIGURE 1 Daily truck hours of travel: road and smart growth models compared with baseline.

Garbage trucks and delivery vehicles cannot always avoid travel on heavily used or local streets.



PHOTO: AAA FOUNDATION FOR TRAFFIC SAFETY

warehouse and distribution centers close to urban centers. The models showed that trips from warehouse and distribution centers to concentrated areas of activity tended to be long in distance and in travel time. Deliveries from closer locations or during times of lower demand for transportation facilities also would benefit freight in smart-growth developments.

A variety of impacts may not translate into regional benefits but may make smart-growth land use developments more attractive to residents and employees and also may reduce the tensions between the freight community, planning professionals, and other interests. Questions remain about how to handle the interaction of freight with other modes at the microscale and how to resolve issues of the last mile, such as noise levels or conflicts with other modes, especially for parking.

Benefits to Explore

For the system as a whole, the modeling results clearly suggested that smart-growth investments benefit truck movements. Nevertheless, the modeling results may have underestimated the benefits, because current trucking models poorly address truck-trip generation, and four-step truck models do not address complicated delivery routes.

As models now in development depict the behavior of trucks and shipping firms more accurately, estimates may show fewer trucks and shorter trips than the current models, or the new models may distinguish better between truck types, allowing for trade-offs with smaller vehicles.

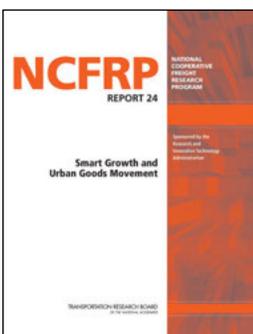
Considerable data development and research, however, are needed to validate the improved models. Many important issues for urban goods movement—for example, truck parking and delivery hours—are difficult to implement and often are not relevant for modeling at the regional scale.

In a longer time frame, planners may be able to

connect the principles of smart growth to goods movement. The focus groups made clear that freight stakeholders would benefit from better relationships between public-sector planners and private shipping and logistics firms. As smart-growth developments mature—perhaps moving warehouse and distribution centers closer to urban centers or allowing for more flexible delivery modes and times—the benefits of smart growth for and from goods movement will be likely to increase.

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NCFRP Report 24, *Smart Growth and Urban Goods Movement*, is available from the TRB Bookstore at <https://www.mytrb.org/Store/Product.aspx?ID=5795> or can be viewed online at http://onlinepubs.trb.org/onlinepubs/nctrp/nctrp_rpt_024.pdf.



Second-Generation, Full-Depth, Precast Concrete Deck System

Nebraska Department of Roads Applies NUDECK to Improve Constructability and Cost-Effectiveness

FOUAD JABER

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Full-depth, precast concrete deck systems offer several advantages in bridge construction compared with cast-in-place concrete decks: improved construction quality, reduced construction time, decreased impact on the traveling public, possible weight reduction, and a lower bridge life-cycle cost.

Precast concrete decks are superior in quality to field-cast concrete decks because the production in a controlled plant environment eliminates the variability caused by weather conditions, casting operations, and curing techniques. Moreover, precast concrete decks significantly reduce—if not eliminate—the risk of shrinkage cracking, because the high-performance concrete, the two-way prestressing, and the delaying of the connection to the stiffer girders restrain deck deformation.

Skewed precast concrete deck panel top view, showing the lifting inserts.



PHOTO: NEBRASKA DOR

Problem

Precast concrete deck systems can be designed to be composite or noncomposite with the supporting girders. Although the noncomposite deck is less expensive than a composite deck, the composite design yields a more economical bridge solution with smaller girders and superior structural performance.

Traditional full-depth, composite precast concrete deck systems make use of continuous open channels along the girder lines or of open discrete pockets spaced at a maximum of 2 feet to accommodate the shear connectors that bond the deck to the girder. These channels or pockets are grouted, and the deck surface is overlaid, similar to methods used on cast-in-place deck systems; however, this increases the duration and cost of construction.

In addition, transverse joints in traditional precast concrete deck systems are either conventionally reinforced or are posttensioned with strands threaded through embedded ducts along the bridge's length. The joints or ducts must be specially grouted. These operations complicate the processes of fabrication and erection and consequently reduce the attractiveness of precast concrete deck systems to accelerate construction.

Solution

The research project sought to develop a precast concrete deck system that would address the shortfalls of traditional systems. Table 1 (page 40) presents a side-by-side comparison of the proposed system and traditional full-depth, full-width precast concrete deck systems according to four criteria: panel length, shear connectors, panel penetrations, and longitudinal reinforcement.

The use of longer panels reduces the number of panels, transverse joints, and cast-in-place operations. Increasing the spacing between the shear connectors simplifies the fabrication of both the precast girder and the deck and minimizes conflicts in matching connectors with pockets during erection.



PHOTO: NEBRASKA DOR

Skewed precast concrete deck panel: bottom view showing the shear pockets.

In addition, using covered pockets with limited penetration yields a more durable deck surface that does not require an overlay; this reduces life-cycle cost.

Placing posttensioning strands over each girder line before the deck placement simplifies the operation of posttensioning and eliminates the need for threading strands and for grouting the embedded ducts. The goal is to achieve a deck with a service-life expectancy that matches the bridge’s design life—75 years, according to the load and resistance factor design manual of the American Association of State Highway and Transportation Officials.

System Refinements

These proposed techniques derived from the experience of the Nebraska Department of Roads (DOR) in constructing Skyline Bridge in Omaha in 2004 using

the first generation of a precast concrete deck system called NUDECK. The second generation of NUDECK incorporates several refinements that improve constructability and cost-effectiveness. Table 2 (page 41) shows a comparison between the first and second generations of the NUDECK system.

Several analytical and experimental investigations were conducted at the University of Nebraska–Lincoln to evaluate the new system’s structural performance and constructability. These included the fabrication of a 50,000-pound deck panel, 42 feet wide, 12 feet long, and 8 inches thick, to demonstrate production and handling operations (see photos, page 39 and this page).

The panel had three covered shear pockets with 4 feet of spacing along each girder line. Each pocket was made of hollow structural section steel with welded anchor bars and lifting inserts to minimize penetrations of the panel.

Demonstration and Tests

The research project also fabricated a 60-foot-long precast, prestressed concrete I-girder (NU900) with embedded shear connectors (see photo, page 41). These connectors were adjustable in height to ensure adequate embedment in the shear pocket and to compensate for camber variability.

Several pull-out and push-off tests were conducted to evaluate the interface shear capacity of the connections. A complete demonstration of the construction sequence of a 60-foot-long girder and five 12-foot-long deck panels was conducted, including the posttensioning and grouting. Strand deviators similar to those used in draping pretensioning strands were embedded in the girder ends; this raised the posttensioning strands at the top of the girder within the end panels to the middle of the deck and achieved uniform longitudinal prestressing at the deck level. Self-consolidating concrete filled the gap between the girder and deck soffit, as well as the shear pockets. The demonstration can be viewed online.¹

The demonstration specimen was tested to evaluate the flexural capacity and stiffness of the composite section, as well as the interface shear capacity of the deck-to-girder connection. The test results indicated that the measured capacity of the proposed system exceeded the predicted capacity of a fully composite system. More information is available in the final report.² The testing procedure and results also are posted online.³

TABLE 1 Proposed and Traditional Precast Concrete Deck Systems: Comparison

Criteria	Traditional Precast Concrete Deck Systems	Proposed System
Panel length	8 ft or less	12 ft
Shear connectors	Either continuous connectors or discrete at a maximum spacing of 2 ft	Discrete connectors at spacing of 4 ft and possibly 6 ft
Panel penetrations	Continuous open channel or open pockets requiring a deck overlay	Covered pockets with grouting ports that do not need an overlay
Longitudinal reinforcement	Conventional reinforcement or posttensioned strands threaded through embedded ducts	Posttensioned strands preplaced in the haunch underneath the deck panels

¹ www.youtube.com/watch?v=Jky8gpaGhRc.

² <http://ne-ltap.unl.edu/Documents/NDOR/NUDECK%20Implementation%20Final%20Report.pdf>.

³ www.youtube.com/watch?v=8Fja_facav8.

Application

Nebraska DOR is implementing the second generation of the precast concrete deck system NUDECK in the construction of the Kearney East Bypass over US-30 and the Union Pacific Rail Road. Construction started in the summer of 2014 and is slated to end in fall 2015.

The project consists of twin bridges: the southbound bridge is to be constructed with a conventional cast-in-place deck, and the northbound bridge with the new precast concrete deck system. This will allow a comparison of the construction and long-term performance of the two bridges in the same environment.

Each bridge has a two-span continuous deck, 41 feet and 8 inches wide and 332 feet long, supported by 10 prestressed concrete girders (NU1800) with 8 feet and 6 inches spacing. The precast concrete deck is 8 inches thick and consists of 28 panels. An online animation presents the construction sequence of the bridge superstructure in detail.[†]

Benefits

Although the benefits of the proposed precast concrete deck system cannot be quantified yet in terms of the

[†] www.youtube.com/watch?v=FOqcmkik_4Y.

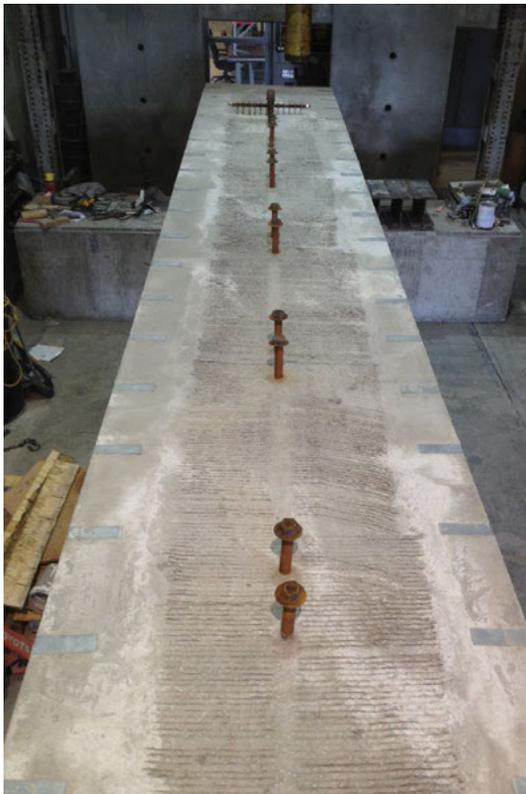


PHOTO: NEBRASKA DOR

Top view of the precast-prestressed concrete I-girder showing the shear connectors.

TABLE 2 First and Second Generations of NUDECK Systems: Comparison

Item	First Generation	Second Generation
Panel length	8 ft	12 ft
Panel thickness	6 in. plus 2 in. Type K cement overlay	8 in. without overlay
Panel-girder connection	12-in.-wide, continuous open channel on top of each girder line, to be filled with conventional concrete	16- x 8- x 5-1/2-in. covered individual pockets at 4-ft spacing, with grouting holes to be filled with self-consolidating concrete
Shear connectors	1.25-in.-diameter studs at 6 in. spacing	Two 1.25-in.-diameter coil rods at 4 ft spacing
Transverse pretension	Four 0.5-in.- (top) and four 0.5-in.-diameter (bottom) strands at 24 in. spacing	Six 0.6-in.- (top) and six 0.5-in.-diameter (bottom) strands at 2 ft spacing
Longitudinal posttension	0.6-in.-diameter strands threaded through the open channel at deck midthickness	0.6-in.-diameter strands laid down at the haunch area below the deck panels

quality, economy, speed, and safety of the construction, the experience of producing and erecting a full-scale specimen has identified potential benefits. Precast concrete deck panels can be produced easily with 6,000-pounds-force-per-square-inch, high-performance concrete that is cured properly and uniformly; this is difficult to achieve with cast-in-place decks. The proposed deck-and-girder detailing is production friendly, eliminating the projection of bars or inserts, which require special forming; moreover, the detailing follows standard production practices.

The cost of the shear pockets and shear connectors ranges from \$2.50 to \$3.50 per square foot of deck surface, depending on the girder spacing. The cost of the proposed posttensioning system ranges from \$2 to \$4 per square foot of deck surface, depending on the bridge length and girder spacing.

In addition, the use of self-consolidating concrete instead of commercial grout to fill the pockets and haunch is expected to improve the economy of the system. The new method is expected to be competitive with cast-in-place deck construction.

For more information, contact Fouad Jaber, Assistant State Bridge Engineer, Nebraska Department of Roads, 1500 Highway 2, P.O. Box 94759, Lincoln, NE 68509-4759; 402-479-3967; or Fouad.Jaber@nebraska.gov.

EDITOR'S NOTE: Appreciation is expressed to Waseem Dekelbab, Transportation Research Board, for his 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).

HIGHWAY CAPACITY MANUAL 2010

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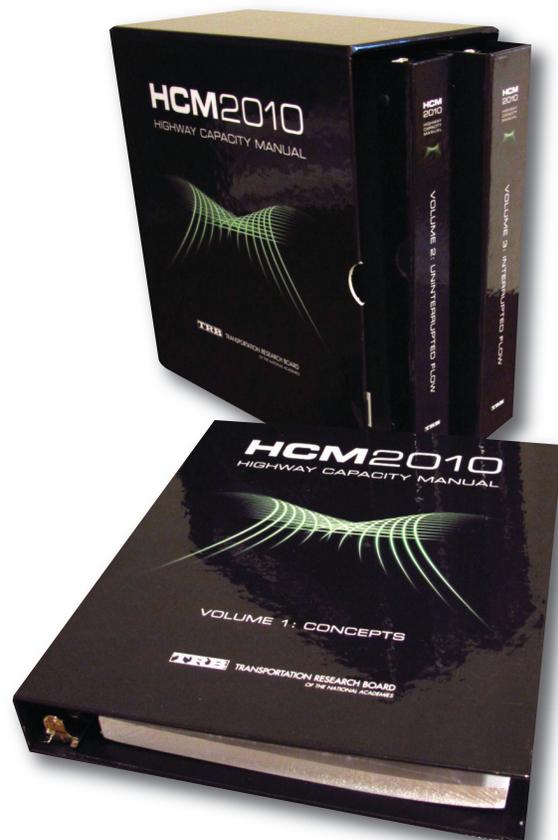
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Gerald McDougall

Southeast Missouri State University

Gerald McDougall, Dean of the Donald L. Harrison College of Business at Southeast Missouri State University (Southeast), first encountered general aviation in the mid-1980s, when the piston-powered aircraft market collapsed and a major manufacturer approached him to conduct a market analysis.

“I became particularly interested in estimating the sensitivity of individuals to the price of airplanes—that is, price elasticity of demand,” McDougall recalls. He conducted a small project that the manufacturer then used in its internal decision making; that project in turn led to McDougall’s longtime TRB involvement, when he was invited to present his statistical findings on price elasticity to a meeting of the Business Aviation Subcommittee.



“The academic is much more successful and impactful if he or she can translate research.”

McDougall received a PhD in economics from Claremont Graduate University in California. In 1973, he joined the faculty at Wichita State University (WSU) in Wichita, Kansas, where Beechcraft, Learjet, the Cessna Aircraft Company, and other aircraft manufacturers were located. “I became interested in continuing research in that area, looking at forecasting aircraft utilization and fleet growth, projecting total hours flown, and developing cost indices,” McDougall comments.

McDougall and colleagues Dong Cho and Philip Hersch submitted research to academic outlets, as well as to the Business Aviation Subcommittee, leveraging the impact of their research to help the industry. Subcommittee members discussed the potential factors affecting aircraft sales, usage, and fleet growth, and McDougall realized that as an economist, he could plug those factors into a framework and use regression techniques to explore various outcomes. “Fortunately, in the area of general aviation and business aviation, there is a wealth of public data, and we can tap into that data for use in estimates,” he adds.

Recently, McDougall began a term as chair of the Business Aviation Subcommittee. “I can take my strategies from the classroom to the committee meeting and use them to engage

committee members in discussion,” he notes. Although he is not an aircraft engineer or designer—and, when he joined the subcommittee, had never flown in a light or business aircraft airplane—McDougall brought a valuable understanding of economics to committee deliberations.

McDougall and his colleagues developed statistical models on fleet utilization and fleet growth, examining how demand was affected by aircraft attributes and how changes in design, size, and structure affected the likelihood a company would purchase a certain aircraft. He connected with aviation consultant Steve Hines in the mid-1980s and a mutually beneficial relationship developed: McDougall helped Hines understand the markets for business aviation and Hines allowed McDougall to disseminate research findings through academic channels.

“The work we did at WSU was a very clear example of good, solid academic research,” McDougall affirms.

In 1989, he joined the Light Commercial and General Aviation Committee, which helped him develop his research agenda and share his findings with the general aviation community. He served as chair of the committee from 1998 to 2004 and now is an emeritus member. McDougall also joined the Selection Panel for the Graduate Research Award Program on Public-Sector Aviation issues in 1990, serving as its chair from 1994 to 1997. Through that panel, he worked closely with graduate students pursuing research in aviation and eventual employment in the aviation industry.

McDougall also was a member of the Steering Committee for Oversight of Federal Aviation Administration–Sponsored Workshops on Aviation Issues and was a member of the Aviation Group.

McDougall was appointed dean of the Harrison College of Business at Southeast in 1993. Under his leadership, the college achieved accreditation from the Association to Advance Collegiate Schools of Business, added a Master of Business Administration and a Master of Science in Organizational Management, increased undergraduate and international program offerings, established the Center for Business and Economic Research and the Douglas C. Greene Center for Innovation and Entrepreneurship, and reorganized the college’s administrative structure to accommodate reductions in state appropriations. He served as interim provost of Southeast in 2013.

McDougall, who always has cultivated cooperative relationships between the aircraft industry and academia, affirms the importance of a broad perspective. “The academic is much more successful and impactful if he or she can translate research,” he observes. “Professionals should be open to academia and should reach out if there are questions they are grappling with—there is probably somebody on a university campus who could help.”

Standing Committees Assess, Look Ahead

In honor of TRB's legacy and its future—the spotlight theme of the 2014 TRB Annual Meeting—more than 80 TRB standing committees shared examples in the past 20 years of committee achievements and of noteworthy research breakthroughs, as well as anticipated research advances. These statements, posted on the TRB website, provide a portrait of the vast improvements in transportation systems from research and innovation. Notable developments in committee research areas are listed below.

◆ In 2011, TRB released Special Report 302, *Federal Funding of Transportation Improvements in BRAC Cases*. The congressionally requested report revealed fundamental, long-standing gaps in coordination and decision-making processes between the U.S. Department of Defense and metropolitan planning organizations. The Joint Subcommittee on Transportation in Military Communities helped to promote the report, from which several funding initiatives have resulted—an estimated additional \$500 million for transportation projects and military directives for more effective coordination with metropolitan planning organizations.

◆ The Application of Emerging Technologies to Design and Construction Committee highlighted digital project delivery in a 2012 TRB Annual Meeting session on using digital design information in construction. This concept was included in the Moving Ahead for Progress in the 21st Century Act and now is the focus of collaboration with groups including the American Association of State Highway and Transportation Officials (AASHTO), the American Society of Civil Engineers, and the International Highway Engineering Exchange Program.

◆ In the 1980s, the Federal Highway Administration led a review of road design standards to accommodate current and future road users—particularly the elderly. Many past and current members of the Safe Mobility of Older Persons Committee were involved in the research and recommendations. Policy recommendations for brighter pavement markings, legible signs, safer pedestrian facilities, and other improvements have been incorporated into state design manuals, and organizations such as AARP have taken up related research.

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For more information about these and other notable committee developments, visit www.trb.org/AboutTRB/KeyResearchAchievements.aspx.



LESSONS LEARNED IN PARKS PLAN—Bryce Lloyd (right), National Park Service (NPS), shares results and best practices from the NPS Long-Range Transportation Plan at a workshop at the Conference on Transportation and Federal Lands, September 15 at the National Academy of Sciences Building in Washington, D.C. The conference featured panel discussions, workshops, and tours of area parks and landmarks.

COOPERATIVE RESEARCH PROGRAMS NEWS

Proposed Enhancements to Pavement Mechanistic–Empirical Design

The AASHTO *Mechanistic–Empirical Pavement Design Guide: A Manual of Practice* (MEPDG) and the AASHTOWare Pavement ME Design provide a methodology for the analysis and performance prediction of pavements and overlays. Some recent studies have indicated that the performance of flexible and rigid pavements predicted by this methodology is not always sensitive to the properties of subgrade and underlying layers.

Texas A&M Transportation Institute, College Station, Texas, has received a \$400,000, 30-month contract (NCHRP Project 1-53, FY 2014) to propose enhancements to MEPDG procedures to reflect more reliably the influence of subgrade and unbound layers, such as properties and thicknesses, on the performance of flexible and rigid pavements.

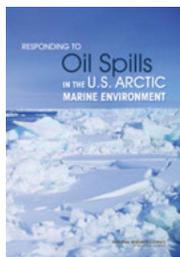
For further information, contact Amir N. Hanna, TRB, 202-334-1432, ahanna@nas.edu.



CLEAR VIEW—Members of the panel for the National Cooperative Highway Research Program (NCHRP) project Horizontal Sightline Offset Design Criteria, Exceptions, and Mitigation Strategies gathered for their first meeting November 17 in Washington, D.C. The panel will evaluate situations in which sight lines along horizontal curves are blocked and will determine ways to provide acceptable solutions.

Responding to Oil Spills in the U.S. Arctic Marine Environment

Division on Earth and Life Studies, Marine Board, National Research Council. National Academies Press, 2014; 210 pp.; \$58; 978-03-0929-886-5.



Explored in this volume is the impact of oil-spill response and environmental assessment in the Arctic region north of the Bering Strait on U.S. waters. The report offers recommendations and identifies key research priorities, critical data and monitoring needs, mitigation strategies, and operational and logistical issues.

Gulf Research Program: A Strategic Vision

Gulf Research Program, National Research Council. National Academies Press, 2014; 76 pp.; \$19.95; 978-03-0931-306-3.

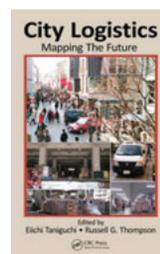


This report outlines the history and mission of the Gulf

Research Program, a 30-year program to enhance oil system safety, human health, and environmental resources in the Gulf of Mexico and other areas. Described are initial activities in research and development, education and training, and environmental monitoring.

City Logistics: Mapping The Future

Edited by Eiichi Taniguchi and Russell G. Thompson. CRC Press, 2014; 231 pages; \$79.95; 978-14-8220-889-4.



Key concepts of city logistics are presented, along with implementation issues, methodologies, new technologies, and policy measures. With case studies from the United States, the United Kingdom, the Netherlands, Japan, South Africa, and Australia, this book provides a comprehensive study of urban freight transportation modeling, planning, and evaluation.

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

TRB PUBLICATIONS

Strategic Issues Facing Transportation, Volume 6: The Effects of Sociodemographics on Future Travel Demand

NCHRP Report 750, Vol. 6

This report presents the results of research on how sociodemographic changes over the next several decades may impact regional travel demand. The accompanying software tool, Impacts 2050, is included on a CD-ROM along with a software user's guide, PowerPoint presentation, and the research brief.

2014; 138 pp.; TRB affiliates, \$55.50; nonaffiliates, \$74. Subscriber categories: administration and management; planning and forecasting; society.

Analytical Travel Forecasting Approaches for Project-Level Planning and Design

NCHRP Report 765

An update to NCHRP Report 255, this report describes methods, data sources, and procedures for producing travel forecasts for highway project-level analyses. Appendixes are included on the companion CD-ROM, CRP-CD-143.

2014; 318 pp.; TRB affiliates, \$73.50; nonaffiliates: \$98. Subscriber categories: highways; planning and forecasting; operations and traffic management.

Recommended Bicycle Lane Widths for Various Roadway Characteristics

NCHRP Report 766

Analyzed in this volume is research and design guidance for bicycle lane widths in travel and parking lanes, particularly those on urban and suburban roadways with level grade and posted speed limits of 30 mph.

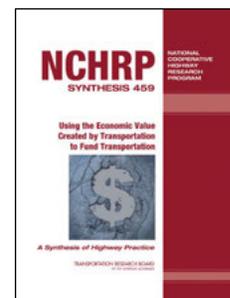
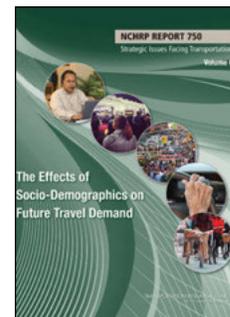
2014; 64 pp.; TRB affiliates, \$39; nonaffiliates, \$52. Subscriber categories: pedestrians and bicyclists; design; safety and human factors.

Using the Economic Value Created by Transportation to Fund Transportation

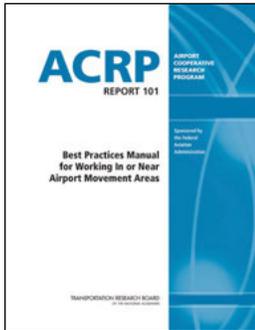
NCHRP Synthesis 459

This synthesis presents information on financing mechanisms used by agencies to capture a portion of the economic value created by public investment in transportation infrastructure to fund transportation improvements.

2014; 111 pp.; TRB affiliates, \$45.75; nonaffiliates, \$61. Subscriber categories: economics; finance; highways.



TRB PUBLICATIONS (continued)

**Sharing Operations Data Among Agencies**

NCHRP Synthesis 460

National and international experience with non-nuclear devices and methods for measuring compaction of unbound materials are presented in this volume.

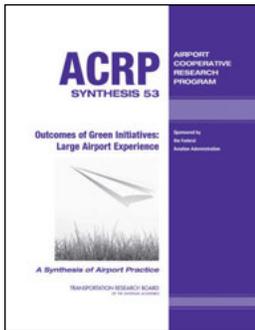
2014; 191 pp.; TRB affiliates, \$54.75; nonaffiliates, \$73. Subscriber categories: highways; operations and traffic management.

Best Practices Manual for Working in or near Airport Movement Areas

ACRP Report 101

This volume comprises a best practices database; training tools, aids, and checklists; and a 45-minute video, *Staying Safe on the Airfield*. These items are included on a CD-ROM with the printed report.

2014; 54 pp.; TRB affiliates, \$46.50; nonaffiliates, \$62. Subscriber category: aviation.

**Development of a Runway Veer-Off Location Distribution Risk Assessment and Reporting Template**

ACRP Report 107

This report explores a method to assess the risk of lateral runway excursions, or veer-offs, and suggests ways to improve veer-off incident and accident reporting. The Lateral Runway Safety Area Risk Analysis tool is included on a CD-ROM with the printed report.

2014; 128 pp.; TRB affiliates, \$48; nonaffiliates, \$64. Subscriber categories: aviation; safety and human factors.

**Developing Best-Practice Guidelines for Improving Bus Operator Health and Retention**

TCRP Report 169

This report addresses some of the health and safety issues common throughout the transit industry and describes actions taken by U.S. and Canadian transit organizations to address health problems in employees.

2014; 322 pp.; TRB affiliates, \$26.25; nonaffiliates, \$35. Subject area: public transportation.

Maintaining Transit Effectiveness Under Major Financial Constraints

TCRP Synthesis 112

This synthesis comprises reports from transit agencies that have implemented—and communicated—plans to increase their cost-effectiveness in challenging fiscal circumstances.

2014; 104 pp.; TRB affiliates, \$18.75; nonaffiliates, \$25. Subject areas: economics; public transportation.

Web-Based Screening Tool for Shared-Use Rail Corridors

NCFRP Report 27

This report describes a tool designed to help perform preliminary feasibility screening of proposed shared-use passenger and freight rail corridor projects.

2014; 71 pp.; TRB affiliates, \$41.25; nonaffiliates, \$55. Subscriber categories: passenger transportation; planning and forecasting; railroads.

Making U.S. Ports Resilient as Part of Extended Intermodal Supply Chains

NCFRP Report 30

This report identifies and elaborates on the steps needed to coordinate freight movements through ports in times of severe stress on operating infrastructure and services.

2014; 99 pp.; TRB affiliates, \$45.75; nonaffiliates, \$61. Subscriber categories: freight transportation; marine transportation; terminals and facilities.

Outcomes of Green Initiatives:**Large Airport Experience**

ACRP Synthesis 53

This synthesis explores the drivers and outcomes of green initiatives at airports and identifies data that can be used to evaluate the effectiveness of various initiatives.

2014; 64 pp.; TRB affiliates, \$39.75; nonaffiliates, \$53. Subscriber categories: aviation; environment.

Electric Vehicle Charging Stations at Airport Parking Facilities

ACRP Synthesis 54

This primer on electric vehicle charging includes information on policy approaches, infrastructure needs, and funding mechanisms that airports have used in electric vehicle hosting.

2014; 62 pp.; TRB affiliates, \$36.75; nonaffiliates, \$49. Subscriber categories: aviation; vehicles and equipment.

Traffic Control Devices, Visibility, and Highway–Rail Grade Crossings 2013

Transportation Research Record 2384

Explored in this volume are countdown-only pedestrian change interval displays, LED luminaires for roadway applications, preventing crashes and gate-breaking incidents at crossings, and more.

2013; 117 pp.; TRB affiliates, \$48.75; nonaffiliates, \$65. Subscriber categories: operations and traffic management; safety and human factors; rail.

TRB PUBLICATIONS *(continued)***Alternative Fuels and Technologies 2013**

Transportation Research Record 2385

Topics presented in this volume include biodiesel from lagoon microalgae, travel behavior and electric mobility in Germany, and plug-in electric cars for work travel.

2013; 69 pp.; TRB affiliates, \$44.25; nonaffiliates, \$59. Subscriber categories: energy; environment.

Safety Data, Analysis, and Evaluation 2013

Transportation Research Record 2386

Authors present research on hot-spot identification, exposure proxies for macroscopic road safety prediction, the identification of crash-contributing factors, and other topics.

2013; 194 pp.; TRB affiliates, \$60; nonaffiliates, \$80. Subscriber categories: safety and human factors; data and information technology.

Bicycles 2013

Transportation Research Record 2387

Bicycle-specific traffic signals, multimodal conflicts in urban onstreet bicycle lanes, North America's first e-bikeshare, and other subjects are examined in this volume.

2013; 156 pp.; TRB affiliates, \$56.25; nonaffiliates, \$75. Subscriber category: pedestrians and bicyclists.

Trucks, Buses, Motorcycles, and Mopeds 2013

Transportation Research Record 2388

Explored are the potential safety benefits of stability control systems for motorcoach buses; the use of powered two-wheelers in Melbourne, Australia; motorcyclists' attitudes and behaviors, and more.

2013; 77 pp.; TRB affiliates, \$45.75; nonaffiliates, \$61. Subscriber categories: safety and human factors; vehicles and equipment.

Roundabouts 2013

Transportation Research Record 2389

The papers in this volume address predictions of capacity for roundabouts, roundabout critical headway measurement, and driver behavior analysis and trajectory interpretation, and more.

2013; 77 pp.; TRB affiliates, \$45.75; nonaffiliates, \$61. Subscriber categories: safety and human factors; operations and traffic management; design.

Traffic Flow Theory and Characteristics 2013, Volume 1

Transportation Research Record 2390

Authors present research on spatiotemporal link speed correlations, Gaussian process metamodels for sensitivity analysis of traffic simulation models, a new car-following model, and more.

2013; 147 pp.; TRB affiliates, \$56.25; nonaffiliates, \$75. Subscriber categories: operations and traffic management; planning and forecasting.

Traffic Flow Theory and Characteristics 2013, Volume 2

Transportation Research Record 2391

Explored in this volume are the modeling and assessment of local perturbations, travel time reliability, speed harmonization, a generalized macroscopic fundamental diagram for urban freeways, and more.

2013; 153 pp.; TRB affiliates, \$56.25; nonaffiliates, \$75. Subscriber categories: operations and traffic management; planning and forecasting.

Statistical Methods and Visualization 2013

Transportation Research Record 2392

Logistic regression models of the safety of large trucks, interactive visualizations for comparing hierarchical data sets, and multiresolution visualization tools for road safety audits are among the topics presented in this volume.

2013; 67 pp.; TRB affiliates, \$44.25; nonaffiliates, \$59. Subscriber categories: data and information technology; safety and human factors.

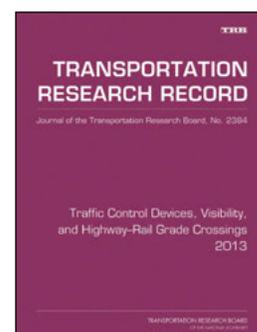
Pedestrians 2013

Transportation Research Record 2393

Papers examine such topics as automated classification of pedestrian gender and age, pedestrian safety issues, the cost of complete streets, and pedestrian crash risk on boundary roadways.

2013; 182 pp.; TRB affiliates, \$60; nonaffiliates, \$80. Subscriber categories: pedestrians and bicyclists; safety and human factors.

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CALENDAR

TRB Meetings

January

29–30 Shifting International Trade Routes Workshop
Tampa, Florida

February

15–18 Geosynthetics 2015 Conference*
Portland, Oregon

March

23–26 2015 Joint Rail Conference*
San Jose, California

April

13–14 Moving Active Transportation to Higher Ground: Opportunities for Accelerating the Assessment of Health Impacts
Washington, D.C.

16–17 Ferry Safety and Technology: Design and Operations Conference
New York, New York

19–22 AASHTO GIS for Transportation Symposium*
Des Moines, Iowa

21–23 International Highway Technology Summit: Cities, Transportation, and People*
Shanghai, China

26–28 International Bridge, Tunnel and Turnpike Association Transportation Finance and Road Usage Charging Conference
Portland, Oregon

May

7–8 Transportation for Sustainability: An International Conference
Washington, D.C.

1015 International Choice Modeling Conference*
Austin, Texas

17–19 9th National Aviation System Planning Symposium
Charleston, South Carolina

17–21 15th TRB National Transportation Planning Applications Conference
Atlantic City, New Jersey

18–22 9th International Conference on Managing Pavement Assets*
Alexandria, Virginia

24–26 5th International Symposium on Nanotechnology in Construction*
Chicago, Illinois

June

1–2 5th International Conference on Transportation Systems Performance Measurement and Data
Denver, Colorado

7–10 American Society of Civil Engineers 2015 Airfield and Highway Pavements Conference
Miami, Florida

10–12 6th International Conference on Bituminous Mixtures and Pavements*
Thessaloniki, Greece

22–24 5th International Symposium on Highway Geometric Design*
Vancouver, British Columbia, Canada

TBD Workshop on 2015 Highway Capacity Manual Update
Little Rock, Arkansas

TBD North American Transportation Statistics Interchange 2015
Washington, D.C.
(Invitation only)

July

12–15 11th International Conference on Low-Volume Roads
Pittsburgh, Pennsylvania

28–31 TRANSED 2015: 14th International Conference on Mobility and Transport for Elderly and Disabled People*
Lisbon, Portugal

TBD 14th AASHTO-TRB Conference on Transportation Infrastructure Maintenance and Operations*
Des Moines, Iowa

August

2–5 International Symposium on Systematic Approaches to Environmental Sustainability in Transportation
Fairbanks, Alaska

9–12 44th Annual International Congress and Exposition on Noise Control Engineering*
San Francisco, California

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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.

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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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