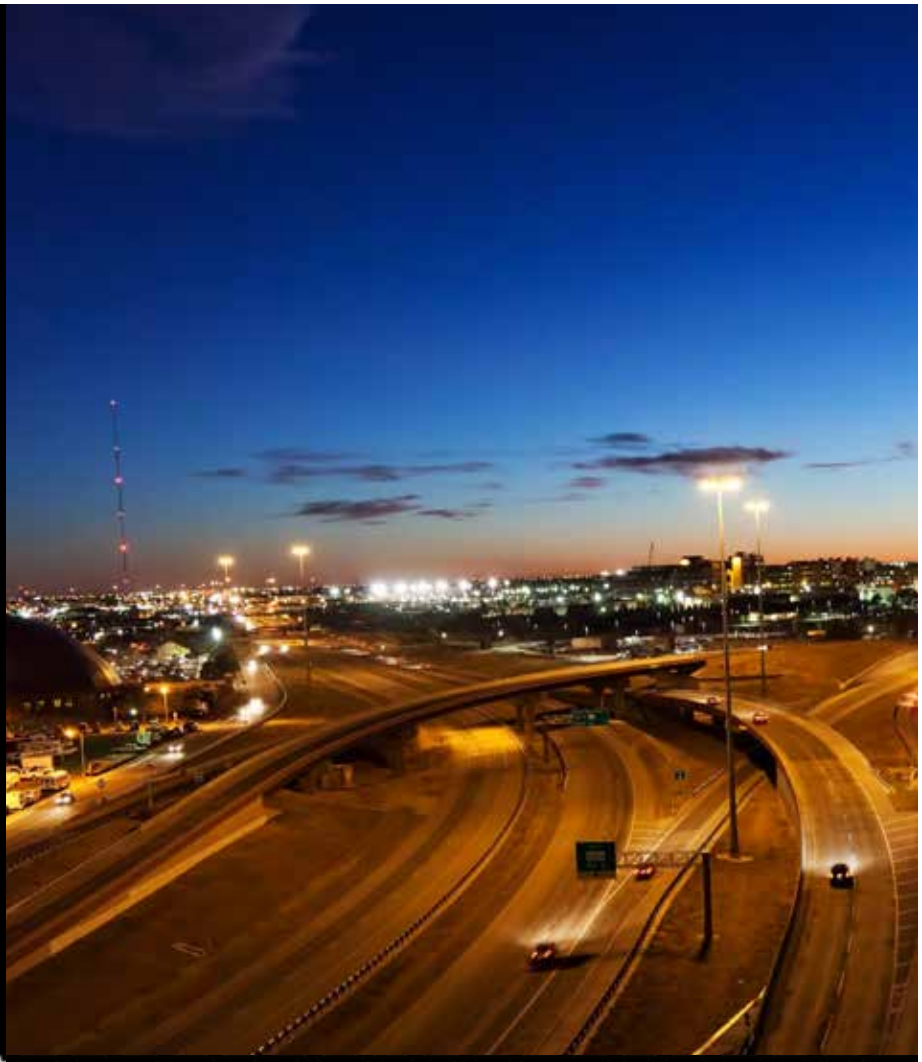
FHWA Research and Technology Evaluation



Program Summary Report

Fiscal Year 2016

Publication No. FHWA-HRT-17-038

U.S. Department of Transportation
Federal Highway Administration

Foreword

The Federal Highway Administration (FHWA) Research and Technology (R&T) Program furthers FHWA's Office of Research, Development and Technology's (RD&T) goal of ensuring transparency, accessibility, and responsiveness of RD&T for all stakeholders.

This report summarizes the 16 evaluations being conducted by FHWA's Office of Corporate Research, Technology, and Innovation Management. Summaries for completed projects include initial findings as well as background on each project.

All information in this report is current as of October 2016.

This report should be of interest to program managers, office directors, and executives within FHWA as well as others within State transportation departments and portions of the Federal Government interested in the outcomes and impacts of FHWA research.

Monique Evans, Acting Associate Administrator
Research, Development, and Technology

Notice

Quality Assurance Statement

Federal Highway Administration (FHWA) provides high quality information to serve Government, industry, and the public in a manner that promotes public understanding. Standards and policies are used to ensure and maximize the quality, objectivity, utility, and integrity of its information. FHWA periodically reviews quality issues and adjusts its programs and processes to ensure continuous quality improvement.

Cover photo ©David Ingram.[1]

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. FHWA-HRT-17-038	2. Government Accession No.	3. Recipient's Catalogue No.
4. Title and Subtitle FHWA Research and Technology Evaluation Program Summary Report		5. Report Date February 2018
		6. Performing Organization Code OST-R V-321
7. Author(s) Lee Biernbaum, Alison Bisch, Gregory Bucci, Christopher Calley, Lora Chajka-Cadin, Sharon Chan-Edmiston, David Epstein, Gina Filosa, Joseph Luna, Alexandra Oster, Margaret Petrella, Carson Poe, Sean Puckett, Sari Radin, Lydia Rainville, and Gina Solman		8. Performing Organization Report No.
9. Performing Organization Name and Address John A. Volpe National Transportation Systems Center 55 Broadway Cambridge, MA 02142		10. Work Unit No.
		11. Contract or Grant No. DTFH6115V00008
12 Sponsoring Agency Name and Address Office of Corporate Research, Technology, and Innovation Management Federal Highway Administration 6300 Georgetown Pike McLean, VA 22101-2296		13. Type of Report and Period Covered Summary Report; Fiscal year 2016
		14. Sponsoring Agency Code

15. Supplementary Notes
John Moulden is the Research and Technology Program Manager and the Contracting Officer's Representative for Contract DTFH for this program summary.

16. Abstract
This report summarizes the 16 evaluations being conducted by the Volpe National Transportation Systems Center on behalf of FHWA's Research and Technology (R&T) Program. The FHWA R&T Program furthers the Turner-Fairbank Highway Research Center's goal of ensuring transparency, accessibility, and responsiveness of R&T for all stakeholders. Six evaluation teams have finished data collection and written reports. One team has delivered a final phase I report and is preparing its phase II report. One team has delivered a draft final report. Of the 10 evaluations currently in progress, 7 teams have submitted final evaluation plans, 2 teams have submitted draft evaluation plans, and 1 team has submitted a preliminary evaluation plan.

17. Key Words Evaluation, Research, Technology, Development.	18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161.

19. Security Classif.(of this report) Unclassified	20. Security Classif.(of this page) Unclassified	21. No. of Pages 51	22. Price N/A

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized.

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
	NOTE: volumes greater than 1000 L shall be shown in m^3			
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	$candela/m^2$	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	$candela/m^2$	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

Table of Contents

List of Tables

List of Abbreviations and Acronyms

Abbreviation	Definition
AASHTO	American Association of State Highway and Transportation Officials
ABM	activity-based models
ABMS	agent-based modeling and simulation
ASC	adaptive signal control
BCA	benefit–cost analysis
BDS	*Bridge Design Specifications*
CMF	crash modification factor
CMP	*Corporate Master Plan for Research and Deployment of Technology & Innovation*
DTA	dynamic traffic assignment
EAR	Exploratory Advanced Research (Program)
EDC	Every Day Counts (Program)
eNEPA	National Environmental Policy Act collaboration tool
EIS	environmental impact statement
EPSP	*Evaluation of Pavement Safety Performance*
FHWA	The Federal Highway Administration
GRS-IBS	Geosynthetic Reinforced Soil— Integrated Bridge System
HERS	Highway Economic Requirements System
HFST	high- friction surface treatments
HRTM	Office of Corporate Research, Technology, and Innovation Management
HSIP	Highway Safety Improvement Program
IAP	Implementation Assistance Program
LRFD	load and resistance factor design
MBE	*Manual for Bridge Evaluation*
MPO	metropolitan planning organization
NCHRP	National Cooperative Highway Research Program
NEPA	National Environmental Policy Act
NHTS	National Household Travel Survey
NPS	National Park Service
NTSB	National Transportation Safety Board
P3	public–private partnership
P3 Program	Public-Private Capacity Building Program
PCP	precast concrete pavement
R&T	Research and Technology
R09	Managing Risk in Rapid Renewal Projects
RAP	reclaimed asphalt pavement
RAS	reclaimed asphalt shingles
RT-TRACS	real-time traffic adaptive signal control system
RTCC	Research and Technology Coordinating Committee
SHRP2	Second Strategic Highway Research Program
SHSP	Strategic Highway Safety Plan
TFHRC	Turner-Fairbank Highway Research Center
TIM	traffic incident management
TRB	Transportation Research Board
UNR	University of Nevada, Reno
VOC	vehicle operating cost
WMA	warm-mix asphalt

Introduction

Highway research—when adopted and implemented appropriately—has the potential to save lives, conserve funds, reduce congestion and travel time, increase business productivity, extend infrastructure life, and alleviate strain on the environment. Federal Highway Administration (FHWA) partners with State transportation departments, local agencies, industry, and academia both to conduct research on issues of national significance and to accelerate adoption and deployment of promising research products. FHWA recently initiated the Research and Technology (R&T) Evaluation Program to assess and communicate the benefits of its R&T efforts and to ensure that the organization is expending public resources efficiently and effectively.

Foundations of the R&T Evaluation Program

Strategic planning documents guide both R&T development and R&T evaluation at FHWA. In the *Research and Technology Agenda*, FHWA presents the mission and priorities of its research and technology activities.[2] The R&T *Agenda* identifies the following six high-priority highway challenges:

1. Advancing safety toward zero deaths.
2. Improving the mobility of people and goods.
3. Maintaining infrastructure integrity.
4. Enhancing system performance.
5. Promoting environmental sustainability.
6. Preparing for the future.

The R&T *Agenda* is intended to catalyze collaboration and accelerate innovation. Meeting the Nation's high-priority highway challenges requires the cooperation and collaboration of numerous stakeholders in the public and private sectors, academia, industry, and the international community.[2] It also requires continually reexamining and improving the process of selecting and executing research projects, disseminating findings, supporting user adoption, and assessing benefits to users and society.

In 2003, FHWA leadership adopted a strategic management framework called the *Corporate Master Plan for Research and Deployment of Technology & Innovation* (CMP), which was developed with input from stakeholders.[3,4] The purpose of the plan is to continue to improve the effectiveness and efficiency of R&T. The CMP is a response to *Highway Research: Systematic Selection and Evaluation Processes Needed for Research Program*, a report by the General Accounting Office to Congress, which recommended that FHWA "develop a systematic process for evaluating significant ongoing and completed research that incorporates peer review or other best practices in use at Federal agencies that conduct research."[5]

Leadership at the Turner-Fairbank Highway Research Center (TFHRC) adopted the 2014 *Strategic Plan for the Turner-Fairbank Highway Research Center* to guide the Center's continued development.[4] The plan sets forth broad principles and long-term goals to be planned and executed during several years. One of these long-term goals is to calibrate the Center's efforts to promote the adoption of research findings:

> *Goal 5 of the Strategic Plan: Research activities and outcomes are appropriately advanced through effective alignment of resources, dissemination of knowledge, and technology transition.*[4]

From a highway research perspective, *technology transition* is the incorporation of technology into operating transportation systems to achieve increased performance (greater safety, capacity, speed, energy efficiency) and/or to reduce costs and emissions. The plan recognizes that the dissemination of knowledge and technology transition require engaging external partners and targeting outreach.(4) Evaluation can improve technology transition by revealing the relationships between research, dissemination of research findings, the decision to adopt findings, and benefits from adoption. These relationships are the focus of the FHWA R&T Evaluation Program.

FHWA developed the R&T Evaluation Program with encouragement from the Transportation Research Board's (TRB's) Research and Technology Coordinating Committee (RTCC). In a September 2016 report, the RTCC communicated its belief that the evaluation program is making "commendable progress" and that the evaluation teams are drawing useful and appropriately cautious interpretations from imperfect data collected in complex situations.(6)

Evaluation Activities

In its initial year, the FHWA R&T Evaluation Program worked with 9 FHWA offices to identify 16 projects for evaluation across all program areas. Each evaluation progresses through an ordered series of deliverables, from a preliminary task management plan to a final report. This report summarizes the progress of these evaluations as of September 30, 2016. Table 1 presents ongoing and completed evaluations, several of which have publications pending. Appendix A provides additional details on each project's status. Full reports are available on FHWA's website.(7)

Table 1. Overview of completed and ongoing FHWA R&T evaluations.

Program Office	Completed Evaluations	Ongoing Evaluations
Exploratory Advanced Research	*(No completed evaluations)*	Agent-Based Simulation Models
Federal Lands	Roadside Revegetation	*(No ongoing projects)*
Infrastructure	Gusset Plates	Geosynthetic Reinforced Soil–Integrated Bridge System High-Recycle Warm-Mix Asphalt Precast Concrete Pavements
Innovative Program Delivery	*(No completed evaluations)*	Managing Risk on Rapid Renewal Projects Public-Private Partnership Capacity Building
Operations	Adaptive Signal Control Technologies	Traffic Incident Management Training
Planning and Environment	*(No completed evaluations)*	Eco-Logical eNEPA
Policy	National Household Travel Survey	Vehicle Operating Costs
Safety	Roundabouts	High-Friction Surface Treatments

The five completed evaluations relied on both review of documents and semi-structured interviews. The Geosynthetic Reinforced Soil–Integrated Bridge System (GRS-IBS), Roadside Revegetation, and National Household Travel Survey (NHTS) teams also analyzed FHWA website usage statistics. In addition, the Roadside Revegetation report draws from the results of a survey conducted by the evaluation team.

The evaluation teams presented R&T Evaluation Program deliverables to FHWA stakeholders on numerous occasions (see table 2).

Table 2. FHWA R&T Evaluation Program presentations.

Evaluation	Date	Stakeholder Audience (Location)
Adaptive Signal Control	8/30/2016	Headquarters and Program Office (TFHRC)
Roundabouts	5/19/2016 8/31/2016	RTCC Meeting (Jonsson Center) Headquarters and Program Office (TFHRC)
Gusset Plate	8/31/2016	Headquarters and Program Office (TFHRC)
National Household Travel Survey	5/19/2016 9/12/2016	RTCC Meeting (Jonsson Center) Headquarters and Program Office (TFHRC)

This report provides FHWA's Office of Research, Development, and Technology with an overview of the entire evaluation effort to date, cross-cutting recommendations, and summaries of each evaluation. The report provides more detail about completed evaluations and those close to completion. Summaries are provided in alphabetical order, separated by status (completed evaluations and ongoing evaluations).

Crosscutting Recommendations

Across the R&T evaluations, three overarching recommendations emerged from the challenges and best practices discovered by the programs being evaluated. These recommendations might serve to inform future FHWA R&T efforts.

- **Improve protocols for internal dissemination** to ensure Division Office and State transportation department staff are aware of research progress and can share accurate and uniform information with potential deployers. This recommendation stems from findings across several evaluations. For example, an industry consultant interviewed for the Adaptive Signal Control (ASC) evaluation noted a lack of communication with Division Offices that hindered the use of the systems engineering document. Evaluators for the Roadside Revegetation effort found that some FHWA Division Office and State transportation department staff are not aware of the program. Potential deployers received mixed messages about the GRS-IBS because of professional differences between geotechnical and hydrologic engineers at FHWA, likely hampering rollout of the technology. Communities of practice, while helpful, provide only a forum for discussion, not a protocol for resolving disagreements. Conflict resolution and negotiation strategies, such as joint fact-finding, may enable individuals with different professional training to work out engineering and policy disagreements. Management might want to implement procedures that keep such disagreements from public view or communicate their content constructively.

- **Further incorporate evaluation into the research process** by routinely collecting and analyzing data on research use. Research use takes many forms: requests for information through email or phone, citation of FHWA reports in follow-up studies, and adoption of methods after a formal training. Staff in FHWA's Public Relations Office might track information requests made through their office in a researcher-accessible format (e.g., Excel), including requests from the media and government officials. These requests are an estimate of demand for FHWA research and potential avenues to increasing dissemination and impact. Evaluators for the NHTS, for example, found that more effort is needed to track usage by Federal, State, and local government as well as the media to inform future evaluations of the program. Project leaders and staff should also track information requests they receive directly from potential deployers. In addition, analyzing citations of FHWA publications would be easier if Transport Research International Documentation and Transportation Research Board publications were again tracked by Thomson Reuters's Web of Science.(8) Finally, evaluators for several programs, including the subjects of two in-progress evaluations—Traffic Incident Management (TIM) and Managing Risk—found that improved tracking of attendees at trainings and demonstrations would permit better evaluations of the relationship between outreach and adoption.

- **Explore collaborative research management arrangements,** including expert advisory panels and stakeholder feedback. The first option enables recognized external experts to inform FHWA decisionmaking. Their involvement adds not only knowledge, but also credibility—necessary especially on high profile or controversial research. A National Cooperative Highway Research Program (NCHRP) panel helped oversee the Gusset Plates project for example,[1] and NHTS convened an expert panel to provide input to the 2016 survey. The second option, stakeholder feedback, enables potential users of new technologies to inform

[1]This particular method of feedback is likely not desirable in future efforts because of the specific legal structure associated with NCHRP, but project participants indicated that the feedback received was helpful for the project.

development, increasing the chances of adoption. For example, the NHTS user community provides NHTS staff with extensive feedback.

Completed Projects

Sources (clockwise from top left): ©Michael Quinn, FHWA, ©Jeremy Brooks, ©Daniel Hoherd, FHWA.[8–12]

Adaptive Signal Control (Office of Operations R&D)

Program Description

In 1992, FHWA initiated research on ASC technology to better understand the potential of this technology to reduce traffic congestion and travel time delay in the U.S. ASC technologies adjust signal timing parameters in real time to accommodate variability in demand using current traffic data. FHWA's ASC research program supported both development and deployment of ASC in the United States. FHWA funded two iterations of ASC development, managed pilot deployments, and developed informational materials on the technology. When development activities were complete, the program focused on fostering ASC adoption by expanding outreach activities, developing guidance materials, and supporting agencies through training and technical assistance.

Purpose of the Evaluation

The ASC evaluation assessed the effects of FHWA's efforts related to developing ASC technologies and supporting the adoption of technology by State and local agencies. The evaluation team constructed three primary hypotheses about how the program was intended to work, centered on accelerated development of ASC, accelerated deployment of ASC, and improved mobility and emission outcomes because of ASC use.

Methodology

Evaluators reviewed research and documentation on the development, deployment, and impact of ASC to pinpoint stakeholders; construct a timeline of development activities; and identify outputs, outcomes, and impacts achieved along this timeline. The evaluation team then conducted 19 interviews with ASC developers, vendors, local agencies, and FHWA program staff to refine and provide context to the information from the literature review. Evaluators designed and fielded an online survey with traffic agencies to connect what was learned from the in-depth interviews and timeline analysis to the direct experiences of the ASC market in considering and deploying the technologies.

Key Findings

Finding: Evidence from the ASC program shows that FHWA had both a direct and indirect effect on ASC development.

Early on, FHWA directly funded the development and pilot testing of three ASC algorithms for a real-time traffic adaptive signal control system (RT-TRACS). Two of the algorithms eventually came to market, while the research encouraged several other vendors to invest in ASC research. Subsequently, FHWA sought to improve upon the previous results by developing a new algorithm. The ACS Lite algorithm was developed by FHWA in partnership with signal vendors who agreed to adapt their equipment to run it. Two of the vendors then developed their own algorithms, one of which is based on ACS Lite. Outside FHWA, the cumulative effect of two development phases was noted to have a significant impact on the traffic signal control market. Several vendors and technology firms learned from the RT-TRACS and ACS Lite programs as they developed or improved ASC products. Since 2009, eight additional ASC technologies launched or started development.

Finding: The FHWA ASC activities helped bring the developer and adopter sides of the traffic signal control market together, accelerating the deployment of these ASC technologies.

Prior to 2009, pilot tests and demonstration sites represented the majority of ASC deployments; only a handful of agencies deployed non-FHWA technologies. Despite low deployment levels, the market began to pay attention; testing and outreach resulted in increased ASC awareness. Without FHWA's programs, it is unlikely that many agencies would have been aware of domestic development and deployment. Starting in 2009, the Every Day Counts (EDC) program shifted FHWA's efforts to outreach, which reached agencies in 42 states. FHWA provided training, guidance documents, and direct support. Study results show that EDC's efforts are associated with increased ASC awareness.(13) Half of ASC adopters report using the EDC Systems Engineering Process and direct FHWA support through the complicated deployment process. Since 2009, over 176 cities have implemented ASC systems.

Finding: FHWA-funded teams and FHWA-influenced technology firms developed effective ASCs during the span of FHWA's ASC program, showing the potential for improved mobility.

Throughout the FHWA program, the effectiveness of ASC technologies improved. Based on recent measures of effectiveness, ASCs can improve measures of travel time, delay, and number of stops in many situations, which can improve congestion on roadways. The relatively small number of evaluations, although promising, speak primarily to the *potential* of the technology to impact congestion and mobility, rather than its fully realized impact.

Recommendations

While focusing on technical issues, there should be consideration of and planning for the longer-term issues of market acceptance and deployment.

Early phases of the ASC program focused on developing technical ASC systems without fully understanding the needs and constraints of the market. FHWA should consider upfront market research to better understand both technology needs and barriers to adoption.

Strategies and processes for transferring a technology from research to the market should be considered when conducting initial research.

For FHWA-developed technologies to be widely used, vendors must have sufficient information on how to offer them to the market. Because different approaches may be appropriate at different times, upfront research with vendors and end-users can help programs better understand how best to meet market needs.

Communication about the technology itself and its related outreach program should be consistently shared throughout FHWA.

There were instances during EDC outreach when FHWA staff did not fully understand ASC and its applications, and this impacted the agencies' ability to pursue ASC. FHWA should ensure that all staff responsible for a topic or product are aware of its applications and are able to communicate its uses and requirements to potential adopters.

Eco-Logical (Planning, Environment, and Realty/Second Strategic Highway Research Program)

Program Description

Developed by a team of representatives from FHWA and seven other Federal agencies, Eco-Logical articulates a vision for an infrastructure development process that endorses ecosystem-based mitigation by integrating plans and data across agency and disciplinary boundaries. Following Eco-Logical's initial development as a guidebook, Second Strategic Highway Research Program (SHRP2) funds were used to create specific tools and techniques to implement Eco-Logical practices at State transportation departments and other planning agencies. FHWA has funded two rounds of pilot projects through the Eco-Logical Grant Program in 2007 and the 2013 SHRP2 Implementation Assistance Program (IAP).[14,15]

Purpose of the Evaluation

This evaluation assessed the effectiveness of FHWA R&T activities on the implementation of the Eco-Logical approach (i.e., ecosystem-based infrastructure planning and mitigation) to transportation project delivery by State transportation departments and metropolitan planning organization (MPO) recipients of FHWA Eco-Logical funding through the 2007 grants and 2013 SHRP2 IAP.

Methodology

The evaluation team used five data collection and analysis methods to inform the evaluation: literature reviews of program materials from 2008 to 2015, participation in a program-sponsored peer exchange, stakeholder interviews in 2016, an analysis of Eco-Logical steps completed by funding recipients, and a qualitative coding analysis of stakeholder comments. Key evaluation questions considered FHWA's dissemination of the approach to stakeholders, how grant recipients chose to incorporate the approach into their business practices, and how the Eco-Logical program and approach contributed to improved project delivery processes and environmental mitigation.

Key Findings

Finding: FHWA funding allowed agencies to pursue previously planned activities sooner, more comprehensively, and with broader stakeholder buy-in.

While several recipients indicated that they would have done their Eco-Logical-related work anyway, FHWA funding allowed them to expand the scope of work, dedicate more resources, and garner additional stakeholder buy-in. Some recipients noted that the success of their Eco-Logical work positioned them to apply and be selected for additional grant opportunities.

Finding: Agencies faced challenges working with their partners because of different missions, goals, and responsibilities; varying levels of support for Eco-Logical activities from federal agency staff at headquarters and regional levels; and staff turnover.

State transportation departments and MPOs sometimes found challenges with convincing local partners to consider impacts on a scale that extended beyond their jurisdictions as planning moved into project implementation. Recipients also noted differences between headquarters and regional level support, as regional staff may be more focused on legal requirements and the specific responsibilities of their jobs, rather than supporting grant projects.

Finding: Eco-Logical led to improved integrated planning between environment, transportation, and land use, and many recipients have incorporated Eco-Logical into their long-range transportation planning and project prioritization process.

Many recipients found value in cross-disciplinary collaboration early in planning through identifying shared goals, data, and plans. Some recipients stated that their Eco-Logical work informed how they prioritize projects. While these recipients did not always attribute project prioritization to impacts, early identification of issues allows agencies to avoid or minimize environmental impacts, which can improve environmental mitigation and yield time and cost savings later in project development. Despite these successes at the regional planning level, several MPOs remarked on their lack of authority when it came to ecosystem level decisions made at the local project-level scale.

Finding: Eco-Logical grant recipients reported few details on the impact of the program. Most comments were positive and without numerical evidence. Some grantees did not know what information to track or how to track the information.

The Eco-Logical projects typically spanned 2–3 years, and given the long timeframe of transportation and infrastructure projects, there was little reporting on impacts. Most comments related to impacts were positive and qualitative and tended to focus on the benefits of data sharing and analysis tools for prioritization. To do so, several recipients indicated they did not know what to track or how or they did not have the necessary resources. Some recipients noted that having examples of the time, cost, and environmental improvements that the Eco-Logical approach may afford would be useful in furthering adoption and implementation of the approach.

Recommendations

Recipient agencies would like FHWA to provide additional support in the form of peer exchanges, webinars, and case studies on Eco-Logical.

Topics of interest include the following: quantifying impacts, overcoming challenges, and receiving more information on applying the later steps of the approach. FHWA can facilitate peer learning on these topics.

FHWA should consider the continuity of awareness about Eco-Logical between headquarters and regional level staff within agencies and ensure consistent information is provided to stakeholders about the program and approach.

FHWA should explore additional opportunities to engage regional level staff in their program activities. FHWA should also examine how to engage local municipalities in implementing Eco-Logical on projects.

FHWA should consider using a set of consistent questions or tracking methods to evaluate the progress of recipient agencies from year to year and to ensure that overall progress on the Eco-Logical approach can be objectively measured long term.

FHWA's interview questions changed over time and did not follow a set structure. This made it challenging to assess trends over time.

Activities to Date and Anticipated Schedule

The evaluation team delivered the draft evaluation report on September 29, 2016. Findings and recommendations presented here may change as a result of revisions for the final report.

Gusset Plates (Infrastructure)

Program Description

The main span of the Interstate 35 West (I–35W) bridge deck truss in Minneapolis, Minnesota, collapsed on August 1, 2007, killing 13 people and injuring 145.[16] While investigating the incident, the National Transportation Safety Board (NTSB) turned to FHWA for technical expertise, focusing on the gusset plate construction of the deck truss. A gusset plate is a thick sheet of steel used to join structural components. Before the I–35W bridge collapse, bridge designers were given considerable discretion in designing gusset plates. In addition, it was assumed that gusset plates needed only to be load rated if there were changes in their condition, such as from corrosion.

Within months of the collapse, NTSB issued its first safety recommendation—H-08-001—to FHWA, requiring that bridge owners conduct load capacity calculations to verify stress levels in all structural elements, including gusset plates.[17] In response to this recommendation, FHWA R&T conducted research and analysis on the failure modes of gusset plates and proposed recommendations for gusset plate design and inspection standards through the NCHRP. The project culminated in NCHRP Web-Only Document 197, which was used to develop new American Association of State Highway and Transportation Officials (AASHTO) load and resistance factor design (LRFD) specifications for the design and rating of gusset plate bridges.[18]

Purpose of the Evaluation

This evaluation aimed to understand how FHWA's investment in gusset plate research impacted the design and rating of gusset plate bridges. This report documents the process in which FHWA responded to NTSB's recommendations—particularly Safety Recommendation H-08-001—by conducting and disseminating key research to improve specifications for gusset plate design and load rating. The evaluation also examined how FHWA research contributed to the revision of *AASHTO LRFD Bridge Design Specifications* (BDS) and the *Manual for Bridge Evaluation* (MBE).[18,19]

Methodology

The evaluation team conducted interviews with key stakeholders and reviewed documents from FHWA, NTSB, and a selection of States. The evaluation team interviewed three NTSB staff members who worked on the I–35W bridge investigation, two FHWA staff members who worked on related efforts (the I–35W bridge investigation, the Performance and Design of Steel Gusset Plate Connections project, and NCHRP Project 12-84), and four current and former members of the AASHTO Committee on Structural Steel Design.[17,20]

The evaluation team also reviewed numerous documents and found six documents especially helpful: NTSB's final report on the I–35W bridge, NTSB's first recommendations to FHWA, a set of correspondences between NTSB and FHWA, FHWA's load rating recommendations, FHWA's guidelines to bridge owners, and NCHRP's gusset plate load rating specifications. (See references 19, 11, 20, and 21.)

Key Findings

Finding: FHWA's technical expertise in bridge infrastructure and its prior history of working with NTSB was critical during the bridge investigation.[16]

FHWA ultimately provided the knowledge and expertise on gusset plate performance that led NTSB to conclude that a gusset plate design error caused the collapse. Few truss bridges are being constructed, but many such bridges will exist in State inventories for a long time. FHWA's input helped constructively refocus the conversation away from preventing gusset plate design errors to how States should maintain existing structures to prevent another collapse.

Finding: FHWA's coordination with key stakeholders contributed to an accelerated timeline to closing NTSB recommendations.[16]

While the Minnesota transportation department and the engineering firm that designed and constructed the bridge were involved in discussions with NTSB, FHWA was the predominant party that participated in NTSB meetings about the problem and potential solutions. It became clear during the investigation phase that the gusset plate design problem had national implications, and FHWA was in a position to provide support on a far-reaching solution. FHWA's close collaboration and coordination with NTSB was a major factor to closing out NTSB's recommendations.

Finding: FHWA's commitment to bridge research and the decision to jointly fund the NCHRP effort accelerated the research timeline from initiation to conclusion.

Initial scoping efforts for what would eventually become NCHRP Project 12-84 began in May 2008. Within 2 months, FHWA and NCHRP reached an agreement to jointly fund the research. The project began in October 2008, less than 1 year from initial scoping. A NCHRP project typically concludes about 6–7 years after funding is approved. It was determined that answers were needed quickly for Project 12-84, and FHWA was able to begin quickly without requesting proposals and selecting a contractor, which takes approximately 2 years. The quick initiation of the research project was integral to promptly updating AASHTO's LRFD BDS and MBE.[18,19]

Finding: FHWA's active and ongoing engagement of transportation stakeholders expedited the delivery of new information regarding the design and load rating of gusset plates.

A review of correspondence between NTSB and FHWA concerning Recommendation H-08-001 showed that FHWA embarked on a series of internal and external outreach efforts related to gusset plate research.[21] FHWA, in conjunction with AASHTO, provided ongoing technical assistance and guidance to FHWA field offices and bridge owners about load rating and the evaluation of gusset plates on steel truss bridges. In 2009, FHWA published *Load Rating Guidance and Examples for Bolted and Riveted Gusset Plates in Truss Bridges*.[11] The agency also sponsored several national teleconferences and a conference to familiarize FHWA and State bridge engineers with using FHWA guidance.

Recommendations

FHWA should remain flexible on how its research funding is used.

In this case, there were approved projects that FHWA had originally intended to pursue regarding steel bridge research. Given the scale of the emergency and the immediate need for research and information, funds were redirected into the Gusset Plate Project. FHWA management showed flexibility with funding, and legislation at the time permitted such discretionary changes.

FHWA should consider how external input was gathered on this project and how FHWA might improve this approach for future high-profile research projects.

External input oversight from the NCHRP panel ensured the project stayed on track and avoided findings that were not useful. This external oversight is atypical in FHWA research programs, and this specific method of comingling resources raises questions about roles and responsibilities, particularly around contracting. Nevertheless, input (and, indeed, funding) from State transportation departments was appropriate and helpful.

National Household Travel Survey (Office of Policy)

Program Description

National travel surveys have been conducted by FHWA for more than 45 years. Now known as the National Household Travel Survey (NHTS), the most recent surveys were conducted in 2009 and 2001. The surveys are the only data in the country that link individual personal travel behavior, household demographic and socioeconomic characteristics, vehicle ownership, and vehicle attributes. NHTS data are used to monitor and track national travel behavior and to provide information to States and MPOs, where local data are often lacking.

Purpose of the Evaluation

This evaluation aimed to understand the extent of use of FHWA's NHTS data and the long-term impacts of their availability and use on policy, program, and regulatory decisions. In addition, the evaluation provided an assessment of NHTS responsiveness to its user community.

Methodology

Evaluators determined the extent and range of NHTS data usage by reviewing FHWA documents and outreach efforts (including NHTS website usage statistics) and by conducting interviews with lead users (academic, government, and consultants). Assessing the impact of FHWA NHTS data on decisionmaking relied on a review of Federal, State, MPO, and academic research products and interviews with NHTS staff and lead users. Document reviews and interviews supported measuring the responsiveness of the NHTS program to user feedback. Through these interviews, the evaluation team compiled a list of lessons learned. The team organized information gathered from documents and interviews in a spreadsheet according to key hypotheses, enabling a synthesis and comparison of information across sources.

Key Findings

Finding: Nearly half of the publications using the 2014 NHTS are in the transportation field with the share of nontransportation publications growing and website data access increasing.

An analysis of the 2014 NHTS Compendium of Uses document demonstrates that the NHTS are used across a range of fields.[22] While 46 percent of publications are primarily transportation focused, more than half of publications have a primary application in some other field, including energy (25 percent), survey methods or analysis (12 percent), environment (9 percent), and health (8 percent).[23] The evaluation team also found that NHTS Compendium publications cover a range of transportation topics. When NHTS Compendium publications are analyzed over time (2011 through 2014), the team found that the share of publications in nontransportation fields (e.g., health, environment, energy) grew significantly. Monthly website usage statistics for July 2013 through May 2015 indicated that use is robust with growth in some (but not all) measures. For example, the number of monthly visits to the website increased from 5,118 to 8,443 during this time period.[23] The data also revealed a cyclical trend to usage, with spikes in the spring and fall.[23]

Finding: While it is difficult to trace the precise decision outputs of NHTS, the interviews suggest that NHTS informs policy and legislative decisions within transportation and other fields.

With respect to legislative uses, the evaluation team found NHTS data referenced in congressional reports, including *2013 Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance*.[24] As an input to U.S. Department of Transportation Secretary Foxx's *Beyond Traffic*, NHTS guides the national dialogue on the state of transportation.[25] NHTS data are also an input to important models, including the model year Corporate Average Fuel Economy standards, which inform policy.[23] In addition, NHTS is used in other fields, including health, energy, and the environment. For example, the Centers for Disease Control and Prevention has incorporated NHTS data in its 10-year agenda, *Healthy People 2020*.[26] States and MPOs also use the data for a range of purposes, including to develop, calibrate, or validate their travel demand models, which are critical to transportation planning and also inform corridor level, interchange, and transit projects. However, tracing how and to what extent NHTS informs policy and legislative decisions is challenging because policy and legislative proceedings do not provide such information.

Finding: NHTS reaches out to its user community through its website, direct contact, and formal events.

NHTS provides user support via its website and through direct contact with users who have questions and requests. NHTS also conducts a number of formal outreach activities, including TRB sessions, committee updates, workshops, and conferences. In 2011, NHTS organized the NHTS Task Force, which serves as a bridge between the NHTS team and the user community. Based on user feedback, NHTS has introduced more online tools (e.g., academy modules) and has changed its survey methodology for the 2016–2017 NHTS.

Recommendations

Conduct NHTS on a more regular and frequent cycle.

The current 5- to 8-year cycle of surveys means that the data are considered "old" well before a new set of data are released. Moreover, the unpredictability of the survey schedule makes it difficult for users to depend on the data.

Institutionalize adequate funding, including staffing.

NHTS is not mandated, and so FHWA must obtain funding for each NHTS cycle, which has been a challenging process. In addition, the funding has not been adequate to meet the needs of the program. NHTS is currently run on a "limited" budget with minimal staffing.

Conduct more outreach, including with congressional policy staff.

With more outreach, NHTS could increase its value to the public and private sector. For example, outreach to congressional policy staff would likely result in more widespread use of the data. This outreach could also serve as a mechanism for better understanding the data needs of policy makers.

Roadside Revegetation (Federal Lands)

Program Description

Native roadside revegetation involves establishing or reestablishing appropriate plant material in areas that road construction projects disturb. Revegetation's benefits include soil and slope stabilization, water quality improvement, aesthetic development, carbon sequestration, weed suppression, and wildlife habitat enhancement. In the United States, 28 percent of land is under Federal stewardship, including national parks, forests, wildlife refuges, and tribal and other Federal lands.[27] Recognizing that sharing information about roadside revegetation processes and techniques advances practice and achieves benefits, FHWA's Federal Lands Highway Division partnered with the U.S. Forest Service to develop a protocol to assess and monitor roadside revegetation. The guide, *Roadside Revegetation: An Integrated Approach to Establishing Native Plants*, documents that protocol.[28]

Purpose of the Evaluation

This evaluation sought to determine how effective the guide and related materials (such as a website and training course featuring the guide) were in achieving their stated goals to accomplish the following:

- Change end-user revegetation practices and adopt practices put forth in the guide.
- Improve the establishment of native plants and generate other positive outcomes.

Methodology

The evaluation team reviewed the literature on revegetation, analyzed website usage and feedback from website users, and conducted an online survey with follow-up interviews. The review included manuals, policy documents, and guides from State agencies, the Bureau of Land Management, and the National Park Service (NPS). Web visitation statistics and end-user emails offered insights about the perceived quality and effectiveness of the guide and website. The survey asked questions on users' awareness of *Roadside Revegetation* and its website, the extent to which stakeholders adopted the practices described in the guide, and the effectiveness of the changed practices in achieving the establishment of native plants and other positive outcomes along roadsides.[29] The project team contacted 10 respondents for interviews based on responses to the online survey and conducted 4 interviews.

Key Findings

Finding: End users have adopted the *Roadside Revegetation* practices, using the guide as a reference tool to reinforce practices that agency policies already mandated.[28]

The NPS, United States Forest Service, and some State transportation departments have policies aligned with roadside revegetation.[27] In addition, visits to www.nativerevegetation.org have increased over time, with 44,621 total users from January 1, 2010, to February 17, 2015—approximately 24 per day. More than 7,000 of those users (nearly 16 percent) returned to the website more than once.[27] The data show that the most visited Web pages are in the technical guide itself. Multiple survey respondents noted that they primarily use *Roadside Revegetation: An Integrated Approach to Establishing Native Plants* as a general reference guide while at the project site and when writing revegetation plans, designing monitoring protocols, developing scopes of work, and analyzing data.[28,27] The technical guide has enabled some practitioners to better define future conditions and end goals for project sites.

Finding: Survey respondents and interviewees believed *Roadside Revegetation* has generally improved erosion, sustainability, and environmental stewardship as well as visitor experience outcomes.[28] There is less indication that the technical guide has improved safety or reduced maintenance costs.

Survey results suggest that the majority of survey respondents agreed or strongly agreed that *Roadside Revegetation* has improved erosion outcomes, facilitated more sustainably designed roadways, improved visitor experiences, and enhanced environmental stewardship.[28] Interviewees and several survey respondents pointed out that the application of nonnative plants is probably less expensive than the use of native plants, but in the long-term, the maintenance of nonnative plants is more costly than the maintenance of native plants.[27] There is less evidence that the technical guide has improved safety or reduced maintenance costs. The majority of survey respondents neither agreed nor disagreed with the statement, "safety has been improved."

Recommendations

Extend outreach to reach a wider audience, especially within FHWA Division Offices.

The project team found that *Roadside Revegetation* is still a useful reference, even for knowledgeable practitioners. Expanding the extent to which end users adopt its recommended practices would be beneficial.[28]

Support the enhancement of the community of practice at www.nativerevegetation.org.

Renewed attention to the community of practice on www.nativerevegetation.org could be a cost-effective way to broaden the sharing of knowledge to improve implementation outcomes.

Tailor future roadside revegetation training courses toward personnel who do not have natural resource backgrounds.

Training courses geared toward personnel who do not have natural resource backgrounds would be beneficial to highlight the nuances of installing and maintaining native plants.

Roundabout Research (Safety)

Program Description

International interest in the modern roundabout as a safety countermeasure began in the 1970s and 1980s. Compared to traditional signalized intersections or other circular intersections (e.g., rotaries and traffic circles), roundabouts can reduce crash severity. Starting in the mid-1990s, FHWA initiated domestic research and evaluation of roundabout safety and design, leading to several papers and the publication of *Roundabouts: An Informational Guide* in 2000.[30] FHWA continued work in this area, encompassing research related to performance data improvement and design state-of-the-practice. Later, FHWA activities across the FHWA Safety Discipline included development and sharing of educational resources, training, technical assistance, and a partnership with NCHRP for the 2010 *Informational Guide* update.[30]

Purpose of the Evaluation

This evaluation focused on FHWA's contribution to roundabout research and technical guides, the use of that information in changing stakeholders' awareness and attitudes, and the eventual adoption and impact of roundabouts as safety countermeasures.

Methodology

The evaluation team used a mixed methods approach to more effectively investigate the outcomes and impacts of FHWA roundabout research. The evaluation team collected documents, analyzed data, and conducted semi-structured interviews. Data sources reviewed in the document and literature search included FHWA program documents, other relevant research, TRB Annual Meetings programs, Roundabouts Listserv archives, and literature on technology diffusion. To assess the influence of FHWA research and outreach to State transportation departments, Evaluators reviewed State-level materials including Strategic Highway Safety Plans (SHSPs), State Highway Design Manuals, and State transportation department websites. Where possible, evaluators used quantitative analysis to better understand the funding, quantity, and safety impacts of roundabouts.

Key Findings

Finding: Early and continued FHWA research increased the quality and availability of domestic roundabout-related safety and performance information.

FHWA laid the foundation for nationwide adoption of roundabouts by providing empirical evidence of the safety and operational benefits of roundabouts and aiding in the development of nationwide design standards for their implementation. Initial FHWA contributions increased the availability of domestic roundabouts information by synthesizing international and (limited) domestic safety and design research. These outputs in turn clarified and focused the research questions for the domestic research and design standards communities (with whom FHWA actively partnered and supported). FHWA targeted materials to a variety of audiences across the technology adoption lifecycle, including the research community, State transportation departments, local agencies, and the public. Interviews yielded information about the timing and effect of research and other activities on the research community and showed that FHWA played a key role in accelerating consideration of roundabouts as a research topic and the development of domestically-focused safety and performance studies.

Finding: FHWA roundabout research increased awareness and changed attitudes in the transportation community toward the roundabout as a safety countermeasure.

FHWA research, culminating in the 2000 *Roundabouts Informational Guide*, increased the availability of information on roundabouts in the United States.[30,31] These products provided interested states and stakeholders with more information on how to use roundabouts as a safety countermeasure and an FHWA endorsement of the technology. FHWA Safety R&D worked closely with the FHWA Office of Safety and the FHWA Resource Center to conduct sustained outreach, including making policy changes and recommendations within FHWA, such as the inclusion of Roundabouts in EDC and Proven Safety Countermeasures. This, in turn, shaped State policies regarding roundabouts and resulted in changes of attitudes of transportation professionals toward roundabouts as an intersection alternative.

Finding: FHWA contributed to an increase in roundabouts built in the United States.

FHWA increased the total number of roundabouts through continued support, research, promotion, and funding. Funding for programs designed to increase safety (Highway Safety Improvement Program (HSIP)) and improve traffic flows and environmental benefits (Congestion Mitigation and Air Quality) provided continued support to the earliest adopters, while imparting a confidence boost to late adopters. However, despite increased construction and acceptance of roundabouts, the rate of adoption of roundabouts in the United States appears to have slowed and lags behind leading international adopters. Negative public attitudes and perceived high costs remain barriers.[30]

Finding: FHWA research and promotion of roundabouts contributed to a reduction in injury crashes and societal costs.

A simplified calculation of the safety effect of the approximately 2,400 roundabouts installed in the United States between 1990 and 2014 finds they averted between 38,000 and 53,000 injury crashes, resulting in a societal cost savings of over $9 billion during that period.[31] While FHWA cannot claim exclusive credit for this benefit, its continued research and promotion of roundabouts has been very positive for roadway safety in the United States.

Recommendations

Begin investing in data collection on research diffusion and technology adoption during the early years of technology implementation.

A lack of data hinders attempts to evaluate the adoption and impact of new transportation technologies. FHWA could strategically select a subset of technologies for systematic collection of adoption data. FHWA should also systematize internal metrics related to research investment and outreach.

Build cooperation across FHWA safety disciplines and the broader stakeholder community.

FHWA's successful internal coordination across the safety discipline led to a highly visible and unified message to stakeholders. Documenting and replicating the coordination mechanisms, strategies, and activities that made this process successful could provide organization-wide benefits.

Conduct additional research to understand roundabout costs and identify and promote information and strategies on reducing those costs.

Although the U.S. increase in number of roundabouts has been significant, their adoption still lags behind other countries. Perceptions and uncertainty about the cost of roundabouts remain barriers.

In-Progress Projects

Agent-Based Modeling and Simulation Research (Exploratory Advanced Research Program)

Program Description

In 2009, the FHWA Exploratory Advanced Research (EAR) Program began investigating the use of agent-based modeling and simulation (ABMS) for characterizing driver and traveler behavior. To date, FHWA has sponsored three projects investigating this topic: (1) *Driver Behavior in Traffic* (Virginia Tech, 2009), (2) *Evolutionary Agent System for Transportation Outlook* (University of Arizona, 2011) , and (3) *Agent-Based Approach for Integrated Driver and Traveler Behavior Modeling* (University of Maryland, 2011).[32–34] ABMS is a computational modeling approach for simulating the actions and interactions of autonomous individuals. ABMS has been used in many research domains; however, little is known about its applicability to highway research.

Purpose of the Evaluation

The evaluation team will evaluate EAR ABMS activities to assess their effectiveness in meeting intended goals and outcomes. This evaluation aims to understand the effect of FHWA R&T activities on the implementation of the agent-based approaches on transportation-related projects and activities.

Methodology

For this evaluation, analysis will be primarily qualitative in nature. Interviews as well as document and literature reviews will provide the majority of the necessary data. Document review and citation analysis will include EAR-funded and FHWA research products, other ABMS research, and partner and research community outputs. Interviews will supplement the document record with program, stakeholder, and research community assessments of the quality and impact of FHWA research.

Interim Results

Finding: Confusion exists regarding the nomenclature and definition of ABMS.

While the EAR program refers to “agent-based modeling and simulation” as “ABMS,” others in the industry refer to the practice as “AgBM.” In addition, there is evidence of confusion regarding what constitutes an agent-based model, specifically the learning and interaction elements, compared to simulation models that simply incorporate individual actors.

Finding: ABMS may serve as a natural next step combining activity-based models and dynamic traffic assignment models.

The transportation industry primarily uses two forms of traffic models: activity-based models (ABM), which focus on travelers, and dynamic traffic assignment (DTA) models, which focus on the transportation network. These practices have been integrated by some practitioners to create ABM-DTA models. ABMS models could inform and enhance ABM-DTA models moving forward.

Activities to Date and Anticipated Schedule

The evaluation team has completed evaluation planning and is currently collecting data and conducting interviews of relevant stakeholders. This included attending the TRB-sponsored Innovation in Travel Modeling conference. The draft final report will be delivered in March 2017.

eNEPA (Planning, Environment, and Realty)

Program Description

eNEPA is an online workspace and collaboration forum for major projects requiring an environmental impact statement (EIS) or an environmental assessment.[35] Since the *Transportation Equity Act for the 21st Century*, a central focus of FHWA efforts to accelerate project delivery has been to establish coordinated environmental review processes with concurrent interagency reviews and established time periods.[36] FHWA developed eNEPA for State transportation departments to use in support of interagency reviews with the intent of creating a transparent and streamlined process across States and transportation projects. The tool was rolled out nationally in August 2013.

Purpose of the Evaluation

This evaluation will seek to understand the breadth and depth of use of eNEPA (i.e., users, types of projects, goals), usability of the tool (including additional desired features), effects on the project environmental timeline (reductions in overall review time), and impacts on interagency collaboration (i.e., timing, quantity, and quality of collaboration).

Methodology

The team will collect data through interviews with FHWA Office of Project Development and Environmental Review program staff members, staff members from up to nine State transportation departments using eNEPA, and up to nine State transportation departments not using eNEPA. Quantitative data collection will include—to the extent availability allows—eNEPA statistics on users, projects, and milestone completion dates (i.e., notice of intent, draft EIS, final EIS, record of decision).

Interim Results

Finding: The tool's lack of flexibility, particularly in terms of its process flow and document review features, greatly limits its overall usefulness.

As of December 2015, only one State transportation department was actively using eNEPA as part of the environmental review process for an EIS project. Other agencies piloted eNEPA but stopped using the tool because of institutional and technological issues. Interviewees identified many recommendations for improving the usability of eNEPA and the user experience. In 2016, FHWA updated the tool to incorporate many of the recommendations.

Activities to Date and Anticipated Schedule

An interim technical memo that summarized the data collection and key findings from the first year of the evaluation was delivered in January 2016 and will be updated in January 2017. Evaluation activities will culminate in a draft report to be delivered in March 2018.

GRS-IBS (Infrastructure R&D)

Program Description

GRS technology consists of layers of geosynthetic textile and compacted granular fill. The U.S. Forest Service first used GRS to build walls for roads in mountain terrain in the 1970s. The Infrastructure R&D team further developed the technology into the GRS-IBS, which is intended to be easy to design, inexpensive, and fast to construct with readily available labor, materials, and equipment. The GRS-IBS team published the *Geosynthetic Reinforced Soil Integrated Bridge System Interim Implementation Guide* in 2011 and results from load testing in 2013.[39] EDC has featured the technology since the initiative's first year.

Purpose of the Evaluation

The evaluation team is conducting a retrospective evaluation of GRS-IBS research, disseminating the results (including through EDC), and developing a path to market acceptance. After reviewing a draft evaluation report in November 2015, the team at TFHRC and other stakeholders requested that evaluators delve deeper into barriers to deployment. The evaluation team was asked to consider whether the concept of a *disruptive technology* might help to explain these barriers.

Methodology

The evaluation relies on more than 35 semi-structured interviews with representatives from State, county, and tribal governments; FHWA departments; AASHTO; and the private sector. The evaluation team developed a schema for formal coding of interview transcripts based on both FHWA's evaluation needs and the diversity of interviewee responses. The evaluation team also analyzed a spreadsheet of completed GRS-IBS bridges provided by FHWA and the National Bridge Inventory to better understand the technology's trajectory and current place in the market by tracking the frequency, relative share, and geographic context of construction.

Interim Results

Finding: FHWA efforts fostered positive attitudes toward GRS-IBS and more market share during the 2010–2015 period.

Nineteen interviewees reported a shift in the attitude of potential deployers toward GRS-IBS. Analysis of available data on single span bridges under 140 ft long showed a considerable increase in GRS-IBS deployments in percentage terms from 2010–2015 compared with 2005–2009, primarily for bridges in the 50–110-ft range. For example, between 2005–2009, no GRS-IBS bridges were built in the 90–100-ft range. Between 2010 and 2015, 6 out of 6 (100 percent) of the bridges built in the 90–100-ft range used GRS-IBS.

Finding: Internal disagreements, including between geotechnical engineers and hydrologic engineers, led users to receive conflicting information.

Ten interviewees, both geotechnical and hydrologic engineers, felt that hydrologic engineers did not become involved in GRS-IBS until late in the research process. They expressed concerns even after FHWA officially started to promote the technology. One hydrologic engineer said that his colleagues, "thought if they ignored it [GRS-IBS], it would go away." Potential deployers ended up receiving different messages depending to whom they spoke.

Activities to Date and Anticipated Schedule

In March 2016, the evaluation team commenced work on an expansion of the GRS-IBS Draft Evaluation Report. The team delivered a Final Task Management Plan in July 2016. Delivery of the draft expanded report is expected in December 2016. The final report is expected in March 2017.

High-Friction Surface Treatments (Safety)

Program Description

FHWA high-friction surface treatments (HFST) research began as part of a larger effort to evaluate a range of surface improvements designed to increase road safety. HFST involve the overlay of calcined bauxite on a base of epoxy along portions of roadways that are susceptible to vehicle slippage (e.g., under precipitation or in curves with inoptimal superelevation). The calcined bauxite supports the grip of tires along the road by inhibiting the formation of a plane of water between the road and tires. The FHWA HFST project culminated in the 2014 report, *Evaluation of Pavement Safety Performance* (EPSP).[38] The report supports the use of HFST to improve safety, although the findings were constrained by limitations in the data and method. Ongoing research on developing crash modification factors (CMFs) will be published in the CMF Clearinghouse and *Interactive Highway Safety Design Manual*.[39] Intended outcomes of the EPSP and associated outreach include the establishment of accepted CMFs, support for HFST as a road-improvement alternative through increased adoption by State and local transportation agencies, and inclusion of HFST as both a safety and pavement feature in pavement-design and roadway-design guides.

Purpose of the Evaluation

The evaluation will focus on FHWA's contribution to HFST research and technical guides, the role of the research and publications in changing stakeholders' awareness and attitudes, and the intended outcomes of the establishment of accepted CMFs. This includes use of HFST in industry-standard publications and adoption of HFST by State and local decisionmakers.

Methodology

The evaluation team has developed evaluation criteria, measures of effectiveness, data inputs, and preferred data sources for each evaluation area. Analysis will be primarily qualitative in nature. Interviews as well as document and literature reviews will provide the majority of the necessary data. Primary data sources will include interviews and key planning and strategic documentation (e.g., transportation meeting proceedings, HSIP reports, and State and MPO materials (design manuals, SHSPs, Transportation Improvement Programs)), as well as outputs from ongoing projects. The evaluation team will also access materials from the CMF Clearinghouse.[40] To assess the extent to which FHWA HFST-related research is likely to influence the attitude of the transportation community toward HFST as a safety countermeasure, the evaluation team will identify evidence of confidence in HFST among State and local decisionmakers and transportation practitioners. Assessing the impact of R&T research on HFST adoption will rely on changes in the number of HFST projects relative to competing countermeasures. Evaluators will also gauge the incremental safety impact of R&T HFST research.

Activities to Date and Anticipated Schedule

The final evaluation plan was completed in July 2015 and updated to incorporate changes to the scope based on developments in the project and to harmonize with parallel HFST research on the development of CMFs. The evaluation team is collecting preliminary data and planning for ongoing data collection. The draft report for this prospective evaluation is scheduled for October 2018.

High-Recycle Warm-Mix Asphalt (Office of Infrastructure)

Program Description

The use of recycled materials, including reclaimed asphalt pavement (RAP) and reclaimed asphalt shingles (RAS), reduces both the amount of new materials required for asphalt mixes and the amount of material going to landfills. At the same time, use of warm-mix asphalt (WMA) technologies is growing, enabling producers of asphalt pavement to lower the temperatures at which the material is mixed and placed on the road, resulting in reductions in energy consumption and emissions. FHWA is conducting accelerated load facility and laboratory testing of WMA to determine RAP/RAS limits and binder performance–grade needs. FHWA will provide states with performance-based specifications for testing mix designs that utilize RAP/RAS. The TFHRC Infrastructure Materials team makes its dataset and core samples available to researchers in other organizations.

Purpose of the Evaluation

The evaluation team will evaluate both the research process and research products of the FHWA R&T project, Advance Use of Recycled Asphalt in Flexible Pavement Infrastructure: Develop and Deploy Framework for Proper Use and Evaluation of Recycled Asphalt in Asphalt Mixtures.[41] The team identified four research areas, each with specific research questions; the four research areas include the following: research selection process, the evolution of the research design, collaboration with other organizations, and initial acceptance of the FHWA research report.

Methodology

This evaluation is qualitative in nature and will use literature searches, document reviews, and qualitative interviews with FHWA staff and members of the asphalt research community (e.g., members of the Expert Task Group).

Interim Results

Finding: The significant outreach conducted by the research team has increased the value of the research.

FHWA solicited (and/or stakeholders offered) input regarding several key areas of the experimental design. By incorporating stakeholder feedback, the interviewees indicated that both the quality and the usability of the research product has been strengthened.

Finding: Collaboration results in more efficient use of resources for both FHWA and the collaborating partners.

FHWA has limited resources and cannot perform all the tests that it might prefer on the sample materials. By sharing samples, however, FHWA enables other organizations to perform their own tests and to validate FHWA results, resulting in a more efficient use of resources within the asphalt community.

Activities to Date and Anticipated Schedule

The evaluation team delivered its Interim Technical Memorandum in June 2016 and its Data Acceptability Memorandum in August 2016. Anticipated dates for other key deliverables include a second Interim Technical Memorandum in June 2017 and a draft report in November 2018.[2]

[2]These technical memorandum were internal deliverables between FHWA and the evaluation team.

Managing Risk in Rapid Renewal Projects (Innovative Program Delivery/SHRP2)

Program Description

The Managing Risk in Rapid Renewal Projects program (R09) seeks to develop a simple, reliable, and credible way for States to conduct risk management. The product that resulted from the program was the *Guide for Managing Risk on Rapid Renewal Projects*.(42) The R09 product was developed through SHRP2 and provides practical tools and techniques for minimizing risk and exploiting opportunities on transportation projects.(42) The tools offered in the R09 product include risk-management checklists, materials for applying risk management, and the curriculum for a 2-day course that provides instruction on the risk management process. Together, these tools are intended to reduce project delays, cost overruns, and traffic disruptions that can arise from unmanaged project risks.

Purpose of the Evaluation

This evaluation seeks to understand how the R09 product and implementation support has changed risk management practices and affected project delivery in four lead-adopter states—Florida, Minnesota, Oregon, and Pennsylvania. The evaluation will focus on three key areas: dissemination, adoption, and project delivery. Dissemination will determine the level of exposure States have had to R09 concepts and processes. Adoption will assess the extent to which states have institutionalized the R09 process. Finally, project delivery will gauge how R09 has affected project cost and timeline projections.

Methodology

This evaluation relies on two methods of data collection: document review and stakeholder discussions. The evaluation team is requesting documentation from the lead-adopter States that demonstrates the extent to which R09 concepts were introduced and distributed, how States are incorporating R09 concepts into standard practices, and the ways in which R09 concepts are being used on actual projects. Evaluators will conduct stakeholder interviews and attend peer-exchange events to supplement its review of documents.

Activities to Date and Anticipated Schedule

The final evaluation plan was delivered in September 2016. The evaluation team conducted a gap analysis of the documentation already collected. Discussions with stakeholders responsible for developing the R09 product started in October 2016. In January 2017, the team attended a peer exchange with the lead-adopter States. At the peer exchange, evaluators held in-person discussions with State transportation department representatives. Data collection is expected to continue through the spring/summer of 2017. The draft final report will be delivered in December 2017.

Precast Concrete Pavement (Office of Infrastructure)

Program Description

Precast concrete pavement (PCP) is an innovative practice of using prefabricated concrete panels for pavement and roadway maintenance and rehabilitation. This practice is often used in high traffic–volume areas and in marginal weather because of the construction and overall travel-time savings that it provides. FHWA has led research efforts in this field since the mid-1990s and has continued to support the development of PCP through technical reports and implementation assistance under SHRP2.[38]

Purpose of the Evaluation

PCP evaluation seeks to better understand the outcomes of this developing technology. While existing research suggests that there are clear time savings and advantages of using PCP, these advantages have not been fully understood or quantified. In addition, while cost information is known, it is unknown to what extent the advantages of PCP exceed the costs, if at all, compared to existing alternatives. The evaluation also assesses the broader efficacy of FHWA's research efforts.

Methodology

This evaluation will use a benefit–cost analysis (BCA) framework to understand the impact of PCP installations. This will be done by comparing each PCP project against an estimated baseline or counterfactual. Because each project type varies, the baseline or counterfactual may vary as well. Once the benefits and costs of using PCP are compared to the individual alternatives, overarching themes and trends will be identified. In addition to the BCA, the evaluation will rely on interviews with State agencies who have conducted PCP projects. These interviews will generate qualitative information on attitudes related to PCP, facilitating quantitative data collection and understanding of the role played by FHWA in the development and adoption of PCP.

Interim Results

Finding: PCP has significant benefits over the high-early-strength concrete alternative.

While both PCP and high-early-strength concrete can be used during overnight closures for rapid repair projects, agencies feel that PCP provides more long-term benefits as it is more durable and requires less maintenance compared to high-early-strength concrete.

Finding: FHWA assistance, particularly workshops conducted, helped State transportation departments implement and adopt PCP.

State transportation departments implementing PCP under SHRP2 reported that assistance provided by FHWA and its contractors was significant and they relied upon it extensively. Particularly, State transportation departments reported that the workshops conducted were extremely helpful in providing the States with information needed to implement PCP.

Activities to Date and Anticipated Schedule

The evaluation team has completed data collection for phase 1 and is currently preparing the Phase 1 Draft Report, which will be delivered in February 2017. Phase 2 will begin thereafter and will be completed in early 2018.

Public-Private Partnership Capacity Building Program (Innovative Finance Support)

Program Description

The Center for Innovative Finance Support (formerly the Office of Innovative Program Delivery), launched the Public-Private Partnership (P3) Toolkit in June 2013.(43) The P3 Toolkit is an educational resource containing analytical tools and guidance documents that assist policymakers and transportation professionals in implementing P3 projects. The toolkit forms the foundation of a broader P3 Capacity Building Program (P3 Program) that includes a curriculum of courses and webinars. The goal of the P3 Toolkit is to build State transportation department capacity for choosing P3s appropriately and executing them well.

Purpose of the Evaluation

The evaluation seeks to understand how the P3 Toolkit influences user decisions and actions regarding implementation of P3s. The team sought to evaluate how the P3 Program compared to other online resources and tools in developing P3s. The primary stakeholders that were considered by the team included FHWA Division Offices, State transportation departments, legislative analysts, and private consultants. The evaluation also attempts to uncover if the FHWA P3 Program has enhanced the state of the practice of P3s overall.

Methodology

The evaluation will develop an initial understanding of the P3 Program by studying existing P3 Program usage data and outreach materials to understand how transportation practitioners are accessing and using program resources. This will be supplemented by interviews with P3 Toolkit users from FHWA Division Offices and State transportation departments to provide context for P3 resource usage. An online survey with FHWA Division Office staff will enhance what is learned in the interviews by measuring information needs, P3 Program resource usage, and program satisfaction.

This evaluation focuses only on resources developed from the launch of the P3 Toolkit through publication of the *Draft Availability Payment Concessions P3 Model Contract Guide*.(44)

Activities to Date and Anticipated Schedule

An updated evaluation plan was submitted in June 2016. The evaluation team anticipates submitting a draft report in December 2016.

TIM Trainings (Operations/SHRP2)

Program Description

TIM is the "planned and coordinated multi-disciplinary process to detect, respond to, and clear traffic incidents so that traffic flow may be restored as safely and quickly as possible."[45] The goal of TIM is to reduce the duration of traffic incidents and improve the safety of responders and those involved with incidents. National TIM Responder Training program contacts are available in each of the 50 States as well as in the District of Columbia and Puerto Rico. More than 5,200 TIM trainings have been conducted and 200,000 responders trained since 2012.[45]

Purpose of the Evaluation

The evaluation team will analyze the relationship between the TIM trainings and three TIM performance measures defined in FHWA's *TIM Performance Measures Focus States Initiative*: roadway clearance time, incident clearance time, and the number of secondary crashes.[45] The evaluation seeks to determine the extent to which any change in the measures is attributable to the trainings.

Methodology

The evaluation team worked with the TIM Program Office to identify States with strong TIM training programs, good data collection practices, and a willingness to participate in the evaluation. Arizona and Tennessee met these criteria. FHWA supplied the location and date of each TIM training along with the number of attendees by responder type (e.g., police, fire, emergency, towing, and State transportation department). Evaluators received 5 years of incident information from representatives of both States in the study. Together, these data sources are sufficient for applying statistical regression to isolate the impact of TIM-trained responders on TIM performance measures holding other factors (e.g., crash severity) constant. Semi-structured interviews with responders and managers will supplement the quantitative results.

Activities to Date and Anticipated Schedule

The preliminary evaluation plan was delivered in July 2016. The evaluation team commenced a pilot study of the Phoenix metropolitan area in August 2016 and discussed preliminary results with FHWA and Arizona partners in September 2016. In September 2016, the evaluation team began its pilot study of Tennessee region 1 (Knoxville) and will discuss preliminary results with FHWA and Tennessee partners in October 2016. An updated version of the evaluation plan that takes into account recently encountered challenges and opportunities will be completed in February 2017. The final report will be delivered in June 2017.

Vehicle Operating Costs (Office of Policy)

Program Description

FHWA Office of Policy has contracted the University of Nevada, Reno (UNR), to conduct research and analysis related to vehicle operating cost (VOC) estimation. The VOC model that is currently used in FHWA's Highway Economic Requirements System (HERS) model is based on a 1982 study and requires updating because of technological developments since then.(46) UNR is in the process of updating the model and will also determine which groups beyond FHWA use the model. This work will continue through 2019.

Purpose of the Evaluation

The VOC evaluation seeks to understand the outcomes of UNR's methodological update. The evaluation team will determine how the new VOC model is incorporated into HERS and other FHWA models and assess the awareness and use of VOC estimates and methods by other entities. The evaluation team will also gauge the impact of updating the VOC model and methods for the identified users.

Methodology

The evaluation team will measure the outcomes of the update by examining case-by-case VOC-model use. Although some applications for the VOC model and methodologies are already known, most notably the HERS model, the team will determine other applications during the course of the evaluation. This evaluation is likely to be quantitative in nature and will analyze documentation, reports, and journal articles. Depending on usage levels, the team will conduct interviews with users to collect qualitative data related to perceptions of the updated equations and methods. Such qualitative data will supplement quantitative findings.

Activities to Date and Anticipated Schedule

As UNR continues their work, the evaluation team will provide annual updates of the evaluation plan and begin full data collection activities in 2019. A final report is expected to be completed in mid-2020.

Concluding Materials

Conclusion

The Federal Government has the responsibility to fund and conduct R&T activities to meet highway transportation challenges and significantly advance technology innovation when private investment is neither present nor sufficient to meet public need.[47] The FHWA R&T *Agenda* considers future transportation issues from two perspectives: challenges and research components designed to meet those challenges.[7] Four of the eight research components (Infrastructure, Operations, Safety, and EAR) take place under the guidance of FHWA's Office of Corporate Research, Technology, and Innovation Management (HRTM).[4] Advancing these research components will require continually reexamining and improving the process of selecting and executing research projects, disseminating findings, supporting user adoption, and assessing impact.

FHWA's CMP emphasizes performance evaluation and measurement.[3] In addition, HRTM leadership has adopted a *Strategic Plan* to guide work at TFHRC. One of the plan's long-term goals (goal 5) is to calibrate HRTM's efforts to promote the adoption of research findings.[3] The plan makes explicit that dissemination of knowledge requires engaging external partners and targeting outreach. Evaluation can serve in the search for effective alignment by revealing the relationships between outreach, dissemination, transition, and increased performance. These relationships are the focus of the FHWA R&T Evaluation Program.

The FHWA R&T Evaluation Program has been designed to further HRTM's transparency, accessibility, and responsiveness of R&T for stakeholders. To support a more coordinated research agenda, FHWA has organized, clarified, and communicated FHWA's R&T mission, vision, goals, and priorities. By sharing this information, FHWA hopes to encourage highway researchers to identify and fill research gaps, reduce unnecessary duplication of research efforts, stimulate collaborative research efforts, and accelerate innovation. In its initial year, the FHWA R&T Evaluation Program worked with 9 FHWA offices to identify 16 projects for evaluation across all program areas. The evaluations represent a mix of retrospective and prospective studies and range in schedule from 6 months to 4 years or more. As of September 30, 2016, six evaluation teams have submitted final evaluation reports. Ten evaluations remain in progress.

FHWA has developed and customized procedures to simultaneously execute multiple related highway-research evaluations. Guides, templates, checklists, and other tools are in place to ensure quality control and prevent duplicated effort. These tools will enable the team to spend more energy on research design, data collection, and analysis while continuing to issue reports that are similar in style and highly readable. The evaluation team will continue to work with FHWA R&T and program offices to produce accurate evaluations that are useful in shaping the Nation's highway research and technology agenda.

Appendix. Project Status

Evaluation Name	Office	Retrospective	Prospective	Status (Planning/ Data Collection/ Analysis/ Report)	Most Recent Deliverable	Final Report Date Expected/Actual
ASCs	Operations R&D	X	-	Project complete	Final Report	January 2016 (Actual)
ABMS Research	EAR	X	-	Data collection in progress	Evaluation Plan	May 2017 (Expected)
Eco-Logical	Planning, Environment, and Reality	X	-	Finalizing report	Draft Report	November 2016 (Expected)
eNEPA	Planning, Environment, and Reality	-	X	Data collection in progress	Interim Memo I	June 2018 (Expected)
GRS-IBS	Infrastructure R&D	X	-	Data collection in progress	Evaluation Plan	March 2017 (Expected)
Gusset Plates[16]	Infrastructure R&D	X	-	Project complete	Final Report	January 2016 (Actual)
HFST	Safety R&D	-	X	Data collection in progress	Evaluation Plan	December 2018 (Expected)
High-Recycle WMA	Infrastructure R&D	-	X	Data collection in progress	Data Acceptability Memo	January 2019 (Expected)
Managing Risk in Rapid Renewal Projects	Innovative Program Delivery	-	X	Data collection in progress	Evaluation Plan	February 2018 (Expected)
NHTS[23]	Policy and Governmental Affairs	X	-	Project complete	Final Report	November 2015 (Actual)
P3 Toolkit	Innovative Program Delivery	-	X	Data collection in progress	Updated Evaluation Plan	November 2016 (Expected)
PCP	Infrastructure R&D	-	X	Data collection in progress	Evaluation Plan	March 2018 (Expected)
Roadside Revegetation	Federal Lands Highway	X	-	Finalizing report	Final Report	March 2016 (Actual)

Evaluation Name	Office	Retrospective	Prospective	Status (Planning/ Data Collection/ Analysis/ Report)	Most Recent Deliverable	Final Report Date Expected/Actual
Roundabout Research	Safety R&D	X	-	Analysis in progress	Draft Phase II Report	October 2016 (Expected)
TIM Trainings	Operations	-	X	Data collection in progress	Draft AZ Pilot Report	June 2017 (Expected)
VOCs	Policy and Governmental Affairs	-	X	Data collection in progress	Draft Evaluation Plan	July 2020 (Expected)

X = project is either retrospective or prospective based on where they are placed.

Acknowledgments

The evaluation team would like to acknowledge the FHWA program offices, the R&T program, and the many individuals who contributed their experience and time to this evaluation effort.

References

1. **Ingram, D.** Raider Parking. A flickr Web site. [Online] Flickr, 2011. [Cited: November 25, 2017.] flic.kr/p/9wKG7p.

2. **Federal Highway Administration (FHWA).** Federal Highway Administration Research and Technology Agenda. Washington, DC : U.S. Department of Transportation, 2014.

3. —. Corporate Master Plan (CMP) for Research and Deployment of Technology & Innovation. Washington, DC : U.S. Department of Transportation, 2003.

4. **Federal Highway Administration (FHWA).** Strategic Plan for the Turner-Fairbank Highway Research Center. Washington, DC : FHWA, 2014.

5. **U.S. General Accounting Office (GAO).** Highway Research: Systematic Selection and Evaluation Processes Needed for Research Program. Washington, DC : GAO, 2002. GAO-02-573.

6. **Transportation Research Board (TRB).** Research and Technology Coordinating Committee Report September 6, 2016. Washington, DC : TRB, 2016.

7. **Federal Highway Administration (FHWA).** Research and Technology Agenda. [Online] Washington, DC: USDOT, 2017. [Cited: November 25, 2017.] http://www.fhwa.dot.gov/research/fhwaresearch/agenda

8. **Quinn, M.** Grand Canyon National Park: Tusayan: South Roundabout. a flickr Web site. [Online] Flickr, 2012. [Cited: November 25, 2017.] https://www.flickr.com/photos/grand_canyon_nps/8033962904

9. **Brooks, J.** Immobile. A flickr Web site. [Online] Flickr, 2007. [Cited: November 25, 2017.] flickr.com/photos/jeremybrooks/463331897/

10. **Hoherd, D.** Untitled. A flickr Web site. [Online] Flickr, 2016. [Cited: October 24, 2016.] flickr.com/photos/warzauwynn/25265164059

11. **Federal Highway Administration (FHWA).** Load Rating Guidance and Examples for Bolted and Riveted Gusset Plates in Truss Bridges. Washington, DC : FHWA, 2009. FHWA-IF-09-014.

12. —. Visualization. A nativerevegetation Web site. [Online] Washington, DC : FHWA, 2014. [Cited: November 25, 2017.] http://nativerevegetation.org/visualize/visualize.aspx

13. **Volpe National Transportation Systems Center.** FHWA Research and Technology Program: Adaptive Signal Control Final Report. [ed.] Sari Radin, et al. Washington, DC : Federal Highway Administration, in press.

14. **Federal Highway Administration (FHWA).** 2007 Grant Program for 15 Eco-Logical Projects. [Online] Washington, DC : FHWA. [Cited: April 18, 2017.] https://www.environment.fhwa.dot.gov/ecological/ImplementingEcoLogicalApproach/Grant_Program_Projects.asp

15. —. SHRP2 Solutions: Tools for the Road Ahead. [Online] Washington, DC : U.S. Department of Transportation. [Cited April 18, 2017.] http://www.fhwa.dot.gov/goshrp2/

16. **Volpe National Transportation Systems Center.** FHWA Research and Technology Program: Gusset Plates Evaluation Report. Washington, DC : Federal Highway Administration, 2016.

17. **National Transportation Safety Board (NTSB).** Collapse of I-35W Highway Bridge, Minneapolis, Minnesota, August 1, 2007. Highway Accident Report NTSB/HAR-08/03. Washington, DC : NTSB, 2008.

18. **American Association of State Highway and Transportation Officials (AASHTO).** AASHTO LRFD Bridge Design Specifications, U.S. customary units. Washington, DC : AASHTO, 2014.

19. —. Manual for Bridge Evaluation: 2011 interim recisions. Washington, DC : AASHTO, 2011.

20. **National Cooperative Highway Research Program (NCHRP).** Web-Only Document 197: Guidelines for the Load and Resistance Factor Design and Rating of Riveted and Bolted Gusset-Plate Connections for Steel Bridges. Washington, DC : Transportation Research Board, 2013.

21. **National Transportation Safety Board (NTSB).** Safety Recommendation H-08-001. Washington, DC, Minneapolis, MN : NTSB, 2008.

22. **Santos, A.** National Housegold Travel Survey Compendium of Uses. an NHTS.ORNL Web site. [Online] Oak Ridge, TN : Oak Ridge National Laboratory, 2014. [Cited: November 27, 2017.] http://nhts.ornl.gov/2009/pub/Compendium_2014.pdf

23. **Volpe National Transportation Systems Center.** FHWA Research and Technology Program: National Household Travel Survey Program Final Report. [ed.] Lora Chajka-Cadin, et al. Washington, DC : Federal Highway Administration, 2017.

24. **Federal Transit Administration (FTA).** 2013 Status of the Nation's Highways, Bridges, and Transit: Conditions & Performance. Washington, DC : Federal Highway Administration, 2014.

25. **U.S. Department of Transportation (USDOT).** Beyond Traffic: USDOT's 30 Year Framework for the Future. Washington, DC : USDOT, 2015.

26. **Centers for Disease Control and Prevention (CDC).** Healthy People 2020. [Online] Atlanta, GA : CDC, October 2011. [Cited: April 4, 2017.] http://www.cdc.gov/nchs/healthy_people/hp2020.htm

27. **Volpe National Transportation Systems Center.** Evaluation of Promoting Roadside Revegetation: An Integrated Approach to Establishing Native Plants. [ed.] Carson Poe and Travis Mast. Washington, DC : Federal Highway Administration, 2017. [Cited: January 12, 2017.] https://www.fhwa.dot.gov/publications/research/randt/evaluations/17008/index.cfm

28. **Western Federal Lands.** Roadside Revegetation: An Integrated Approach to Establishing Native Plants. A nativerevegetation Web site. [Online] Washington, DC: U.S. Department of Transportation, 2016. [Cited: June 19, 2017.] nativerevegetation.org

29. **Federal Highway Administration (FHWA).** Roadside Revegetation: An Integrated Approach to Establishing Native Plants. Washington, DC, Vancouver, WA : FHWA, Western Federal Lands Division, 2007.

30. **Transportation Research Board (TRB).** Roundabouts: An Informational Guide - Second Edition. Washington, DC : TRB, 2000. NCHRP Report 672-03-65A.

31. **Volpe National Transportation Systems Center.** FHWA Research and Technology Program: Roundabouts Final Report. [ed.] Jonathan Badgley, et al. Washington, DC : Federal Highway Administration, in press.

32. **Federal Highway Administration (FHWA).** Driver Behavior in Traffic. Washington, DC : FHWA, 2012. FHWA-PROJ-09-0039.

33. —. VASTO Evolutionary Agent System for Transportation Outlook. Washington, DC : FHWA, 2015. FHWA-PROJ-11-0040.

34. —. Agent-Based Approach for Integrated Driver and Traveler Behavior Modeling. Washington, DC : FHWA, 2013. FHWA-PROJ-11-0028.

35. —. eNEPA Portal. An fhwaapps.fhwa.dot Web site. [Online] Washington, DC : U.S. Department of Transportation, 2017. [Cited: November 27, 2017.] https://fhwaapps.fhwa.dot.gov/enepap/

36. —. TEA-21 Moving Americans into the 21st Century. An fhwa.dot Web site. [Online] Washingotn, DC : U.S. Department of Transportation, 2015. [Cited: November 27, 2017.] https://www.fhwa.dot.gov/tea21/index.htm

37. —. Geosynthetic Reingorced Soil Integrated Bridge System Interim Implementation Guide. Washington, DC : U.S. Department of Transportation, 2011. FHWA-HRT-11-026.

38. —. Evaluation of Pavement Safety Performance. Washington, DC : U.S. Department of Transportation, 2015. FHWA-HRT-14-065.

39. —. Interactive Highway Safety Design Model (IHSDM): Overview. [Online] Washington, DC : U.S. Department of Transportation, 2016. [Cited: April 4, 2017.] http://www.fhwa.dot.gov/research/tfhrc/projects/safety/comprehensive/ihsdm/

40. **Federal Highway Administration and North Carolina Highway Safety Research Center.** Crash Modification Factors Clearinghouse. cmfclearinghouse Web site. [Online] Washington, DC : U.S. Department of Transportation, 2016. [Cited: April 4, 2017.] http://www.cmfclearinghouse.org/

41. **Federal Highway Administration (FHWA).** Advance Use of Recycled Asphalt in Flexible Pavement Infrastructure: Develop and Deploy Framework for Proper Use and Evaluation of Recycled Asphalt in Asphalt Mixtures. [Online] Washington, DC : FHWA, 2016. [Cited: April 18, 2017.] https://www.fhwa.dot.gov/research/tfhrc/projects/projectsdb/projectdetails.cfm?projectid=FHWA-PROJ-11-0070. FHWA-PROJ-11-0070.

42. **Golder Associates.** Guide for the Process of Managing Risk on Rapid Renewal Projects. Washington, DC : Transportation Research Board, 2014.

43. **Federal Highway Administration (FHWA).** FHWA P3 Toolkit. an FHWA.DOT Web site. [Online] Washington, DC : FHWA, 2017. [Cited: November 27, 2017.] https://www.fhwa.dot.gov/ipd/p3/toolkit/

44. —. Draft Availability Payment Concessions Public-Private Partnerships Model Contract Guide. Washington, DC : U.S. Department of Transportation, 2015. Notice FR Doc. 2015-25656.

45. —. Traffic Incident Management - Emergency Transporation Operations - FHWA Operations. Federal Highway Administration. [Online] Washington, DC : U.S. Department of Transportation, 2017. [Cited: April 4, 2017.] http://ops.fhwa.dot.gov/eto_tim_pse/about/tim.htm

46. —. Highway Economic Requirements System Technical Report. A Trid.trb Web site. [Online] Washington, DC : U.S. Department of Transportation, 2000. [Cited: November 27, 2017.] https://trid.trb.org/view.aspx?id=725673

47. —. The FHWA 2015 R&T Story: Research and Innovative Solutions for the Nation's Highway Challenges. Washington, DC : FHWA, 2015.

U.S. Department of Transportation
Federal Highway Administration

HRTM-10/02-18(WEB)E