Transportation Research Implementation: Application of Research Outcomes

DETAILS

149 pages | 8.5 x 11 | PAPERBACK
ISBN 978-0-309-39808-4 | DOI 10.17226/22185

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CONFERENCE PROCEEDINGS 51

Transport Research Implementation
Application of Research Outcomes

Summary of the Second EU-U.S. Transportation Research Symposium

Andrea Meyer and Dana Meyer, Working Knowledge
Rapporteurs

April 10–11, 2014
Paris, France

Organized by the
European Commission
Office of the Assistant Secretary for Research and Technology,
U.S. Department of Transportation
Transportation Research Board

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

Washington, D.C.
2015
www.TRB.org

Transportation Research Board Conference Proceedings 51
ISSN 1073-1652
ISBN 978-0-309-29559-8

Subscriber Categories
Education and training; finance; research, data and information technology; policy

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Printed in the United States of America.

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This report has been reviewed by a group other than the authors according to the procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

This project was organized by the European Commission; the Office of the Assistant Secretary for Research and Technology, U.S. Department of Transportation; and the Transportation Research Board of the National Academies.

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Preface

This document provides a summary of the entire content of the Second EU-U.S. Transportation Research Symposium held April 10–11, 2014, in Paris, France; all presentations, comments, and discussions are included. The summary is organized by symposium session or breakout session with a concluding section that synthesizes the suggestions that emerged from the symposium. This format was selected to give the reader a full understanding of the ideas expressed as well as to document the lessons learned and offer recommendations for successful implementation of research outcomes.

The purpose of the Second EU-U.S. Transportation Research Symposium was to promote cooperation across the Atlantic and share best practices for the implementation of research outcomes in the field of surface transportation at the local, state, national, and international levels. EU-U.S. cooperation can optimize public funding of transportation research. This symposium was the second in a series of four annual symposia, the first of which, "City Logistics Research: A Transatlantic Perspective," took place in Washington, D.C., on May 30–31, 2013 (*1*). The overarching goal of the symposia series is to promote common understanding, efficiencies, and transatlantic cooperation within the international transportation research community while accelerating transportation sector innovation in Europe and the United States.

An EU-U.S. planning committee handpicked a group of high-level researchers, infrastructure owners, research managers, funding agency officials, private-sector experts, managers, and end users from the United States and the European Union to attend the 2-day symposium and provide ideas on how to improve the implementation of transportation research to increase long-term returns on investments. The symposium's multifaceted structure and interactive format enabled the widest input from the 62 assembled experts.

The symposium was divided into five sessions that featured a total of 29 presentations and extensive question-and-answer sessions to cover the context of the issue, stakeholder perspectives, institutional incentives for implementation, research for implementation, and the bridge between principles and practice. The symposium format included two cycles of breakout group discussions that tapped into the combined expertise of the group to consider key questions. The first day's breakout session focused on stakeholders' perspectives on implementation and divided the participants into three stakeholder pools: funders, researchers, and implementers–users. Each stakeholder group looked at the drivers of successful research, impediments to research application, and inhibitors to deployment from its particular perspective. The second day's breakout session randomly assigned funders, researchers, and implementers–users to groups to further discuss and summarize ideas for increasing the success of transportation research and removing the impediments to its implementation.

The symposium opened with two presentations of commissioned white papers that gave an overview of the hypotheses about successful transportation research and discussed 13 case studies of successfully implemented research. The text of both papers is included in the appendixes to these conference proceedings. One finding was that research and research-derived innovations face two valleys of death: first, when a line of research fails to reach some sort of prototype or early commercialization stage, and second, when the prototype or early product is not adopted at scale.

Throughout the symposium, participants provided suggestions for making research more deployable and for breaking down barriers to implementing innovation in transportation systems. Participants offered a wide variety of suggestions for improving the efficacy of transportation research to produce successful implementations at scale. Some suggestions focused on research methods, researcher incentives, and more systematic tracking of research and research outcomes. Other suggestions emphasized the need for greater involvement of all stakeholders, better communications between researchers and stakeholders, and opportunities to improve research efficiency via joint projects. The participants also identified some systemic obstacles that could be mitigated to accelerate the adoption of research.

This report, prepared by the symposium rapporteurs, is a compilation of the presentations and a factual summary of the ensuing discussions at the event. The planning committee's role was limited to planning and convening the conference. The views contained in the report are those of individual symposium participants and do not necessarily represent the views of all participants, the planning committee, the Transportation Research Board (TRB), the European Commission, the U.S. Department of Transportation, or the National Research Council.

This symposium summary was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making the published summary as sound as possible and to ensure that it meets institutional standards for objectivity, evidence, and responsiveness to the project charge. The review comments and draft manuscript remain confidential to protect the integrity of the process.

TRB thanks the following individuals for their review of the summary: Michael Bonini of the Pennsylvania Department of Transportation, James Dockstader of the Florida Department of Transportation, Barbara T. Harder of B. T. Harder, Inc., and Laura Melendy of the University of California, Berkeley.

Although the reviewers listed above provided many constructive comments and suggestions, they did not see the final draft of the symposium summary before its release. The review of this summary was overseen by Susan Hanson of Clark University (emerita). Appointed by the National Research Council, she was responsible for making certain that an independent examination of this summary was performed in accordance with established procedures and that all review comments were carefully considered. Responsibility for the final content of this summary rests entirely with the authors and the institution.

Reference

1. *Conference Proceedings 50: City Logistics Research: A Transatlantic Perspective.* Transportation Research Board of the National Academies, Washington, D.C., 2013. http://www.trb.org/Publications/Blurbs/170031.aspx.

Acronyms

AAR	Association of American Railroads
AASHTO	American Association of State Highway and Transportation Officials
ACRP	Airport Cooperative Research Program
AID	Accelerated Innovation Deployment
AIS	Automatic Identification System
BASt	Federal Highway Research Institute (Germany)
BNSF	Burlington Northern Santa Fe railroad
BRT	bus rapid transit
CEDR	Conference of European Directors of Roads
CEE	Central and Eastern European
CEN	European Committee for Standardization
CEO	chief executive officer
CIP	Competitiveness and Innovation Framework Programme (European Union)
CMU	Carnegie Mellon University
COMPRIS	Consortium Operational Management Platform River Information Services
COST	European Cooperation in Science and Technology
CPB	Corporate Partnership Board
CRADA	cooperative research and development agreement
CRPs	cooperative research programs
DOT	department of transportation
ECDIS	Electronic Chart Display and Information System
EN	European Standard
ENR1	ERA-NET ROAD 1
ENR2	ERA-NET ROAD 2
EPA	Environmental Protection Agency
ERA-NET	European Research Area–Network
ERA-NET ROAD	Coordination and Implementation of Road Research in Europe
ERRAC	European Rail Research Advisory Council
ETG	Expert Task Group
ETP	European Technology Platform
EUTRAIN	European Transport Research Area International Cooperation Activities
FAA	Federal Aviation Administration
FEHRL	Forum of European National Highway Research Laboratories
FERSI	Forum of European Road Safety Research Institutes
FFRDC	federally funded research and development center
FHWA	Federal Highway Administration

FRA	Federal Railroad Administration
FTA	Federal Transit Administration
GDP	gross domestic product
HCM	*Highway Capacity Manual*
HMCRP	Hazardous Materials Cooperative Research Program
HSM	*Highway Safety Manual*
IHSDM	Interactive Highway Safety Design Model (software)
INCARNATION	Efficient Inland Navigation Information System
INDRIS	Inland Navigation Demonstrator for River Information Services
IP	intellectual property
IPR	intellectual property rights
IPTP	International Public Transportation Program
IT	information technology
ITF	International Transport Forum (of OECD)
JRC	Joint Research Centre (of European Commission)
KYTC	Kentucky Transportation Cabinet
LCC	life-cycle costing
MOU	memorandum of understanding
MUTCD	*Manual on Uniform Traffic Control Devices*
NAPA	National Asphalt Pavement Association
NASA	National Aeronautics and Space Administration
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NCRRP	National Cooperative Rail Research Program
OECD	Organisation for Economic Co-operation and Development
OEM	original equipment manufacturer
OST-R	Office of the Assistant Secretary for Research and Technology
OTT	Office of Technology Transfer (Emory University)
PAM	Program for Asset Management (Netherlands)
PCaTS	pedestrian countdown timers at traffic signals
PIANC	World Association for Waterborne Transport Infrastructure
PPLT	protected–permitted left turn
PPP	public–private partnership
PVO	Platform Expansion Joints (Netherlands)
R&D&I	research, development, and innovation
RAC	Research Advisory Committee
RAMS	reliability, availability, maintainability, and safety
RFP	request for proposal
ROI	return on investment
RWS	Rijkswaterstaat (Netherlands)
SBIR	Small Business Innovation Research
SHEEP	security, health, environment, economics, and politics
SHRP 2	second Strategic Highway Research Program
SME	small and medium-sized enterprise
TADS	Trackside Acoustic Detection System
TCRP	Transit Cooperative Research Program
TFHRC	Turner–Fairbanks Highway Research Center
TNO	Netherlands Organisation for Applied Scientific Research
TRB	Transportation Research Board
TTCI	Transportation Technology Center, Inc.
UHPFRC	ultrahigh-performance fiber-reinforced concrete
UNIFE	Association of the European Rail Industry
UTC	university transportation center
WMA	warm-mix asphalt

Contents

Welcome and Introductory Remarks

Jean-Bernard Kovarik of the French Ministry of Ecology, Sustainable Development and Energy opened the meeting by saying that the goal of the symposium was to cooperate across the Atlantic and exchange information on transportation and mobility. Cooperation between the United States and the European Union is necessary to optimize public funding of transportation research and to provide quality research outcomes via fast implementation of transportation services, which is how the outcomes are measured. Transportation is facing challenging issues, such as balancing demand and land planning. Other challenges include energy efficiency, reliability in mass transit, climate change, safety, security, and the social acceptability of new technologies in our connected world. Given these common challenges, cooperation across the Atlantic could be beneficial. Kovarik congratulated the planning committee for its organization of the symposium and its cross analysis of tangible examples through the white papers commissioned. Innovation is important for human jobs and progress in transport as well as other sectors, he said. He concluded his remarks by saying that "humans are the ultimate target of the economic advancement" and that he looked forward to a fruitful meeting.

Alessandro Damiani, Head of Unit, Horizontal Aspects of the Transportation Directorate, Directorate-General for Research and Innovation of the European Commission in Brussels, Belgium, thanked the participants, the French hosts, the U.S. Department of Transportation (DOT), and the Transportation Research Board (TRB) partners for making this symposium possible. He likewise thanked the white paper authors, speakers, and participants. The European Commission is proud to be part of this endeavor, he said, given the good preparation and white papers that laid the groundwork for a productive 2-day discussion. This is the second symposium in the series of four. The first one had good follow-up, and the theme for this symposium was how to get the most out of transportation research efforts. Whether as a funder or user or researcher, that outcome is important to all. Regardless of whether participants' transportation research budgets are expanding or shrinking, all decision makers and politicians expect a better return on investment on the research. In the United States and the European Union, the contexts are different and the institutional framework and governance are different, but, as the white papers showed, the challenges are quite similar, and all participants could learn from each other's successes and failures.

Kevin Womack, Associate Administrator, Office of the Assistant Secretary for Research and Technology, U.S. DOT, encouraged the U.S. and European participants to interact with each other by participating in the discussions and in open debate during the sessions. The goal of this symposium is to encourage conversation and consider new ideas, he said.

Robert E. Skinner, Jr., Executive Director, Transportation Research Board of the National Academies, Washington, D.C., expressed gratitude to Mr. Kovarik and the European Commission partners. Despite changes taking place in some of the institutions, this series of symposia is promising, and it meets on a semiregular basis. He said further that "we all have a piece of the innovation process and yet are often limited by our own narrow perspectives." He thanked Jesús Rodríguez and John Mason for chairing the planning committee and said he looked forward to the discussions.

SESSION 1

Setting the Scene

John F. Munro, *University of Maryland, College Park, Maryland, USA*
Ángel Aparicio, *Universidad Politécnica de Madrid, Spain*
Joris Al, *Forum of European National Highway Research Laboratories (FEHRL), Brussels, Belgium*
Mark Vandehey, *Kittelson and Associates, Portland, Oregon, USA*
Terry Hill, *Arup Group Trusts, London, United Kingdom, and International Organization for Standardization, Geneva, Switzerland*

Transportation Research Implementation in the European Union and the United States: Observations and Working Hypotheses

John F. Munro and Ángel Aparicio

John Munro began by saying that his goal was to provide a few points that would stimulate discussion and offer a contrast to the second white paper. The bottom line of his and his coauthor's white papers is that the research implementation processes in both the United States and Europe are unsatisfactory and in need of vast improvement. For the past 40 years, most conventional studies of transportation research transfer have focused on a reductionist view of symptoms rather than on an exploration of the underlying core causes, he said. For example, the studies have looked at details such as the existence of champions within a project but have not risen to consider the systems level. The reductionist approach looks at little things rather than examining the systemic conditions that impede implementation. Munro urged that, ultimately, there is a need to move from incremental to paradigmatic change on both sides of the Atlantic.

As pointed out in his white paper, there are critical areas of overlap between the United States and the European Union in terms of outcomes that are affecting the research dissemination process. The factors causing the problems differ, but the outcomes are similar. For example, in both the European Union and the United States, the research implementation process lacks sufficient government involvement in commercialization. Munro referred to this as the "valley of death." There are two valleys of death: one technological and one financial (commercialization) (Figure 1).

Systems-Level Factors Promoting Research Implementation

There are four key systems-level factors that would allow a better research implementation process that are not present in the United States or in the European Union, Munro said. These factors, which are summarized in Figure 2, are

1. Sufficient funding for research implementation,
2. Organizational centralization and coordination,
3. Comprehensive data collection and analysis, and
4. Effective use of intellectual property (IP) tools.

The lack of funding is a serious problem in the United States, where commitment to improving infrastructure has declined and the U.S. government has historically been reluctant to put money into commercialization. That reluctance is changing somewhat with the U.S. Federal Highway Administration (FHWA), but little has been done to fund commercialization. The organizational structures are complex and overlapping, and it is difficult for one hand to see what the other is doing. Similarly, although some good metrics are present in the European Union at the national level, such as in France, EU-wide metrics are poor in terms of information collection on outcomes, levels of commercialization, and revenues versus costs.

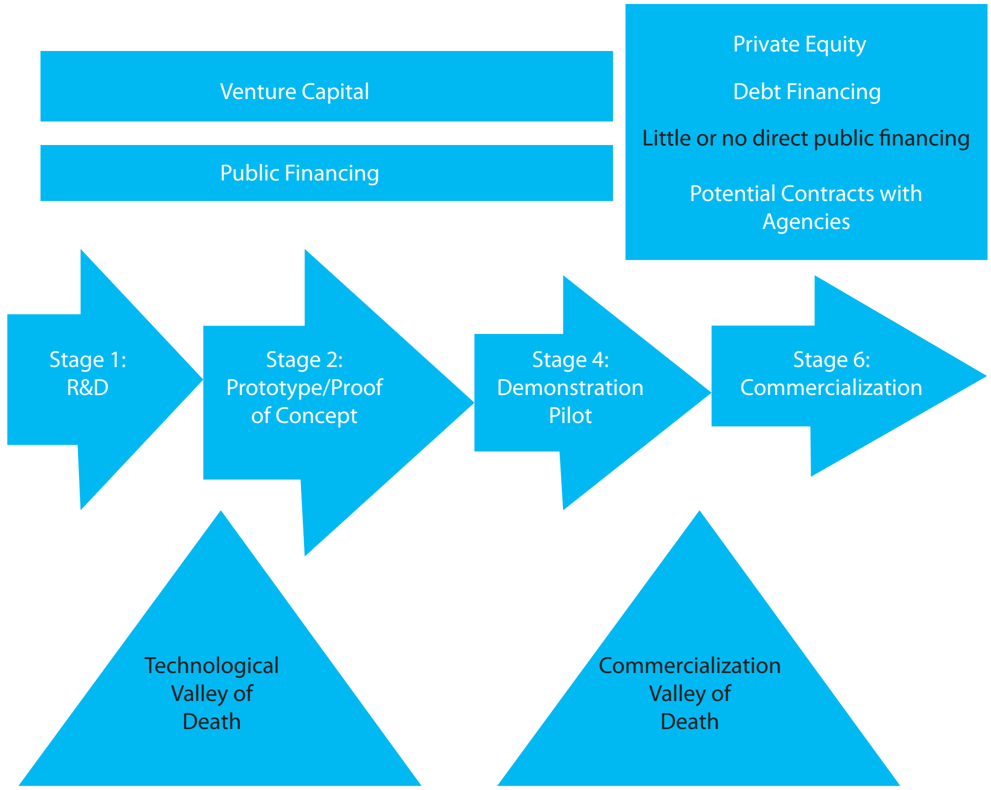


FIGURE 1 **Two valleys of death: technological and financial (commercialization). (Source: Adapted from Jenkins and Mansur 2011, Figure 1, p. 5.)**

Munro asked his coauthor to elaborate, and Ángel Aparicio emphasized that the lack of funding has been evident over the past decade. He noted that in the European Union, individual countries do research and implementation, but not at the EU level. The European Commission encourages young researchers to enter the field, but there are few professional career opportunities to allow them to do so. Second, in the 2 to 4 years after a research project ends, there is a lack of comprehensive monitoring that would show whether the project had been commercialized. In that regard, the attention to the research ends too soon.

On the issue of revenue, Munro added that many U.S. states are backing out of research programs because of budget uncertainties. Even for small research projects of $1 to $2 million, a state governor may decide not to pursue the project in favor of immediate needs such as filling potholes. Federal officials are more receptive to operational stakeholders or to infrastructure issues than to research, because research delivers intangible benefits that are not real time.

Myths That Impede Effective Research

Next, Munro discussed myths that impede effective research implementation. One of these strongly held myths is that funding should decrease as research approaches commercialization. Although American institutions such as the National Aeronautics and Space Administration (NASA), the National Cancer Institute, and the U.S. Department of Agriculture are heavily involved in the transfer of research, in transportation the situation across states is so complicated and overlapping that control of the process is not good.

Part of the solution to metric issues rests in the development of a more robust IP system in Europe and the United States, Munro continued. Some agencies, such as NASA and the National Cancer Institute, develop IP well, but others, such as the U.S. Department of Transportation (DOT), do not. Munro speculated that the lack of IP development could be due to a fundamental belief that it was inappropriate for public money to be translated into IP that could be licensed. The belief structure that IP is contrary to the proper role of government is typical of both the United States and the European Union.

Áparicio expanded on the final myth, which holds that transport research problems are modal and that research implementation should therefore be left to the modes. This myth leads to incremental rather than disruptive innovation, he said.

Munro concluded with a list of 12 hypotheses, such as that a lack of integrated IP systems is impeding innovation

	European Union	United States	Cause	Comment
Sufficient Funding for Research Implementation	Insufficient	Insufficient	Austerity budgets and a lack of legislative and policy emphasis on commercialization.	In the European Union and the United States, not only is overall funding insufficient, but the funding targeted toward research dissemination is insufficient or nonexistent.
Organizational Centralization and Coordination	Some coordination through EU research framework programs	Insufficient	In the United States, the historical evolution of modal administrations has contributed to a lack of coordination. Also, the complexity within specific modes such as FHWA limits coordination.	The United States lacks an integrated national plan for transportation, although Secretary Foxx has committed to developing such a plan.
Comprehensive Data Collection and Analysis	Ex-post evaluation, unable to identify actual implementation of results	Insufficient	Both the European Union and the United States lack mechanisms to monitor programs and evaluate outcomes effectively.	In the United States, until the passage of MAP 21 and the diminishment in available funds, there has not been the political will to develop an effective data collection and analysis process that crosses modes.
Effective Use of Intellectual Property Tools	Insufficient	Insufficient	Neither the European Union nor the United States has fully exploited intellectual property tools.	U.S. transportation modes vary in their willingness to use intellectual tools. Some of the differences relate to organizational culture.

Partially Meeting

Not Meeting

FIGURE 2 Conditions necessary for implementation of research: Europen Union versus United States.

on both sides of the Atlantic. He noted that the Office of the Assistant Secretary for Research and Technology (formerly the Research and Innovative Technology Administration) had been innovative in getting an IP attorney and beginning to think about IP in a new way, but that most authority was in the modal administrations and, therefore, implementation of IP changes was difficult. Munro stressed the importance of taking a systems approach to achieve paradigm change. Transportation could not simply identify individual elements at a reductionist level if it hoped to move forward dramatically.

Lessons Learned from Case Studies of Successful Research Implementation in Europe and the United States

Joris Al and Mark Vandehey

Joris Al conducted the first half of the presentation, explaining that the main body of his and Vandehey's white paper consisted of 13 cases: six from the United States and seven from EU countries. The cases studied research implementation projects across diverse modes, with an emphasis on rail and roads but also covering infrastructure (construction and maintenance), transportation (urban and highway), traffic management (including intelligent transportation systems), and management issues such as life-cycle costing systems. The paper provided specific lessons learned from each case as well as general findings that corroborated those of the first white paper. Al directed participants to the executive summary of the white paper, which relates each of the cases to the main lessons learned.

Method

Next, Al explained the method used in the paper and remarked on some of its limitations. The paper centers on successful cases, and the coauthors began with no predetermined theory. Instead, they took a neutral approach by examining the existing literature and conducting interviews with experts about the implementation of each case. Each case yielded several lessons, which were then consolidated into a list of eight main lessons. Each case was interesting in its own right, Al said, and at the end the coauthors compared the findings from their 13 cases with evaluations by the European Rail Research Advisory Council (ERRAC) and the Transportation Research Board's second Strategic Highway Research Program (SHRP 2) on the uptake of research. Their findings were consistent with the conclusions of the ERRAC and SHRP 2 evaluations.

Al noted the time constraints that the coauthors faced, in that they had only 2 months in which to write the white paper. That time frame would not have been a problem had there been consistent or consolidated information on implementation, but no such sources were available. Rather, the information on implementation was limited and fragmented and therefore took time to gather. In addition, there were no standard terms or definitions. Another limitation Al noted was that the white paper looked only at successful cases, but there are lessons to learn from failures, too. Despite the time constraints that necessitated a somewhat superficial and broad treatment, he said, the findings were consistent among the cases and with the three other evaluations and thus were representative.

Implementation Issues

Al continued his portion of the presentation with a discussion of issues related to implementation. He noted that definitions of research and implementation were not exact. The research in the cases that were reviewed ranged from fundamental or basic research to applied or practical research. Most of the cases fell into the category of practical research, although a few were fundamental research. Similarly, the cases focused on successful implementation, but what defines "successful implementation?" Is it when a piece of legislation is proposed? when a law is put into practice? when a practice is evaluated and deemed a success?

Similarly, there are differences between innovation and research. Innovation is a very different process from research. Innovation usually starts with a solution, which research then validates; research starts with a problem and ends in an innovative solution.

Finally, there was a lot of literature on research but not on implementation, Al said. It is harder to trace an implementation back to the research that created it because there is no clear one-on-one relationship. Therein arises the question of whether the innovation would have been implemented anyway, without the research. Much of the research did end in implementation because it was practical research, but whether the research was efficient is hard to say.

Al concluded his part of the presentation by saying that successful implementation has three constants:

1. Consistent communication,
2. Smooth governance, and
3. Finance and capacity assured throughout the process.

He ended with a chart of implementation strategies that provides researchers with clues as to how to shape their research to improve implementation (Figure 3).

Main Lessons from Case Studies

Mark Vandehey then continued with the second half of the presentation by identifying eight main lessons learned from the case studies. These lessons are not revolutionary concepts, Vandehey said, but it is possible to see their power and impact when several of the lessons are used in one project. When more of these lessons can be integrated into a research project, the project is more likely to end with successful implementation. The lessons are as follows:

1. Stakeholder involvement. Key stakeholders should be involved early and continuously in the process of implementation planning. Stakeholders play a role in communication and are often early adopters, so planning for stakeholder involvement at the outset helps get implementation.
2. Resources for implementation. Resources for implementation should be secured. Researchers tend to focus on the up-front costs of research and not to think about the implementation side, Vandehey noted. SHRP 2 had it right, he said, when it devoted funding and resources to implementation from the outset. The funding should be for activities such as training, pilot studies, and outreach, as well as for staffing resources.
3. Development. Postresearch development is critical. Specifically, technology is often not "market ready." Technology needs pilot testing, but if there is no funding for pilots, the research stalls. In an interview with Neil Pedersen of SHRP 2, Vandehey was told that funding for development should be two to three times the level of research funding to get the research market ready.
4. Early adopters and champions. Early adopters are valuable in getting the word out early and showing the early successes of the research. Early adopters help catalyze more adoption.
5. Overcoming institutional barriers. Researchers should plan to address institutional barriers. Multiple

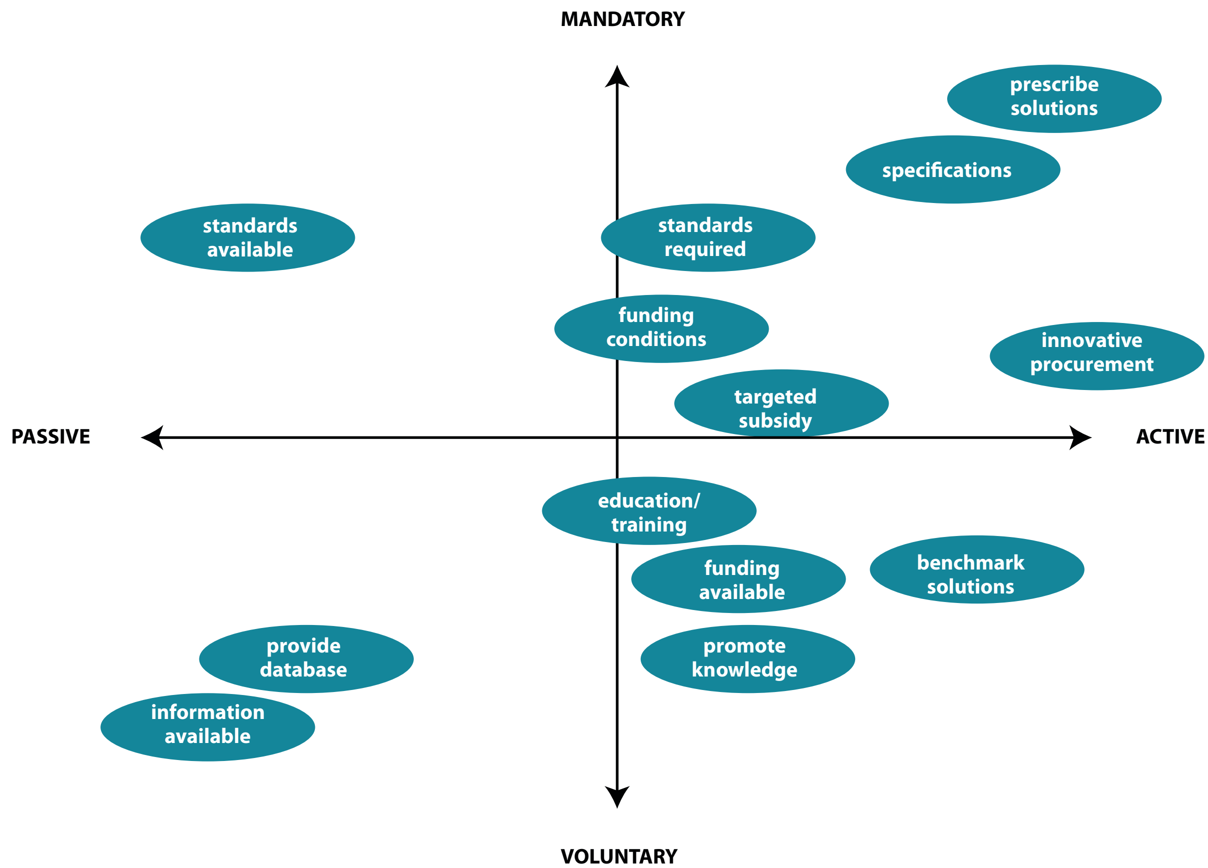


FIGURE 3 Implementation strategies.

layers of approval—policies, approval procedures, standards—as well as procurement rules and regulations come into play. Implementers of successful projects think early on about how to overcome those institutional barriers, and stakeholders can be helpful in overcoming some of the barriers.

6. Government leadership. Government leadership can be valuable as a catalyst for change, to accelerate innovation. For example, FHWA's Every Day Counts program shows the benefits of having the federal government play the lead role in getting innovation adopted.

7. Communication. Communication, both internal and external, should start at the research phase to get the word out and create a pull factor that generates demand and plants the seeds of implementation. Al and Vandehey found many examples of how continuous communication educates the users and the public.

8. Market readiness. Market readiness tills the soil in advance to make it ready for the seeds of research to grow. It is important to get the market ready to implement the research.

Table 1 can be used to delve into the 13 cases in greater detail on the basis of their themes. Because it was found that the more themes a case had, the more likely it was to be successfully implemented, a key lesson for the future is that if researchers want to maximize the chances of successful implementation of research, they should try to incorporate as many of the eight lessons as possible into each research project.

Vandehey ended with some general suggestions for maximizing the impact of the findings. First, all the lessons should be translated into specific courses of action. Second, continuing to develop case studies of success stories can be beneficial because it is hard to find these cases in the literature and because few studies document a project from the start of the research through to implementation. Therefore, developing cases such as the ones in this white paper would be useful. Third, Vandehey suggested developing a primer on best practices for facilitating the research process so that future researchers could have more of a road map to follow and planners could set up their research in a way that would position it for implementation.

Al closed the presentation by saying that the system was a series of components and that it was important to think about how the components fit together. It was also important to note that more funding must be allocated to the development side of R&D. Research is just the start, he said.

TABLE 1 Themes Exemplified in Each Case Study

Case Study	Stakeholder Involvement	Resources for Implementation	Development	Early Adopters and Champions	Overcoming Institutional Barriers	Governmental Leadership	Communication	Market Readiness
European Union								
Asset Management (the Netherlands)					X	X		X
ALJOIN					X			X
INNOTRACK	X		X				X	X
River Information Services	X		X	X	X			
SAMARIS, ARCHES, and CERTAIN		X	X				X	
Silent and Durable Road Expansion Joints (IPW, the Netherlands)		X	X		X			X
Climate Change	X			X		X		
United States								
Highway Safety Manual	X	X			X	X		X
Flashing Yellow Arrow Left-Turn Display					X	X		
Modern Roundabouts	X			X			X	
Warm-Mix Asphalt Pavements		X	X					
Heavy Rail Acoustic Bearing Detector			X	X				
Bus Rapid Transit				X		X		X

Note: ALJOIN = Crashworthiness of Joints in Aluminum Rail Vehicles; SAMARIS = Sustainable and Advanced Materials for Road Infrastructures; ARCHES = Assessment and Rehabilitation of Central European Highway Structures; CERTAIN = Central European Research in Road Infrastructure; IPW = Netherlands' Innovative Road Maintenance program.

Keynote Speech

Transport Research Implementation: What Society Really Needs

Terry Hill

Terry Hill began by saying that he and the symposium's participants share a common ambition for innovation to be an enabler that improves society. He said that during his presentation, he would be direct about the challenges being faced and that he would be thought provoking and a bit radical.

Hill is with Arup, a firm with a staff of 11,000 and annual sales of £1 billion. Thirty percent of the company's revenues are derived within the United Kingdom, and the other 70% is derived equally from the United States, Europe, and China.

The company chooses to invest in research on the built environment. The company has to make the research count because it is a commercial enterprise. Arup is researching low-emission autonomous vehicles, rapid transit, and transportation infrastructure. Hill reflected on the aforementioned valley of death and commented that valleys often contain the most fertile ground.

Infrastructure Projects

Hill noted the massive scale of infrastructure projects. Big infrastructure projects in Europe include the UK's €8.1 billion Channel Tunnel, London's €18 billion Crossrail project, Sweden's €4 billion Öresund crossing, and, in the United States, New York City's $17 billion Second Avenue subway and Los Angeles, California's, $1.2 billion Gerald Desmond Bridge replacement. Infrastructure changes lives and induces transformational change, Hill said. Consider how public health improved after the advent of city sewers, how the U.S. West was opened up by the railroad, or how the city of Malmö in southern Sweden was transformed after the construction of the Öresund bridge. London would not have hosted the Olympics were it not for the High Speed 1 railway that connected the United Kingdom to the rest of Europe by providing high-speed rail service from London to the Channel Tunnel.

International Standards

Hill heads the International Organization for Standardization (ISO), which has 19,000 standards designed to enhance society through the supply of safer and more efficient goods and services. Standards are an enabler of innovation because they develop a common understanding, Hill said. This is particularly important for emerging technology that could otherwise face barriers. That is why standards can make such a difference in creating a common framework for innovation and in setting the rules of the game. Standards create a common vocabulary and identify essential characteristics and best practices.

Construction Industry

Hill said he began his presentation by listing how much large infrastructure projects cost because he wanted to underscore the point that it is costly to make these transformations. It takes billions of dollars to do so. Why do such projects cost so much? Is it a fundamental truth that big infrastructure must be costly, or should society challenge that assumption? The majority of the cost of big infrastructure is in the construction—80% of the costs are construction costs, and the remaining 20% are the system costs. Is it reasonable for construction to cost so much? Worse, construction costs show no downward trend, which is remarkable, given how costs come down in other sectors, such as technology.

Construction is an unfortunate necessity. It is not sophisticated, and it is very expensive. In 2010, Hill was asked by the UK government to investigate the construction element of infrastructure. The United Kingdom has one of the safest construction industries in the world, but it has not achieved cost reductions.

One of the UK government's goals in 2010 was to achieve a 15% reduction in construction costs. To do so will require five actions:

- Publication of a pipeline of projects among which to invest;
- Identification of funders and delivery agents by governance, to ensure that there is a single controlling mind;
- Discipline;
- Appropriate standards; and
- Performance criteria.

One way to ensure that standards are appropriate is to encourage derogations and to use a red–amber–green approach to rating which standards are required. That is, if a standard is red, it is mandatory; if it is amber, it is advisory; and if it is green, it is simply illustrative of how something could be done.

Finally, it is important to ensure that construction projects are fully designed before they are built. Hill also stressed that procurement needs a more risk-based approach that looks at the total supply chain to reduce costs. If those actions were taken, then the construction industry would have confidence to invest in training, research, and innovation.

Will this fivefold program result in a sea change in construction research? The consequences of overly expensive transport infrastructure projects are serious. Infrastructure is political, and funders are forced to be risk averse. We have to figure out why politicians, funders, and bankers are all nervous about the costs of infrastructure, Hill said.

All stakeholders have to control the risks, because the consequences of risk aversion are serious, primarily because the first response to uncontrolled risks is simply not to invest in infrastructure at all because of the risks and high cost. However, avoiding investment in infrastructure means that all of society suffers. The second consequence of risk aversion is that much-needed projects are delayed for decades. The Crossrail project was first identified 50 years ago, but the €18 billion cost delayed it. "Perhaps the only way you get to invest in infrastructure is if your city hosts the Olympics," Hill joked. Third, risk aversion means that when the investment finally takes place, it is too little too late. The investment is undertaken because there are no alternatives and citizens finally call for action, but the solution is suboptimal. Finally, investment is undertaken, and jurisdictions try to squeeze greater performance out of existing infrastructure that is already overloaded.

The construction industry has not yet had its revolution, as has the aerospace industry with its jet propulsion and fly-by-wire, the pharmaceutical industry with its stem cell research, or the automotive industry with its onboard computer management and fuel and emissions efficacy. The oil and gas industry has had revolutions in offshore extraction and hydraulic fracturing. Even the food industry has had a revolution with genetically modified organisms, or GMOs. True, there have been some construction industry advances, such as low- or no-energy buildings, better tunneling, and higher skyscrapers, but these advancements are incremental rather than game changing, which forces private companies and the public to make do or to make patch solutions.

Compared with other industries, the construction industry is the biggest of all in terms of revenue or employment, but it is the least affected by the technological revolution. The construction industry is still stuck in the industrial revolution, mid–twentieth century era of internal combustion engines. The digital revolution has hardly affected it. Why? The root cause is the fragmented nature of the industry.

Consider other industries, which have large, dominant players, Hill said. If the European Commission wants to speak to the automotive, airplane manufacturing, or drug industries, there are a few key players to contact. The major work of building an airliner or a new car or drug is undertaken by the private sector. The scale of building an offshore oil platform is the same as building a big bridge, but the oil industry is able to handle it privately through megacorporations that assess the risk and manage the project. The problem with the construction industry is that the bulk of the work is carried out by small and medium-sized enterprises (SMEs). For example, in the United Kingdom, there are 300,000 construction firms with an average employee headcount of only seven, Hill said.

The construction industry should be dynamic and light on its feet, because SMEs are at the heart of innovation, but SMEs are not designed to take on large construction projects. No existing construction company could take on the risk of a large infrastructure project. There is high project cost but a low capital asset base and risk-averse funders. There are huge upside innovation benefits but only small players to deliver them.

The solution, Hill said, is that we have the risk allocation wrong. Construction needs help and cannot just pass the risk down the supply chain. Commissioners of projects must share this risk. There is a need for smarter procurement by highly trained experts who incentivize innovation, and a need for large companies rather than small companies that are only hired for one local construction job. Construction companies do not have the stable structure that the automobile industry has, for example, with its original equipment manufacturers and Tier 1 (direct) suppliers to manage it.

Research and Innovation

Research and innovation should be allowed its serendipity and some failure, Hill said. A recent article in the *Economist* magazine ["Rise of the Robots," March 29, 2014] shows the three positive factors for advancement: easier R&D, imagination, and investment. José Viegas, who recently spoke at a European Commission meeting, described condition-aware infrastructure based on sensors, such as are common in the aerospace industry. When a jet engine needs attention, it sends a signal back to the manufacturer that it needs repair. The same can be done with remote monitoring of infrastructure.

Harvard's Justin Werfel is developing distributed autonomous control rules for self-building infrastructure. What is the revolution that may happen? The advancements could make infrastructure safer, green, and smart. Then politicians would champion it and not be wary of it, Hill said.

In 2010, the United Kingdom targeted a 15% cost reduction through governance and smart procurement. With Construction 2025, a joint strategy of government and industry for the UK construction sector, the United Kingdom is targeting 50% greener, 50% faster, and 33% cheaper construction projects.

Achieving the Construction 2025 targets cannot be done by doing the same things we do now—we need to do new things, Hill said. Without research and development, infrastructure will have to be built the old way: high carbon, low innovation, and high cost. Big construction is risky. Innovation in construction is constrained by the risk aversion of governors who want the tried and tested old techniques because of a failure to invest in research. When one looks at the percentage of an industry's total revenue that is invested in R&D, construction is not even listed in the table. It is the biggest of all industries but does not invest in research. Infrastructure construction does not have private financing. Coordinated and directed research is needed to avoid overlap, Hill urged. Big innovation projects are too daunting for individual companies, so innovation is inhibited and there is a fear of legal challenges. The market needs unlocking, transparency, and innovation, Hill concluded.

Discussion

John Mason opened the audience discussion of the three talks by saying that the goal of the dialogue was to enhance the implementation of the research and that regardless of one's position as a researcher, funder, or implementer, enhancing the return on research funding and improving the infrastructure was of interest to all.

Bill Millar asked Joris Al to say more about Table 1 and Al's comment that the way to increase the opportunity for success was to fill in more of those spaces.

Joris Al replied that through the white paper research, it became evident that the more of these key elements were in the research project, the more likely the project was to be implemented. The elements serve as accelerators, so when more of the elements can be strung together—for example, putting resources toward implementation early on, getting adopters involved early on, and starting communication early—implementation is more likely to take place. He added that he was looking forward to the upcoming presentation about SHRP 2 the next day because he had attended one of SHRP 2's implementation workshops and seen that they were thinking about the majority of these elements, and so he was interested to see how successful they had been.

Patrick Malléjacq added that research results must be disseminated but that it was not easy to promote what you had just achieved. Transnational projects on road research need reports and conferences to push the results to the end users and to gain peer pressure for implementation. Risk aversion is certainly present in France with regard to funding the road sector, he continued, because if the innovation does not work, the implementer will be fired. He wondered how to mitigate risk. The insurance industry may offer a model for how to handle the risk, he suggested.

To Malléjacq's first point, **Al** answered that much of the dissemination of results comes from the research side and not from the implementation side. However, researchers need to disseminate what the implementer needs, not what the researcher needs. The Innotrack example described in Al and Vandehey's white paper made that clear. All 50 products were directed at dissemination.

Francesca La Torre, a professor at the University of Florence, Italy, explained that she is a researcher and also a designer. As a designer, she wants innovation, but she has to convince road administrators to implement the innovation. She wondered how to improve this development chain, so that when a research team produces a good innovation, there is opportunity to push it forward to a larger scale.

Terry Hill answered that the researcher has to be tough and loud, but there are obstacles. For example, in London, the biggest highway project will focus on improving the existing infrastructure, namely, widening and upgrading the M25 motorway around London. The standards were set, but then an innovation arose in the form of composite materials. The innovation was stopped, however, because it did not comply with the specifications. For each administrator, it was "above my pay grade," even though the benefits of the new material were huge. The innovators had to push higher and higher in the hierarchy, finally up to the minister, who gave the go-ahead for the new material, which ultimately saved £200 million.

Hill then had a question for Munro, who had wondered why the public sector was not taking out patents. It is assumed that if a company gets government money, it is not allowed to have IP rights. Hill pointed to what happens in other sectors, such as finance and retail, which do massive amounts of research but do not publish the results or even get patents, because doing so would require disclosing the innovation. They do the research themselves for their own benefit. Hill agreed that IP rights were a constraint. He was in favor of public and joint funding to generate IP, and he saw a need to work out how to protect IP so that researchers and implementers could benefit while allowing the public to benefit from the investment of public funds.

John Munro added that if a project is developed with public money, it has to stay in the public sector, so there is a hesitancy to issue exclusive licenses and a reluctance to change the IP regime. In the historical development of the federal highway program in the United States, the U.S. DOT has been a distributive agency that distributes funding to states as the primary customers. The U.S. DOT has not embraced the marketplace. It continues to be a fundamental obstacle for market mechanisms to promote innovation. The IP issue is also a constraint on measuring research outcomes, because IP and revenues from IP licensing would be an easy way to measure and monitor research outputs. Outcomes would be easy to track if there was a payoff from the research. At best, there are discrete case studies that evaluate and monitor an implementation, but there is no broad vision of how to incorporate the market into the process. The United States is a capitalist nation, and some citizens complain about the encroachment of government, but in this case the government does nothing to utilize the market in an effective way.

Beverly Scott said that too often in research, "we have a conversation with ourselves." She urged researchers to think broadly in order to get public support.

Liam Breslin of the European Commission appreciated the comparison of the construction industry with the aerospace industry. The aerospace industry uses composite materials and structures with sensors built in to detect minor cracking; if cracking is detected, a signal is sent back to the manufacturer to alert them to do maintenance. He also praised Munro and Aparicio's paper, elaborating that he works with Damiani in the European Commission on formulating research programs. One of the problems the European Commission faces is being so busy with running a new program that it lacks the time to revisit the implementation of previous programs. He detailed that within Horizon 2020, there will be 600 new research proposals that have to be evaluated in 3 weeks, and then the follow-on projects will be negotiated. He noted with regret that he funded very good projects 8 or 9 years ago that are delivering results, but that he lacks the staff to see what needs to be done for the projects' implementation, so it falls on the consortia to follow up on implementation. In the automobile industry, he pointed out, companies know what they need, and when the research is done, companies are ready to pick it up; in transportation, however, there is no industry to pick up the project.

Munro agreed but said it went back to setting up a system of IP in the United States and European Union that would provide incentives for the private sector to implement the research in exchange for an exclusive license. The current belief is that if one does not keep the research open, one is not upholding the public trust; however, if the government got the IP, licensed it, and gathered revenue from it, then it could reinvest the revenue in further research. Such an approach would be especially beneficial as budgets decrease. The salient licenses could be auctioned off, as NASA does, as a way to generate revenue for research. Doing this would provide opportunities, Munro said, if the transportation industry were willing to do a paradigmatic shift. IP is a core condition, in that a systematic way to manage IP across modes and within modes should be developed. American universities and NASA have centralized IP management, and the transportation sector should consider doing so as well.

Phillippe Citroën of the Association of the European Rail Industry (UNIFE) said he sees reasons to be optimistic. The European Commission has, in 3 years, built the Shift²Rail initiative and discovered that public–private partnerships can be a useful tool. Industry is ready to match the €450 million funding put in by the public sector, which will bring the total funding for the initiative to €920 million for 2014–2020. Operators, infrastructure managers, and universities have been able to do cooperative projects together and be as close to the market as possible. The rail industry has to be more competitive, especially to face Asia, he said.

BREAKOUT SESSION 1

Stakeholder Perspectives on Implementation

Alessandro Damiani, *Directorate-General for Research and Innovation, European Commission, Brussels, Belgium*
Francesca La Torre, *University of Florence, Florence, Italy*
Harold (Skip) Paul, *Louisiana Department of Transportation and Development, Baton Rouge, Louisiana, USA*

In the first breakout session, symposium participants divided into three groups: funders, researchers, and implementers–users. Each group discussed the three questions of the conference:

1. What are the driving elements in successful funding leading to deployment of innovative solutions?
2. What are the impediments to the application of research outcomes?
3. What are the factors that are inhibiting transport research from being deployed into real transport systems?

Funders' Breakout Session

Alessandro Damiani recapped the discussion from the funders' group's five key points:

1. Involving stakeholders from the start,
2. Involving researchers in the deployment of the research,
3. Emphasizing the policy context,
4. Recognizing the importance of communication, and
5. Using loans or equity resources to bridge the valley of death.

First, involving stakeholders from the start is essential in the process of identifying priorities and drawing up the research agenda. Facilitating a close-knit partner community of funders and researchers is of paramount importance in this process. The risk of involving industry and end users is that these groups tend to look at things incrementally. That is, few of them have a broader, holistic view that includes disruptive innovation. Stakeholders need to have more vision, and the way to accomplish that could be to have a coalition that works together, such as the European Technology Platform. By working together, stakeholders could achieve a vision collectively and overcome the obstacles of the incrementalist view.

Second, on the topic of stakeholders, researchers talk about stakeholder involvement, but the question is, who are the stakeholders? It is actually a complex picture requiring several different stakeholder profiles. How can stakeholders be encouraged to take risks and be prepared to share risks? Some participants suggested involving stakeholders in setting priorities and in the research process. Stakeholders should be involved in setting priorities, but researchers likewise should be involved in the deployment of the research. In short, users should be engaged in and with the research teams, and researchers should be engaged in deployment, as it is not a linear process. For example, Transport for London mandates that research projects have a sponsor in order to obtain funding.

Third, the funders' group emphasized the policy context, that is, political stability, the long-term policy perspective, and the importance of a sound regulatory environment. The obstacles to creating an innovation-friendly policy environment include the lack of enabling legislation, standards, and general political uncertainty. There is a need to fund research to reach standards and to affect legislation so that legislation and standards are innovation friendly.

Fourth, the group discussed the importance of communication, not just to disseminate success stories but also to raise public awareness and nurture a culture of innovation. Researchers need not just to define the beauty of the research but to redefine the research in terms of having a solution to a problem rather than having a good research outcome.

Fifth, some in the group suggested that bridging the valley of death was important, perhaps through loans or equity resources. One way to achieve this goal could be to link research funding with implementation funding, so that the funding does not stop at the doorstep of deployment. For example, there could be implementation agencies that operate alongside research agencies. Distinguishing between demand-driven and supply-driven loans could be another way to facilitate funding over the valley of death.

Procurement and IPR also drew attention from the funding group. Procurement, which is based on the lowest-bid practice, can hamper innovation. Public procurement of innovation is a good practice that would encourage risk-sharing among procurers. There is a need for procurement to be based on performance rather than on compliance with technical standards. IP rights need to reconcile the need for openness (for public benefit of the public investment) with protection of IP so that partners can invest to commercialize the innovation.

Researchers' Breakout Session

Francesca La Torre reported on the researchers' breakout session, noting that the researchers asked themselves six questions:

1. Are we delivering implementable research?
2. Do we contribute to the implementation of our research outcomes?
3. Are we satisfied with our research outcomes and output? That is, do we focus only on the output of the research or on the outcome of the research?
4. Are we selling the new solutions, that is, evaluating new solutions and proving their effectiveness?
5. Are we really considering implementation when conducting our research?
6. Do we consider only academic recognition rather than successful implementation of our research? For most academics, the measure is academic recognition, although that priority is starting to change.

The researchers also made the point that implementation does not simply mean a demonstration or a pilot project, but actual implementation in real-world situations.

Three Types of Research

The research group then made a distinction between three types of research: basic, development, and implementation research (Figure 1):

- Basic research is driven by and conducted by researchers (as opposed to end users) and includes blue-sky, or visionary, thinking. Basic research may have some contribution from end users, but it is primarily research driven.
- In contrast to basic research, development research is driven by end users and conducted by researchers. It gives the mortar that pulls together different existing projects to produce end results that the end user needs.
- Implementation research is driven and conducted by the end user (manufacturers and contractors) and

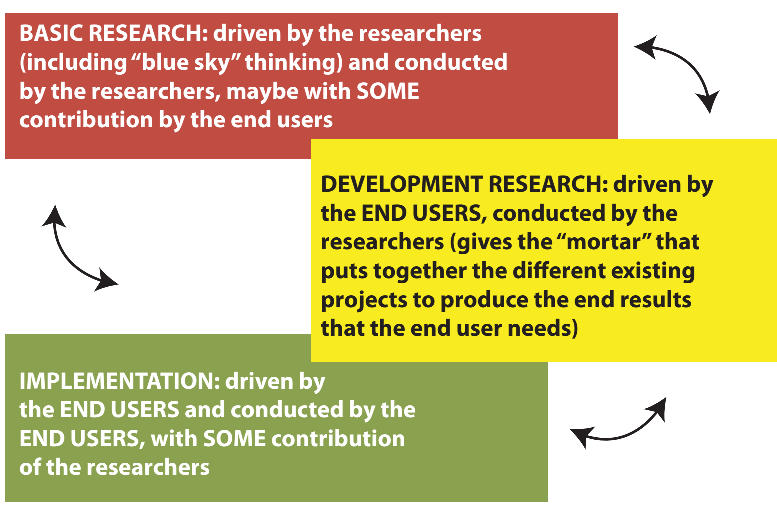


FIGURE 1 Types of research.

validated by researchers. Therefore, researchers make some contribution to implementation research, but it is primarily driven and conducted by end users.

Key Points

Next, La Torre described the 10 key points that arose from different participants in the breakout discussion. In no particular order, the points are as follows:

- Researchers need to be free to do blue-sky research. Researchers are researchers, and they need to be free to create innovation.
- There is a need for funding for the implementation of research, not just the research itself.
- Research is most likely to be implemented if there is a linkage of projects; that is, the plans for implementation ideally begin when the research begins, and implementation continues to overlap with the research. If it is not possible to begin the implementation at the time the research effort begins, then the research project should at least be linked to the implementation project.
- Two of the elements that support research that leads to implementation are allocating researchers to the implementation and having demonstrations and pilot tests. In addition, publicizing the implementation and making it visible to the public also help, because the public will be judging the project.
- Some noted that the implementation process is not linear and that a systemic approach that looks at both research and implementation in depth would be helpful.
- Certain members of the group suggested that the implementation strategy be made part of the scope of the research project and included in the work package to ensure that the implementation gets done.
- Others in the group suggested awarding final payment on a research project only after "the end user is convinced of the utility of the research product in practice," which may mean waiting some time after the project, even years.
- Some in the group thought that requiring third-party evaluation of the research implementation could be beneficial.
- A few in the group suggested including the cost-effectiveness of the research and identifying possible deployment issues to help the implementation.
- Many in the group stressed the importance of disseminating research outside the research community, to decision makers and end users.

The researchers' group then discussed five points that they would emphasize above all others:

- Monitoring research outcomes for a sufficient length of time at the end of the project;
- Funding implementation;
- Providing incentives for manufacturers to do research, which independent researchers can then validate;
- Changing IP rights so that IP does not go to the funding agency but could go to manufacturers that would implement the research; and
- Educating all stakeholders (e.g., designers, contractors, and decision makers) on the processes and tools needed to help implement transportation research.

Discussion

Discussion of these points was then opened to symposium participants. **Jesús Rodríguez** commented that there is a need to change the way academics are evaluated. Often, academics are not interested in participating with industry because they are not evaluated on implementation. In Europe, he said, it is normal to be a researcher and then to go to work for the end user for which the product of the research was intended. He suggested that this researcher–to–end user model could be one to follow.

Implementers–Users' Breakout Session

Harold (Skip) Paul reported on the implementers–users' breakout session, which covered the following topics:

- Risk and procurement rules as impediments to the implementation of innovation,
- The need to drive innovators to be interested in transportation, and
- Stakeholder involvement.

Risk, an impediment to the implementation of innovation, can be addressed by giving implementers political cover for potential failure. There need to be ways to reward taking the risk of implementation or to spread the risk around. A change in public demands can be advantageous because it can allow innovation to be deployed. For example, the second Strategic Highway Research Program (SHRP 2) looked at innovations that existed but were not being used. SHRP 2 validated innovative ideas. With that validation, risk was reduced. SHRP 2 was initiated by 10 chief executive officers from lead states looking at soft-side issues. Because SHRP 2 was a national program, the states had political cover to explore the innovations; that is, they could say, "We need to do this because it is a federal program," and thus had an excuse to make the leap to implementing the innovation. More risk could be taken. Risk was also mentioned as a problem for industry because of the possibility of failures. Operators often have to risk failure to get innovation. It is important for research commissioners to understand that it is okay to fail.

Second, procurement rules sometimes impede innovation because they focus on the lowest initial cost rather than on the overall life-cycle cost. Procurement rules make it harder to implement innovation because innovation may have a higher initial cost but a lower life-cycle cost because of aspects that the innovation offers, such as reduced maintenance costs. Also, when the case for using life-cycle costs is made, it is important to have valid measures that are performance based.

Third, there were those in the group who wondered what was different about industries such as the defense, aviation, and pharmaceutical industries, which spend huge sums on innovation. Although transportation is typically the second-highest budgetary expenditure, transportation is not always seen as essential. Transportation infrastructure is not considered to be an innovative, cutting-edge area. There is a need to drive innovators to be interested in transportation. Perhaps attracting players such as Google to the industry or engaging in more marketing to raise the profile of transportation would be helpful. With respect to defense, aviation, and pharmaceuticals, size also matters.

Finally, a predominant theme from the implementers' discussion was stakeholder involvement in deployment, because implementation is about end users. For example, for rail projects to succeed, commissioners needed to know that operators were on board. Involving stakeholders can shorten the time to acceptance.

SESSION 2

Institutional Incentives and Disincentives to Successful Implementation

Ann Brach, *Second Strategic Highway Research Program, Transportation Research Board, Washington, D.C., USA*
Steve Phillips, *Conference of European Directors of Roads, Paris, France*
Michael Trentacoste, *Turner–Fairbank Highway Research Center, McLean, Virginia, USA*
Liam Breslin, *Surface Transport Unit, European Commission, Brussels, Belgium*

Institutional Program Experiences Addressing Research Implementation

Ann Brach

Ann Brach explained that she would reflect on the lessons of implementation in the second Strategic Highway Research Program (SHRP 2), an applied research program, as well as in the first SHRP program.

SHRP 2

The key lesson from SHRP 2 was on the importance of specific strategic objectives—real-world needs—that drove the research agenda. The important point, Brach said, was that there was an overarching agenda, not just a set of individual research projects. She stressed that implementation is very context dependent and people oriented. In particular, implementation depends on investing time and money in development and creating a culture of innovation.

Brach outlined the basics of the SHRP 2 program, which is almost at its completion. The program was authorized by the U.S. Congress in 2005 and was a short-term, focused effort with $223 million allotted for the R&D phase. This program has a duration of 9 years and will end in March 2015. The program is governed by stakeholders and has more than 50 committees and 500 committee members. SHRP 2 is a contract research program that has awarded 131 contracts to more than 400 research organizations. To date, the program has delivered 300 distinct deliverables that are packaged as 60 products.

The strategic objectives were key to the program's success. The objectives were identified by state departments of transportation (DOTs) and industry leaders who wanted to focus on customer-oriented goals. The objectives of SHRP 2 were to make highways safer (through revolutionary change by conducting a study of unprecedented scale to understand driver behavior); to fix the aging infrastructure of highways without causing undue delays to drivers (renewal); and to reduce congestion by increasing physical and operational capacity.

In contrast to SHRP 2, the first SHRP program focused on materials and operations, such as the quality of asphalt pavements, deterioration in concrete structures, and snow and ice removal. Thus, the first SHRP program focused more on agency costs and savings, while SHRP 2 focused on end users.

Rationale for SHRP 2's Four Strategic Priorities

Next, Brach described the strategic rationale of each of SHRP 2's four focus areas: safety, renewal, reliability, and capacity. In the safety area, the biggest challenge was highway fatalities and injuries. In the United States, more than 30,000 people die annually on highways. That figure would be well over 100,000 were it not for the safety improvements already made, on the basis of the increased number of vehicle miles traveled. Nonetheless, the figure is still too high. Driver behavior is the primary factor in most crashes and a contributing factor to almost all crashes, yet the driver is the least understood factor in these crashes and is the hardest to study. Therefore, SHRP 2 decided to make a revolutionary improvement in highway safety by focusing on the driver to gain knowledge of driving behavior and interaction with the vehicle, roadway, and environment. Specifically, SHRP 2 saw the opportunity to do a naturalistic driving study by recruiting volunteers who agreed to have a variety of data-capturing instruments installed in their cars. The miniaturized sensors were inconspicuous but had computing capacity that allowed for the capture of real-world driving behavior. The sensors enabled the recording of drivers in their native habitat and delivered objective data on what happens before a crash, during a crash, or when a driver avoids a crash, as compared with normal driving.

The next SHRP 2 focus area, renewal, has examined the state of aging infrastructure, both of the Interstate highway system and of other roads. Facilities are aging, but users and the economy depend on them, so the infrastructure cannot simply be taken offline to be repaired. Rather, the infrastructure needs to be renewed quickly, with minimal impact on users, and in a way that produces long-lasting facilities. Most states have devised fixes, so there is knowledge about how to carry out isolated projects but not systemwide projects. The goal of this strategic priority, therefore, was to provide tools to enable rapid systemwide renewal of infrastructure for ordinary projects by addressing the lack of standard methods and specifications and the lack of reliable performance information and by dealing with human and institutional challenges such as risk and worker fatigue. Having standards and specifications will help states adopt a new practice or identify a successful practice from elsewhere. Similarly, to address topics such as fatigue, the transportation industry can look at how other industries have tackled these issues. For example, in the health care industry, nurses performing shift work face severe fatigue issues.

The reliability focus area looked at travel time and the issue of congestion that happens with nonrecurring events. The objective was to provide agencies with knowledge and tools to systematically improve travel time reliability. The tactics addressed the need for data, performance measures, monitoring methods, analysis and modeling, and planning and design tools. In particular, the tactics included integrating information on the ordinary processes that state DOTs use and the institutional issues of running a system to be more operations oriented. This focus area dealt with a wide variety and high volume of data, and the area's emphasis was more on management and institutional work than on engineering.

The capacity focus area dealt with another aspect of congestion: the difficulty in obtaining approval for new capital projects that would increase capacity and in getting those projects built. The biggest impediment to increasing capacity through new construction is not a lack of knowledge about how to build a highway, but the lack of agreement among people with regard to economic, environmental, or community goals, especially across state lines. In short, the issue is one of people and institutions. The decision-making process requires that people have the right information (e.g., knowledge of the highway planning and permitting process) at the right time. The information must be available and transparent. Transparency will speed the approvals process, because people will not have to revisit questions or be confused about the roles of the multiple players. One outcome in this focus area was a web-based system to help a state DOT work its way through the capacity and project approval processes and keep track of its decisions.

Context Is Important

Brach next talked about the importance of context. Whereas basic research can be done in a vacuum (the more basic the research, the more it can be done in a vacuum), research that aims for implementation in the real world needs to take into account the economic, cultural, institutional, political, and technological contexts into which the innovation will be introduced. For example, in the first SHRP program, one research outcome was the development of a new asphalt, but then contractors in all 50 states who were part of the asphalt paving industry needed to be involved before the innovation could be implemented. In SHRP 2, the capacity focus area had to deal with political and institutional issues. Some states will adopt a new approach, while others have reasons or misconceptions that make them reluctant to adopt it. Those states will not adopt the new practice until they are convinced by their peers in other states that the new approach works and is valuable. For example, some states are reluctant to work with the U.S. Environmental Protection Agency, so they need to learn from other states how the process works.

Brach also noted that sometimes the innovation is in the context itself. That is, taking isolated technologies and plugging them into the context will be incremental innovation. In contrast, asking people to change their context or to organize themselves differently would be a step-change innovation that might be disruptive. The latter situation is an example of innovating the context itself. For example, the first SHRP program developed a new approach for snow and ice removal. The change was not simply to use a better kind of salt, which could have been plugged into the existing system. Rather, the new approach required pretreating and different positioning, so it required a different thought process rather than a simple substitution of a new salt. Similarly, in SHRP 2, the reliability focus area has worked on business practices and a phased approach to creating an operations-focused state DOT. Changes cannot be implemented if the DOT will not innovate its institution, so SHRP 2 is helping state DOTs do that.

People Are Important

Brach added that just as context is important, so are people. Potential users will be more likely to implement an innovation if they have heard about it from a colleague or from one of their direct reports. They will not implement something just because of a slick sales talk. Users want to hear from their pavement engineer, for example, that the innovation will actually work. The greater the risk of implementing the innovation, the greater the need for people to trust the person who is promoting the innovation. Therefore, the first SHRP program tackled the need for buy-in of innovation by using the lead state approach, in which the states who were early adopters of an innovation told other states about their experiences with that innovation at a conference sponsored by the American Association of State Highway and Transportation and Officials (AASHTO) and the U.S. Federal Highway Administration (FHWA).

In SHRP 2, the Transportation Research Board (TRB) and AASHTO hired respected state DOT leaders to spearhead implementation efforts, because doing so was considered to be more effective than having staff from Washington, D.C., or researchers perform that function. Implementation is more empirical than theoretical, Brach said. Potential users need to see the innovation in use and be able to interact with it or test it themselves, not just read about it. That is why pilot projects and demonstrations are vital. In SHRP 2, the renewal, reliability, and capacity focus areas are using pilot projects and demonstrations. Workshops are also important, and SHRP 2's safety focus area is conducting workshops on using the project outcomes. Finally, it is essential for potential users to travel and have opportunities to talk with others and see how innovations work.

Idealized Linear Process

Brach discussed the idealized linear process of how research moves to implementation (Figure 1). The assumption implied in this idealized view is that research produces ready-to-use products. Brach posited that development may be a missing link in this process (Figure 2). In her opinion, research does not produce ready-to-use products. "They're not shrink-wrapped solutions," she said. Therefore, after the research phase, during which study and experimentation lead to developing new knowledge, tools, and methods, a development phase is needed. The development phase includes lab tests, field tests, modifications, market research, creation of ancillary tools, and technical assistance before the concept is marketed to users.

The development phase is not trivial; it takes time and can cost several times more than the research phase. The development phase is perceived as less creative, but in fact it requires a different kind of creativity. This phase also shows the weak points of the research results, which researchers do not always want to see, and it requires confrontation of realities that may contradict original beliefs or circumstances. However, the development phase is necessary to address the context and people.

Culture of Innovation

Brach concluded with a discussion of the culture of innovation. Culture is ingrained in people and is built up over time and passed on through generations. Therefore, building a culture of innovation takes time, but the culture will endure.

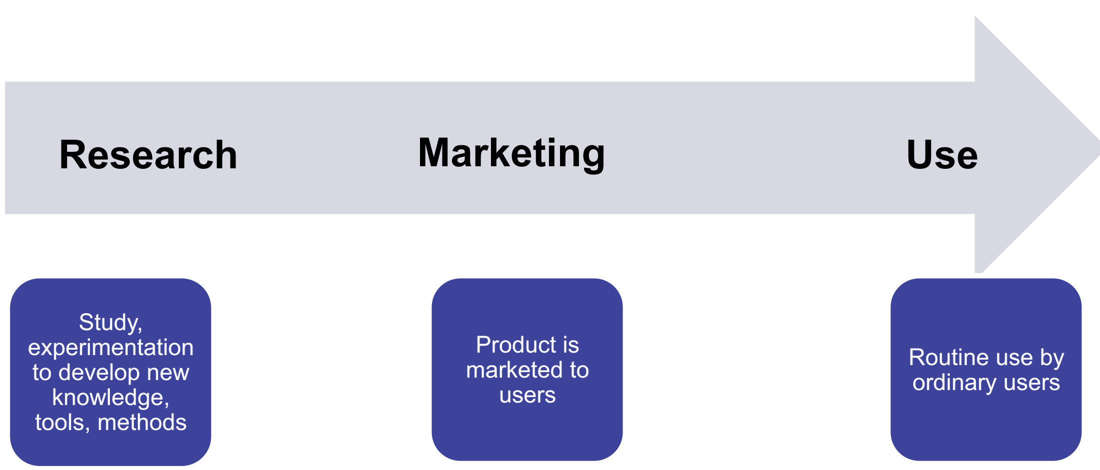


FIGURE 1 The idealized linear process. Implied assumption: research produces ready-to-use products.

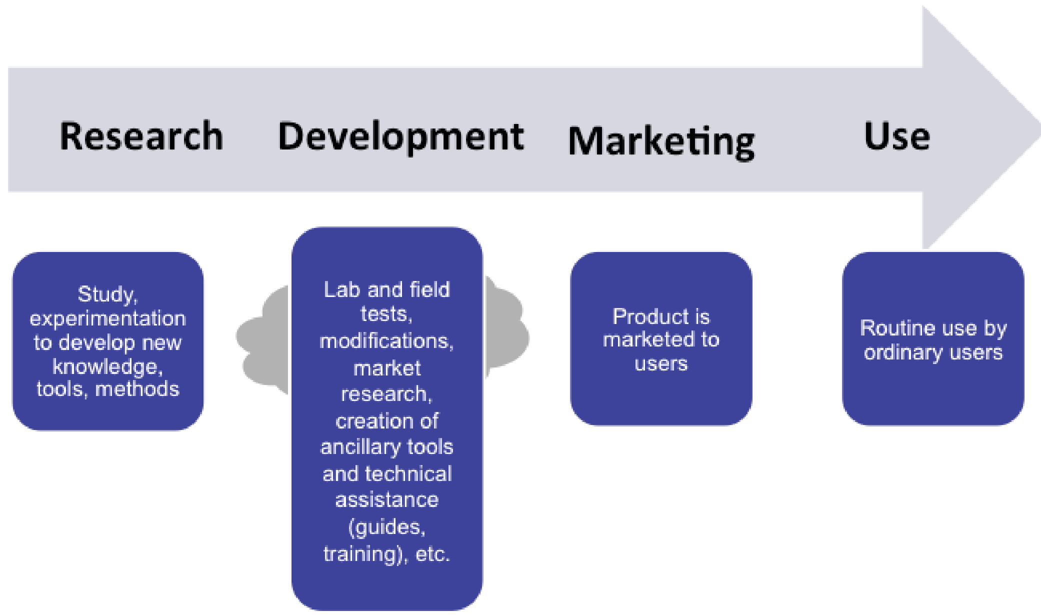


FIGURE 2 The missing link.

Building a culture of innovation requires respecting how people learn; both theory and practice are needed. Brach suggested putting the best people into development and being grateful that they "sweat the details," because that is how to move products correctly into practice.

Some of the key points to understand about building a culture of innovation are that the process is multistepped, iterative, and sometimes unpredictable. There will be failures, but they should be treated as something to learn from, not as shortcomings that require punishment. Another important point is funding activities such as pilots and demonstrations so that the innovation can be tested, which will help it get implemented and be used. Finally, although funding of travel for key staff may be politically difficult to achieve, it is important so that they can talk openly with their peers. People often do not write or publish information about how an implementation failed or how a product failed to live up to expectations; they are more likely to discuss a product's shortcomings during informal conversations. Sharing such valuable information will help get innovations implemented.

Building Research Programs for Deployment: Road Authorities Working Together

Steve Phillips

Steve Phillips began by providing background on the Conference of European Directors of Roads (CEDR): how the program was built, its funding instruments, and its outcomes. CEDR does not have all the answers yet with regard to building a research program geared toward deployment, he said, but it is achieving successes.

Conference of European Directors of Roads

CEDR is a nonprofit foundation based in Paris. Its membership comprises 27 European directors, and its presidency rotates annually. An interesting challenge that the organization faced has been how to get road directors to work together. CEDR's mission encompasses six main issues:

1. Looking at what is coming in the future;
2. Creating a network of personal contacts among road directors internationally (innovation will not happen without a network that involves people talking about the innovations they have tried);
3. Being a platform for understanding and responding to common problems;
4. Developing a strong involvement in EU developments on matters relating to the road system and its infrastructure;
5. Using existing representation in relevant international groups for the future benefit of other countries, regions, and organizations developing standards (many countries in Europe are involved in standards bodies, but coordination is lacking; CEDR can provide some of that coordination and can give its members an opportunity to resolve their issues before getting into discussions on standards); and

6. Making use of the results of common (cross-national) research as well as the research results of each member country, which is necessary for implementing innovation.

Before the founding of CEDR, road administrators across Europe were looking at common research to identify research needs at the European level. The needs were presented to the road directors, who then looked for local funding. To move forward, however, there was a need to professionalize the approach for selecting research projects for funding and to make that approach more recognized, which is how CEDR and the European Research Area–Network (ERA-NET) got their start and support from the European Commission.

ERA-NET Road Research and ERA-NET Plus Infravation

After 2003, when CEDR was formed, the ERA-NET Road Research project (ERA-NET ROAD) lasted from 2005 to 2011. After that, CEDR continued with its own common procurement of research. Next, Infravation, an international cooperative infrastructure innovation program, was launched in 2014.

ERA-NET ROAD 1 (ENR1) cooperation (from June 2005 to March 2009) was financed by the European Commission, which gave funding to the 11 different partners of the project to develop common tools and common ways of working.

ERA-NET ROAD 2 (ENR2), also financed by the European Commission, continued on after ENR1 and committed to use 10% of the National Roads Authorities' research budget on transnational collaborative research by 2013.

ENR follows a four-step process to identify research needs (Figure 3). The first step is to see if the research has been done elsewhere and, if so, to determine its relevance and whether it can be used. If previous research on the topic is nonexistent or irrelevant but the need for the research exists throughout the European Union, then the European Commission might fund it. If the existing research is only applicable for some countries, then those countries can fund the research jointly. This collaboration approach reduces duplication of research. Previously, each road operator worked independently with its own research labs in its home country, a practice that led to much duplication of effort.

Three other aims of collaborative research are to provide for an exchange of knowledge, improve the quality of research to identify international best practices, and provide better value for the money invested. The quality of research also improves when there is an element of competition. One country funding its own research does not drive competition. Moreover, by pooling their research money, countries can fund bigger projects and get more bang for their buck, Phillips said.

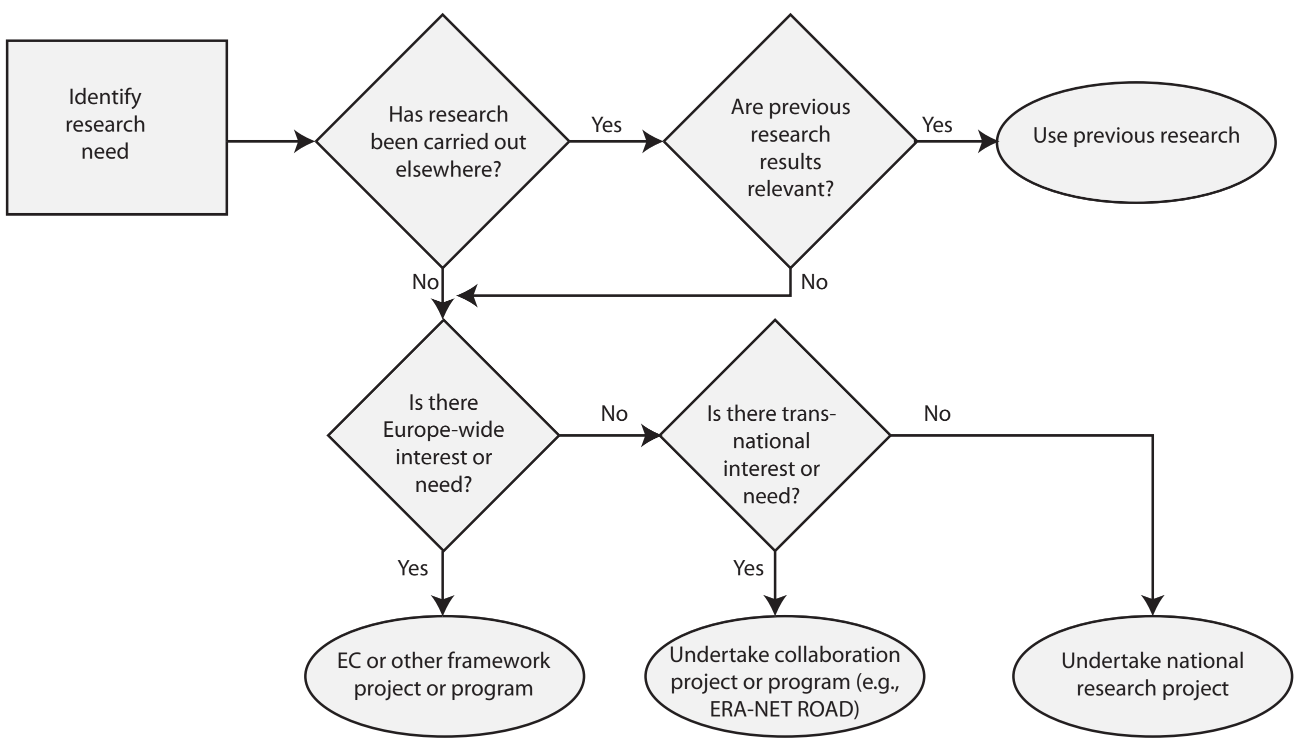


FIGURE 3 ENR four-step process. (Source: CEDR.)

The main ENR tasks were to develop toolkits (namely procedures for coordination, management, and monitoring); to develop seven strategic research opportunities; and to launch a transnationally funded joint program with a common bank account. ERA-NET's first strategic research opportunities included safety in road design, coming to grips with climate change, and asset management.

CEDR Transnational Road Research Program

Next, Phillips described the process of CEDR's transnational road research program. First, descriptions of research needs are developed. Second, commitments are obtained from the funding countries. Third, there is an open call for proposals across all of Europe, not just from the funding countries. Fourth is the evaluation process, and then a program executive board is created from members of each country that contributed funds, so that each has a seat in overseeing the running of the project. Individual members of the program executive board are appointed as managers for a project.

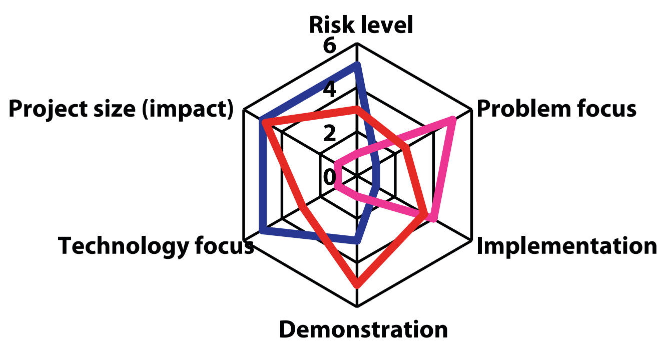
Infravation (infrastructure innovation) is a scaled-up research program that focuses on projects that are too large for a lone country to do on its own. The joint effort also increases market uptake and reduces the valley of death, because numerous countries are looking for results from the projects. In short, Infravation pools expertise, experience, and budgets, and it increases the potential market uptake.

The scope of Infravation is broader than that of ENR, which was problem focused. European Commission projects are high risk; Infravation projects match these projects in size but have a greater focus on implementation than European Commission transportation research projects do (Figure 4).

Innovation and Implementation

Phillips showed a slide of the innovation adoption curve (Figure 5) and highlighted that the innovators who take up the innovation first are "well-informed customers who are able to try the unproven product." In the context of road projects, road directors are in a position of being able to try new products. The adoption curves can vary for directors who are implementing a product, because they all require different levels of proof that the product works. Road directors cannot be scared of risk, however, because then innovation cannot happen, Phillips said.

Phillips concluded with some comments based on his experience with implementation. First, because of the way ENR was developed, there have been good cases of implementation, but the implementation has been focused on the countries involved. It has not expanded to other countries. One program—the asset management research program—had money left at the end of the research to develop case studies. The issue remains that those involved in the definition of the research were the ones who implemented the research, so the range of users is not yet broad, Phillips said. Another issue is that English is not the dominant language everywhere; as a result, uptake decreases when results are published only in English. The final issue, which relates to intellectual property and ownership of the results, is a point of discussion on improving the understanding and application of intellectual property rights related to transport research.



CEDR (ENR) projects	Infravation	EC FP projects
Low risk	Controlled risk	High risk
Problem focused	Challenge focused	Technology focused
Immediately implementable	Demonstrate implementation	Prototype
NRA (usually) owns results	Industry owns and shares results	Industry owns result

FIGURE 4 Intended focus of Infravation (NRA = National Road Administration}. (Source: CEDR.)

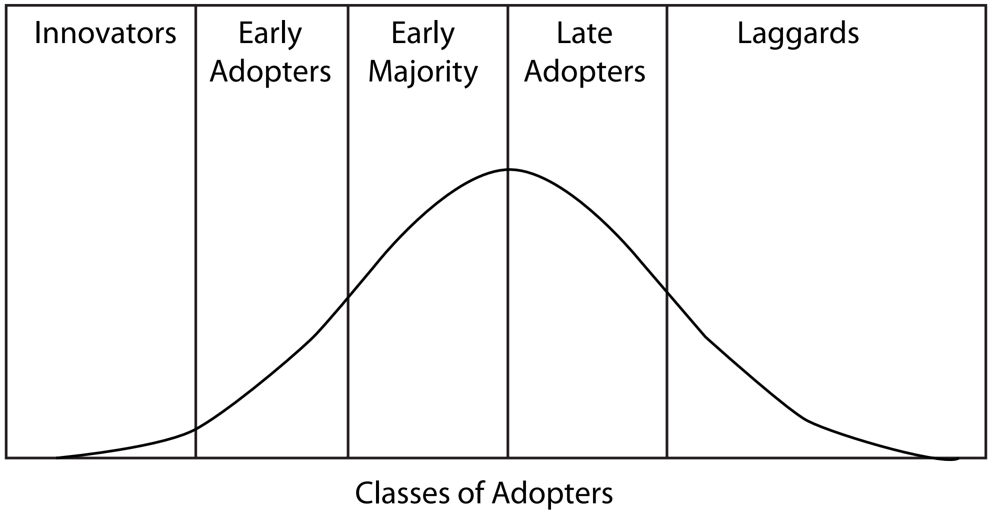


FIGURE 5 Innovation adoption. Innovators are well-informed customers who are able to try unproven products. Early adopters are usually educated opinion leaders. The early majority are careful consumers who tend to avoid risk. The late majority are somewhat skeptical customers. Laggards are those who avoid change. (Source: E. M. Rodgers, *Diffusion of Innovations,* 5th ed., Free Press, New York, 2003, p. 281.)

There are attempts to encourage ownership by those who take on the risk of doing the research, but there is still the need to protect road owners when they want to use the research for their own purposes and eventually implement the products of research through incorporation in their standards of practice. The challenge is how to finesse both sides—the side that funds the research and the side that implements it.

Discussant 1: Michael Trentacoste

Michael Trentacoste linked the presentations in this session to the white papers presented in the first session, noting that they all described what has proven successful in the past and provided examples on which to build. For example, Ann Brach talked about the strategic objectives defined by stakeholders at the start to set the research topic areas. SHRP 2 exemplified this strategy because it involved using stakeholders during the research stage to ensure that the products were practical. The entity that proposed the project took the lead on it, but the stakeholders to whom the results would be delivered commented on the research and took the lead in the initial pilots as early adopters. The involvement of stakeholders in SHRP 2 provided the opportunity for the stakeholders to be involved in piloting the research products, Trentacoste said.

The second white paper mentioned communication as an issue, and communication is also related to this session's presentations. Specifically, communication involves ensuring that the entire population of stakeholders knows what results will come out of SHRP 2 or ERA-NET products and is prepared for the results.

Another point of commonality was leadership buy-in, such as leadership buy-in from the states in overseeing SHRP 2. Leadership on the federal level was important for the program. Trentacoste noted the memorandum of understanding (MOU) that was drawn up between TRB and partners, in which the parties defined how they would cooperate and agreed that implementation would be critical. That MOU on how they would move forward was a critical aspect of implementation.

When Congress did not pass new legislation to fund the implementation of SHRP 2, TRB and state organizations said there would be no funding of new research and instead used available money to implement existing research outcomes until they got approval for new funding. This decision to fund implementation of existing research rather than pursue new research was made so that the value derived from the research could be shown.

Ensuring that there was funding for implementation was a key ingredient for getting early adopters. Trentacoste quoted U.S. Secretary of Transportation Anthony Foxx, who said that it is not possible to fund all the new research needs; therefore, more value must be gotten from current investments, and the way to get that value is through innovation.

Discussant 2: Liam Breslin

Liam Breslin began by saying that as a result of this series of EU-U.S. collaboration symposia initiated by

Damiani and TRB, two new EU-U.S. research projects had begun. Both projects pair researchers in Spain and Portugal with two FHWA projects. Breslin provided this example to show that this series of symposia was leading to collaboration between the European Union and the United States and that the series can continue to result in cross-Atlantic twinning.

Breslin praised Brach's report on SHRP 2 and its philosophy because the SHRP 2 approach was different from the approach that has been taken in Europe. He appreciated its lessons and different perspective and liked how SHRP 2 aimed to be revolutionary in its approach and to look directly at drivers "in their natural habitats." He also liked that renewal was part of the operating process. Finally, he liked how SHRP 2 approached congestion by looking at the opposition and how to facilitate understanding. He said that in the European Union today, if an entity wanted to build more highways, people would not want that, so it would not be easy to do. Brach's emphasis on the importance of people is true, he said.

Breslin then commented on the difficulty of getting different countries and authorities to work together. The European Union has 28 member states from Ireland to Sweden to Portugal and has countries such as Iceland wanting to be part of it. In short, the authorities working together are diverse. Transportation research cooperation began in 2005 with ENR1, which showed that the countries could work together. The transportation research budget in Europe is only 6% of the total research budget. The other 94% is supplied by individual countries working on their own and with industry, so the EU funding is like a glue that ties it together.

On the topic of joint research collaboration, Breslin noted a comment by the European Commissioner for Research, Innovation and Science, Máire Geoghegan-Quinn, on food safety research being done in Europe. The commissioner, who was to be at the Transport Research Arena (TRA) annual meeting to be held in Paris on April 11–17, 2014, said she was horrified when she saw that 26 countries were working independently on salmonella research, because they could be working together rather than each doing it separately. ENR1 got countries working together on transportation issues, and that is continuing with ENR2. Everyone is taking chances together, Breslin said.

The European Commission is now looking at the subsequent step. Breslin referred back to Terry Hill's point about construction and roads: can they step up to the plate? In the railroad industry, after hard work, Shift²Rail was implemented. Shift²Rail is the first European rail joint technology initiative to seek focused research and innovation and market-driven solutions by accelerating the integration of new and advanced technologies into innovative rail product solutions. There were obstacles to the implementation of Shift²Rail, but they were overcome. Breslin concluded by asking what will be next after Infravation.

Full Group Discussion

John Mason initiated the full group discussion by referring back to Beverly Scott's comment that transportation researchers are mostly having a conversation with themselves. He asked individuals in the group to consider what they would say to decision makers about the incentives and disincentives to move research to implementation.

Breslin, in response to a participant's question about the old ENR and Infravation, said that those two projects are focused projects delivering intermediate development but bringing basic research to a knowledge level that can be used by practitioners.

In response to Breslin's question about next steps, **Phillips** said that Infravation is just starting but that the next steps would be about how to widen the transitional program and remain focused on readily implementable research. Perhaps the word "research" should be taken out of the title and replaced with "innovation," he suggested. FHWA is a partner in Infravation, as are non-European counties such as Israel. Infravation focuses on challenges and is taking risks. Perhaps there will be an opportunity in the future to blur the distinction between the Infravation research and the European Commission's research, Phillips said. The European Commission is one of the funders of Infravation. The original vision was for Infravation to be multimodal and take a more holistic approach to infrastructure research. One of the next steps could be to take advantage of the benefits of public–private partnerships, such as the green car initiative that already exists and is being led by the automotive sector. The multimodality objective could also be improved on. It would be good to address a broad range of infrastructure topics to be funded and not put them in silos, he said.

Breslin added that Infravation is a follow-on to ENR and that it includes non-EU countries as well as countries within the European Union and has an emphasis on demonstration. Infravation is challenge focused and multimodal.

Cristina Marolda of the European Commission Directorate-General for Mobility and Transport and cochair of Horizon 2020 said that, in particular, she cares about all aspects of the transportation system, including infrastructure. Infrastructure is multimodal and therefore cannot focus just on one mode. With regard to Phillips' cube graph (Figure 4), she said that all of the elements are needed: you cannot focus just on one element. She agreed with Breslin about a continuation of Infravation but said perhaps its scope and framing could be expanded to support more focus on the infrastructure problem. The question today is how and where the European Commission can give added value. Who are the stakeholders in each of these? Should the effort focus on one phase of the innovation chain?

Patrick Malléjacq said he worked with CEDR on a road project and in 2010 had to convince CEDR to continue funding it. A key element of convincing them to continue funding was demonstrating how useful the project was. "Demonstrate its usefulness or pull the plug," Malléjacq said. Continuation of funding is a strong motivator, he said, and the project stepped up its simulations. The project's researchers also asked road administrators to talk with their road administrator colleagues about how much money they saved on maintenance costs after they implemented the research results.

Brach talked about disincentives from her SHRP 2 experience. She said that one thing she heard a lot was that for decades, state DOTs were losing staff because of retirements and because of political and economic reasons. As a result, the state DOTs had smaller staffs, and institutional memory was being lost and not replaced. Younger people did not know the context. Innovation takes time to learn, and people do not have the time. Thus, SHRP 2 provides technical support in the form of consultants who are paid to help train state DOT staff. SHRP 2 is paying lead states to engage others. It is a practical move that was in direct response to a disincentive to adopt the innovation.

Joris Al added that another disincentive is that the implementing agencies do not know where a particular kind of research has been implemented, even in their own countries. Is there a responsibility to provide information on the implementation of one's research?

Trentacoste answered that in the United States, the Every Day Counts initiative at FHWA is a partnership between the federal government and the states. States own their highways, and the federal program wanted to do more than just push innovation out. Therefore, states that have adopted an innovation measure its impacts. There was enough of a sampling to measure the cost savings. The Every Day Counts program keeps track of which states have implemented a new technology and has mapped out deployment information about that technology. The deployment information is available online, so that others can see who has implemented it. Thus, the results are communicated. That practice has carried over into the SHRP 2 program to show not just what research was accomplished, but who implemented it. Also, implementation of research funding is advertised by AASHTO. For lead adopters to get funding, they must work with a contractor to measure the outcome and evaluate the implementation results. That is what the funding provides: getting the research piloted so that it can be spread. The evaluation measures the output and outcome to see the impact and documents both what worked and what did not.

Breslin agreed that more should be done to publicize the research that has been implemented. The European Commission has a portal called the Transport Research & Innovation Portal [http://www.transport-research.info/web/] that has all the transportation research activities taking place at the European and national levels. The website provides program information by country and by organization. That is one step to communicating transportation research. In addition, most modes have technology platforms. That is, modes such as rail, auto, and air all set out the technology road map, such as electrification, and show how they are achieving their targets. Not all modes do it, but it is useful. TRA, whose annual meeting was on April 11–14, 2014, also does that. ERA-NET, in which different countries work together, also provides a way for countries to compare programs and talk together.

Phillips agreed that someone has to take responsibility for implementation. Twelve years ago, there was a European conference on transportation research, and the intent was that there was a need to develop platforms that were not just for researchers but also for practitioners and users to report on what they had used. Phillips said that for a long time he has been a fan of the U.S. Local Technology Assistance Program model, which takes the best of the results and develops them to a national level. Harold Paul has a domestic transportation research program management scan program that has a big focus on implementation, Phillips said.

Pam Hutton of AASHTO responded to the question about who is responsible for documenting implementation. She said that FHWA and AASHTO believe that they are responsible for documenting research implementation. For the program evaluation aspect, AASHTO cooperates with FHWA to provide case studies for nearly all the products being implemented as users implement them. FHWA funds implementation assistance by providing money to AASHTO so that states can document implementation. States implement the research products and provide data that become part of the case studies.

Alessandro Damiani commented on the issue raised by Joris Al about research follow-up and monitoring. Damiani asked Brach whether a systematic, postprogram follow-up was incorporated into the overall program management.

Brach answered that at TRB there were no plans to monitor beyond the end of the program because the unit will be dissolved, but that FHWA and AASHTO would be doing the case studies.

Damiani then posed a similar question to Phillips: how many deliverables came out of Infravation, and does Infravation have a way to monitor downstream implementation?

Phillips prefaced his answer by saying that SHRP 2 was a program of more than $200 million that went on for 9 years and delivered 300 projects. To date, Infravation has delivered 67 projects, but some of those projects had multiple outputs, so the total is probably about 100 outputs. All the outputs are widely disseminated at EU seminars at the end of every program. Two years after the completion of a program, road directors are invited to present what has happened with the implementations in their countries. The most recent seminar was about the safety program, so the results of those implementations were presented. These follow-up discussions take place after 2 years and after 5 years. Some in the group are also looking at AASHTO and SHRP 2 as models for how to improve.

Jesús Rodríguez commented on the vital issue (and high cost) of expanding the life of existing infrastructure. New Eurocodes will cover the evaluation of existing structures. He said it was interesting to consider that construction processes could adapt existing bridges to new functional requirements. Infrastructure needs innovation but cannot wait for Infravation. Infravation includes some of this, but more progress is needed now because megaprojects are already taking place—the main Spanish construction groups are working on major projects right now, including on existing infrastructure.

Lynn Peterson of the Washington State DOT said she was "all about the practical." She urged consideration of the pros and cons of adding a clause to the reauthorization of transportation funding. The clause would stipulate that if federal money is invested in a project, the project needs to document how the research was used and what cost savings or cost efficiency was achieved. AASHTO could help track the use and cost savings, or there could be an app to crowdsource the data. At TRB's annual meeting in 2014, a case study on "Crowdsourcing and Its Application to Transportation Data Collection and Management" was presented (*1*). Following that advice, AASHTO and TRB do not have to try to get all implementation data themselves, she suggested. Rather, the implementation data could be crowdsourced, so that engineers could share their results.

Hutton said AASHTO provides state DOTs with a contact so that peers can talk to each other, because championing a particular research effort or implementing a new tool is more readily acceptable if one hears about it from a peer. That kind of interaction is more useful than brochures, she said.

Terry Hill returned to a comment Brach had made about human capital, remarking that given all the young people coming into the field, there is a shortage of knowledge about how to commission research projects. It is difficult to expect young people to know how to fund radical innovation if they have never done it. They do not know how to make tough calls on investments, he said. To tackle this, Hill helped develop a leadership academy for infrastructure innovation at the Saïd Business School, University of Oxford, United Kingdom. This academy helps new transportation professionals learn from experienced professionals from a variety of countries. The fact that the program was at Oxford helped attract students. This type of leadership academy could be a model for the U.S. states that are seeing their experienced personnel retire.

Brach added that AASHTO is hiring those retired people, and that FHWA is providing technical assistance by paying consultants who are knowledgeable about innovation and can teach the new hires.

Munro asked Trentacoste where one could go to get the quantitative data on implementation that he mentioned.

Trentacoste replied that the FHWA website has a page on the evaluation reports being published. Soon there will also be information on SHRP 2 evaluations and other FHWA programs. The data are listed by technology and indicate the number of states that have implemented the innovation (e.g., warm-mix asphalt or roundabouts). Trentacoste also added that an implementation done once is just a demonstration, but if states change their design criteria or their design manuals, then the innovation can be considered in all design contracts.

Munro asked a follow-up question about the percentage of innovations tracked in the systems Trentacoste mentioned. Trentacoste replied that SHRP 2 had upwards of 60 innovations and that Every Day Counts had seven or eight in each Every Day Counts area.

James Bryant of TRB asked Trentacoste to elaborate on the culture of innovation, why FHWA kicked off Every Day Counts, and how states can create innovation cultures.

Trentacoste replied that when FHWA Administrator Victor Mendez took on his position, he went to Congress and learned that it takes 13 years to deploy an innovation. Administrator Mendez then charged his team with coming up with initiatives to speed up the deployment of innovation. In the past, the main initiatives focused on workshops, which were more of a push approach. Speeding up the innovation deployment process would mean creating more of a pull process. To lead state DOTs to ask questions, the team decided to create regional summits for decision makers to talk about the benefits of the technologies. The next step was to create an ongoing process in the states to consider what each state needs. AASHTO allocated $100,000 per state to form an innovation council at the state level to help create an innovation culture and make it more permanent by involving all parties.

Ángel Aparicio commented that innovation is an enormous effort compared to the money received and asked whether there were hopes to increase the resources dedicated to innovation and reduce the gap between research and implementation.

Brach replied that in U.S. highway research, almost everything is paid for by the Highway Trust Fund, which is in trouble, so there is zero hope of increased funding. However, increased funding must happen, so there is a long-term hope that the issues will be solved.

John Inglish said that from the perspective of the U.S. states, holding peer exchanges and the lead state exchange have been of great value. These exchanges drive out fear of not wanting to speak freely in a wider forum. He also mentioned user liaisons, outreach to users, and working with TRB and AASHTO to coordinate with the *Highway Safety Manual* (*2*) as other methods for implementing research.

Mason concluded the discussion by reiterating the value of involving non–transportation people in the discussions. In the area of incentives, he mentioned that the United States has a national program called the Small Business Innovative Research Program, which is a two-phased approach to innovation. In the first phase, awards generally do not exceed $150,000 for early R&D for ideas. Then, as the innovation passes through further phases, more funding is provided to help get the innovation to commercialization. As another example, the U.S. Department of Energy has performance contracts that provide a fee and overhead. Then the project is evaluated on its performance, and if the performance has improved, then additional funds are given. These are examples of incentives offered at the federal level, he said.

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SESSION 3

Framing and Conducting Research to Ensure Implementation

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Policy, Data, and Research: Getting Value from International Collaboration in Research and Policy Analysis

José Viegas

José Viegas described the history of the International Transport Forum (ITF) of the Organisation for Economic Co-operation and Development (OECD), an intergovernmental organization whose core goal is to help the ministers of transportation of its member countries make good policy decisions. ITF's focus is on information, and it advises its members on the importance of good transportation policy.

ITF has 54 member countries, of which 21 are not OECD members, even though ITF is housed within the OECD. The organization's presidency rotates annually. The map of ITF member countries that Viegas showed illustrated good participation from countries across the northern hemisphere but some gaps in the southern hemisphere.

Steps for Successful Research and Policy Analysis Projects

ITF research is done cooperatively by member countries, and one of the organization's most important activities is defining standard terminology to create reliable, comparable data across countries, so that, for example, the number four in one country means the same thing in other countries. The second step after the collection of reliable data is to select the research project's format, topic, and partners. The third step is the dissemination of the results through various channels and engaged stakeholders.

It all starts with good data, Viegas emphasized. He believes that ITF is the most reliable organization in the world for transportation data. As an academic, Viegas frequently uses ITF sources, such as its glossary for transportation statistics. Terminology is key, Viegas said, because direct translation of a name can mean a lot. ITF's glossary has been translated into 30 languages. ITF also provides procedures for how to collect data because (in road safety, for example) different sources in the same country sometimes report different figures for how many people were seriously injured in road accidents in that country. ITF plays an important role in the harmonization of methods and definitions as well as in the development of new indicators and collection methods, both of which can advance the international statistics agenda

Next, Viegas described some of the data collected at ITF, such as annual and quarterly trends per ton-kilometer and passenger-kilometer, and accidents. ITF also collects data on global trade and transportation. One interesting finding that shows the value of good data in creating a basis for international comparability is that the transportation of intermediate goods accounts for 50% of all trade movements. ITF is also doing important data collection work on investments in infrastructure and the valuation of assets and how they can be used. ITF has collected global data on carbon dioxide emissions and road safety data from 70 countries.

Collaborative Research Projects

Collaborative research projects undertaken across national boundaries are at the core of ITF. Representatives of research institutes from ITF member countries select topics for which international collaboration provides value; these are referred to as "common value topics." The countries propose topics, and the topics that receive the most votes are selected.

Each research project lasts 18 to 24 months, and six to 12 countries are involved. Experts nominated by member countries form a working group, which is appointed for the duration of the 18- to 24-month project cycle and delivers a report with policy conclusions and recommendations at the end of the project. The research institutions are the orchestrators, Viegas said. A few of the best-selling reports from research projects are *Cycling, Health and Safety* (*1*); *Workshop on Motorcycling Safety* (*2*); and *Infrastructure Adaptation to Climate Change and Severe Weather* (forthcoming) (Figure 1). [ITF publications are available on the ITF website, http://www.internationaltransportforum.org/.]

ITF roundtables are another example of an ITF product. The ITF roundtable was created 61 years ago, and more than 150 have been held to date. About four roundtables now take place each year. Each roundtable features 25 to 30 invited experts who present their papers and engage in an in-depth discussion of a selected topic from the ITF program of work. The roundtables focus on diverse views and implications for policy. Viegas attended his first roundtable in 1984 and finds them to be a very exciting intellectual exercise. Each roundtable produces a report, and these reports, such as *Long Run Trends in Car Use* (*3*), *Better Regulation of Public–Private Partnerships for Transport Infrastructure* (*4*), and *Improving the Practice of Transport Project Appraisal* (*5*), are heavily downloaded.

ITF Annual Summits

ITF also holds an annual summit with ministers of member countries and high-level industry and academic participants—about 1,000 each year. The summits include a ministerial meeting and declaration from ministers; ministerial roundtables; and panel discussions with ministers, industry, researchers, and civil society. Other important features of the annual summit are bilateral meetings for captains of industry, networking, and an exhibition hall.

The ministerial roundtables follow the Chatham House Rule, namely, that what is said in the roundtable is unattributed when discussed outside the meeting. This approach allows for candid discussions. Viegas attended one such roundtable last year with two ministers and a chief executive officer (CEO). The ministers and CEO sat together for the 2-hour duration of the roundtable. When the roundtable ended, they said that given another 2 hours, they likely would have come to agreement on a seemingly impossible issue, given the open discussion format of the roundtable.

Each summit has a theme, such as funding transport or transport and innovation. The 2014 topic is transport for a changing world, that is, how transportation can play a role in making the world a better place.

Significant work goes into feeding research inputs into each summit. There are summit expert sessions that deliver conclusions to feed policy debate and background reports that provide research evidence on the summit's

- Representatives of research institutes from ITF member countries select topics for which international collaboration provides added value ("common value topics").
- Experts nominated by member countries form a Working Group with a 2-year project cycle and deliver a report with policy conclusions and recommendations.
- Recent examples:
  - *Cycling, Health and Safety*
  - *Workshops on Motorcycling Safety*
  - Infrastructure Adaptation to Climate Change and Severe Weather (forthcoming)

FIGURE 1 ITF collaborative research projects. (Source: ITF.)

theme. Selected research center materials form the basis of summit debates.

For example, on the topic of infrastructure, the UK Department of the Treasury provided input on valuing and managing infrastructure investments. Four examples of inputs for the 2013 funding transport summit were *Funding Urban Public Transport: A Case Study Compendium* (40 cases) (*6*), *Spending on Transport Infrastructure 1995–2011: Trends, Policies, Data* (*7*), *Airports in the Aviation Value Chain: Financing, Returns, Risk and Investment* (*8*), and *The Potential of Private Institutional Investors for the Financing of Transport Infrastructure* (*9*).

Viegas has received much positive feedback on the summits, such as an investment bank saying the summit document on the topic was the most valuable one available and another quoting the value of the report on the seamless transport summit.

Policy Review and Analysis

ITF recently introduced an initiative at the other end of the policy chain—namely, policy review and analysis—in response to direct requests received from ministers.

For example, ministers have called ITF when they have had a critical transportation policy issue they needed help with. ITF has helped ministers in South Korea, Mexico, Finland, Sweden, the United Kingdom, and France. A minister from Mexico, for instance, called ITF to review a proposed policy. ITF offered some changes, and the Mexican government responded positively because ITF was able to show that some of the assumptions going into the policy were not right. In South Korea, the senate approved transportation demand studies to which again ITF was able to propose some useful corrections. The South Korean minister commended ITF's contribution.

In these ways, ITF delivers value to its members. ITF has the capacity to quickly organize these reviews in a variety of formats (e.g., roundtable, report, panel review) by calling on its in-house resources as well as its worldwide network of experts. Countries pay for this service at marginal cost.

Adding the Corporate Perspective

ITF incorporates the government and academic perspectives but to date has been missing the corporate perspective, Viegas said. To gain the point of view of corporations on research and policy analysis, ITF added the Corporate Partnership Board (CPB) to its structure. Companies from across the world in all transportation modes and in key contributing sectors such as energy, finance, and information technology are invited. The kickoff meeting of the CPB took place on January 20, 2014, with 13 companies from the Americas, Asia, and Europe. ITF expects the membership of the CPB to grow to about 50 companies over the next 3 years. The CPB will add the corporate perspective to ITF transport policy analysis work, and this perspective will both lead to more solid findings and advice and provide additional funding for ITF. Two thematic project series will be proposed: "Emerging Issues in Transport Policy" and "Innovation Challenges in Transport Systems." The first theme aims to identify emerging issues sooner; the second theme aims to identify barriers to innovation, such as a legal structure that forbids the innovation or a lack of financial incentives for implementing an innovation. ITF currently has four projects in these thematic areas. The projects are motivating initial funding and are helping to recruit young people to participate in the research.

Viegas offered some concluding thoughts related to implementation. First, implementation is harder for ITF because the outcome is policy advice, not technology. However, as the summit roundtables have shown, having a 2-hour meeting dedicated to policy issues can yield much forward movement. In the upcoming spring meeting, countries will report on policy impacts and explain what they have done or what they have seriously considered in their policies to fund transportation.

Transportation Research Board's Cooperative Research Programs: Considering Implementation from the Start

Stephen Andrle

Stephen Andrle noted that the second Strategic Highway Research Program (SHRP 2) and the Transportation Research Board's (TRB's) cooperative research programs (CRPs) have been considering implementation from the start. With regard to the two types of research being discussed at the symposium—high-level game-changing research versus more day-to-day research—Andrle placed SHRP 2 in the latter category, as this program's research is all user driven and problem driven. There are also some research products that have risen in standing, such as the *Highway Capacity Manual* (*10*). People love to hate the manual, Andrle said, but they are aware of it and it is continuously updated. The manual has had more impact than was imagined five editions ago.

One of the best practices learned from SHRP 2 and other TRB projects is that "You need to get the research right from the start," Andrle said. The first meeting is critical, because that is when objectives are laid out. If committees ask the right questions, they will get the right responses back.

TRB Cooperative Research Programs

Andrle described TRB's numerous Cooperative Research Programs over the years. The oldest program was the National Cooperative Highway Research Program (NCHRP), which was started in 1962. Research topics are chosen by the American Association of State Highway Officials (AASHTO) Standing Committee on Research. Fifty years ago, it would have been unusual to have an external committee picking research topics, but the funding is allocated by AASHTO and it chooses the research topics. The cooperating bodies in this program are the state departments of transportation.

The Transit Cooperative Research Program (TCRP) began 30 years later, in 1992. This program focuses on public transportation systems, and transit officials participate. The Airport Cooperative Research Program (ACRP) was initiated in 2005, with airport operators as its main body. The National Cooperative Freight Research Program (NCFRP) began in 2006 with funding from FHWA but has run out of funding and is winding down, as is the Hazardous Materials Cooperative Research Program (HMCRP), which was started in the same year. Finally, the National Cooperative Rail Research Program (NCRRP) was begun in 2012 with the participation of both freight and intercity passenger rail practitioners.

Organizationally, all of TRB's cooperative research programs are under one staff structure, though each has different characteristics. All are targeted to problem solving and are industry driven, Andrle said, adding the caveat that the term "industry" in this case refers to state departments of transportation rather than to for-profit corporations. Therefore, using the term "stakeholders" would perhaps be less misleading, but the point is that these entities are the owners or adopters who will apply the research, and they are the ones driving the research.

Common Characteristics of the Cooperative Research Programs

Next, Andrle described the characteristics that the CRPs have in common: they are industry driven, with a governing board and project panels; they focus on applied problem-solving research; and they use a competitive procurement process. Writing a request for proposal (RFP) is an art it itself, Andrle remarked.

Industry-Driven Research

Andrle next described the solution and selection processes that the CRPs use. The CRPs conduct annual solicitations for research problem statements from practitioners. The problem statements are reviewed by committees of other practitioners. Committees need to be composed of the right people so that they know the right questions to ask, Andrle added. For industry-driven research, the program governing boards consist of customers for the potential research. These boards are responsible for project selection and for researching the right topics. In addition, project panels are formed to oversee each research project selected. The panels consist of knowledgeable practitioners in the subject area that covers the relevant technical disciplines related to that project. The panel determines the research scope and products, selects researchers through competition, and monitors and reviews the research.

Andrle discovered that, compared with SHRP 2, which organizes research top-down into four general topics, ownership in the CRP projects is cooperative. The participants know that their programs got picked, so they have ownership, Andrle said. The people who will use the research have ownership, and therefore they care. The best outreach people sat on the committees, which was another mechanism that worked, Andrle said. With SHRP 2, it was harder to tell what would get traction; some things were picked up but others were not.

Applied Research

Andrle showed a slide (Figure 2) of some of the products that have come out of the programs and that have good shelf life, such as the *Highway Capacity Manual* (*10*). The manual is not mandatory, he said, but it almost has the force of regulation in the United States and has been the primary source of analytical methods for new roads.

Some products are turned over to AASHTO for implementation and dissemination. Initially, AASHTO committees give research problems to the CRP; the CRP carries out the research and then gives the research back to AASHTO for implementation and outreach, Andrle explained.

Examples of research topics and products that came out of the transit program, TCRP, include

- Fuels [*Guidebook for Evaluating Fuel Choices for Post-2010 Transit Bus Procurements* (*11*)],
- Sustainability [*Building a Sustainable Workforce in the Public Transportation Industry—A Systems Approach* (*12*)], and
- Public transit service [*Transit Capacity and Quality of Service Manual* (*13*)].

These research products have staying power, but they can become out of date. Policies have changed for

FIGURE 2 Results of CRP programs. (Source: TRB.)

light rail, for example, but researchers can go back to the funding source and say they need to do another manual. This is different from research funded by the states. Allocation of the projects is the same, but the difference is the ability to keep the procedures current under applied research.

Andrle also showed examples of research products from the airport program, ACRP. Issues such as storm water are a problem at airports because they have so much pavement. The research projects address real problems, Andrle reiterated.

Dissemination and Implementation

As regards dissemination, TRB does not do implementation because the states are the ones that build the highways. Therefore, the states need to do the implementation, but TRB does try to set research projects up so that they are suitable for implementation. Each program has various dissemination mechanisms, including a TRB e-newsletter, a CRP website linked to the TRB website, various listservs, social media, conference displays, webinars, and workshops. There is also an ambassadors program in which people are paid to talk one-on-one with users (e.g., those at an airport) or, more broadly, through a speakers' bureau. The dissemination activity is not advocacy, but simply dissemination.

In terms of measuring implementation, TRB uses primarily soft methods such as project panel member surveys and industry surveys. It also measures impacts on practice and collects anecdotal information. For example, TRB's bimonthly magazine, *TR* News, has a section in each issue titled "Research Pays Off" that features an article about where research has proven to be cost-effective. TRB staff track down and document the research's impact. Finally, TRB maintains close ties with industry association committees.

The TRB website contains information on all of its CRPs (NCHRP, TCRP, ACRP, NCFRP, HMCRP, and NCRRP) and has a search engine for locating information from as far back as 1988 on anticipated, active, and completed research projects. The website provides access to committees and a who's who on topics, Andrle said. Finally, the site lists RFPs and has a registration form for automatic notification of calls for proposals.

Designing Road Safety Research Aimed at Increasing Implementation Possibilities and Assuring Actual Safety Improvements

Horst Schulze

Horst Schulze started with three central statements:

- Transportation safety improvements can be assured through effective transportation safety management.
- Effective transportation safety management must lean on evidence-based research.
- Transportation safety management should be considered as an implementation of research results aiming to attain policy objectives.

German Road Safety Program

Schulze then described the lessons learned from the German road safety program, which began in 1970. At that time, there were about 20,000 deaths annually on German roads, but after the road safety program began, the number of deaths decreased. Schulze showed a chart of fatality numbers that indicated certain points at which big decreases in fatalities took place; those decreases were always tied to the implementation of a new safety measure. The first big decrease took place with the introduction of a blood alcohol limit of .08 for drivers and the implementation of speed limits on rural roads.

Schulze said that the mandate for improved road safety obliged research to answer the right questions and implement the right safety measures to effect decreases in fatalities. The annual death rate is now just 3,400. The latest decreases occurred after the introduction of the two most recent measures: a lower blood alcohol limit of .05 and accompanied driving, meaning that until novice drivers reach a certain age, they (particularly youths) are only allowed to drive when they are accompanied by an experienced driver.

Schulze then moved from the detailed level to the more abstract, discussing how the road safety management research program was created and run. The program was designed by politicians, he said, but researchers also helped to define the targets. The research gets implemented by different actors, and after implementation there is another instrument involved: that of control and quality assurance. In the 10-year plan, there are reports every 2 years about how the program is working. If deviations are found, corrections can be made. The review mechanism helps to ensure quality and that the results are on target.

European Road Safety Program

In addition to the German Road Safety Research program, there is also a Europe-wide road safety management program that also has research related to policy goals. The central goal for the European program is to reduce fatalities and serious injuries. However, there is a question as to how good results will be implemented and who will control the quality assurance, because unlike the German program, the European program does not have those mechanisms in place (compare Figures 3 and 4).

Schulze next presented three general tasks that are needed to improve transportation safety in Europe:

1. Improve coordination of policy objectives and research, so that policy aims are properly translated to transportation safety research.
2. Establish a constant evaluation (controlling) process to evaluate safety measures and to communicate the evaluation outcome to policy and research.
3. Close the gap between research and implementation. Specifically, Schulze thought that research should be more closely involved not only in developing but in conducting implementation actions and evaluating the effects of road safety regulations.

There is a continued and growing role for research that contributes more to transportation safety improvements, Schulze said, because even though the number of road fatalities in the European Union has decreased considerably, the reduction is below the targeted goals. Indeed, in the past few years, the reduction in road fatalities has been minimal, and injuries resulting from road accidents have barely decreased. In short, deaths, injuries, and property damage resulting from road crashes are still unacceptably high, and

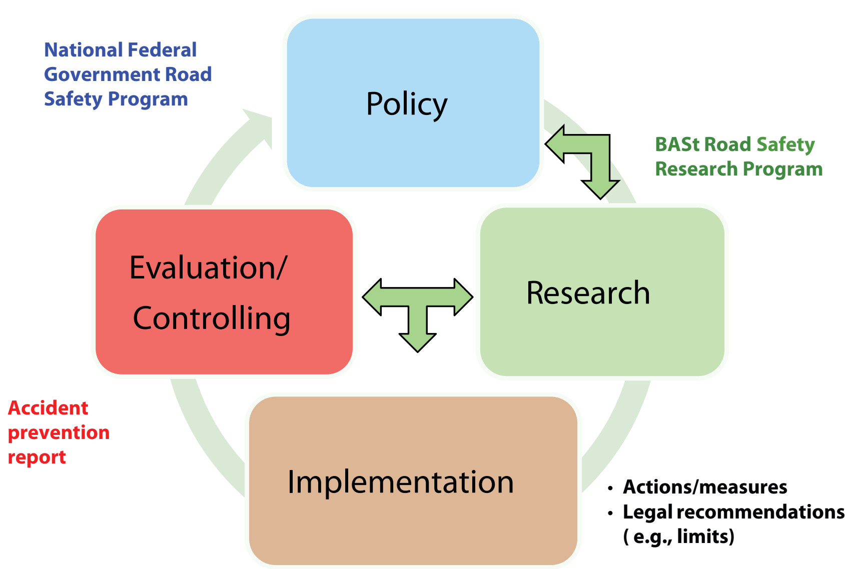

FIGURE 3 Road safety management in Germany. [Source: Forum of European Road Safety Research Institutes (FERSI).]

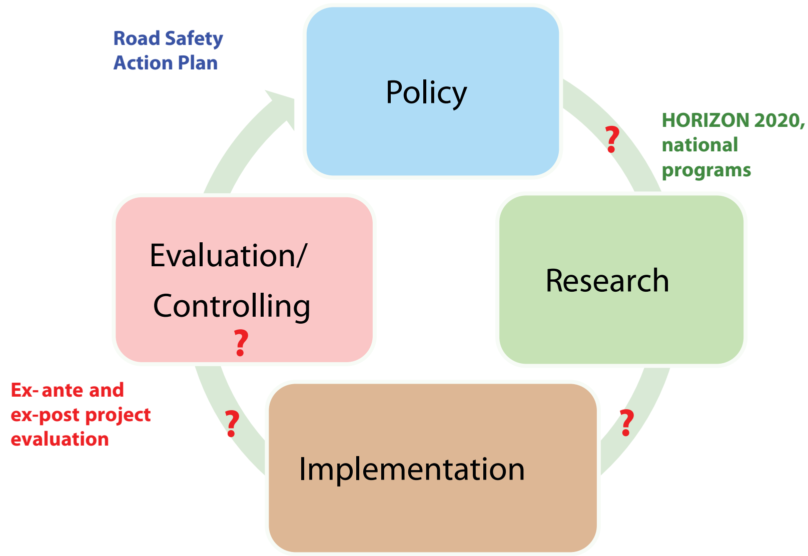

FIGURE 4 Road safety management in Europe. (Source: FERSI.)

there is a growing need to merge policy, research, implementation, and control.

Forum of European Road Safety Research Institutes

The Forum of European Road Safety Research Institutes (FERSI) was established as a network of research institutions that have a mandate from their governments to implement road safety research and to provide policy advice about road safety. Although FERSI had been an informal network since 1991, it became a nonprofit association registered in Brussels in 2012.

To fulfill their mandates, FERSI members have to be proactive and to be thinking about safety problems 4 to 5 years ahead, because that is how long it takes to do research and translate the research into policy measures and recommendations.

FERSI sees nine key priorities and challenges for road safety research for the next decade:

1. Aging of society. More of the population is older than 60 years of age, and as drivers age, they develop impairments that reduce their driving performance. Society must do all it can to keep the elderly mobile but must also find ways to do this safely and to provide alternative modes when the elderly are no longer able to drive safely, Schulze said. The aging of society also implies the need to develop reliable diagnostic tools to assess whether an elderly person is still capable of driving safely. In addition, perhaps training programs could be developed to improve mobility or safe driving behavior among the elderly.

2. Vulnerable road users. People are moving out of the countryside and into cities, where there are more jobs and opportunities for education. In a city, however, a car is a burden because of limited parking and expense. Therefore, more people become pedestrians or cyclists, who are more vulnerable road users. Research can help find answers to questions such as what safety issues will arise with an increase in electric bikes, or how to overcome the conflict between reducing road injuries and promoting the health benefits of walking and cycling.

3. Cultural diversity. The safety measures that work in the Netherlands may not work in Serbia because of cultural factors. In addition, new EU member states have much higher numbers of road fatalities. Research is needed to establish effective data collection for culture-specific research as well as to identify which dimensions of road safety research are influenced by cultural factors.

4. Vehicle automation and intelligent transportation systems. As vehicle automation increases, humans will still be in cars and interacting with the increasing automation. Schulze posed the following questions: How can a driver's attention be ensured in the case of continuous automation? What are the safe ways to transition from automated to driver-only modes? Will automated safety features lead to more careless driving and thereby ultimately reduce road safety (the risk homeostasis effect)? If so, which types of driver-monitoring technologies are needed?

5. Burden of injuries. The paradigm of road safety has expanded beyond reducing fatalities to reducing injuries as well. In this area, unanswered questions include the following: Which factors have caused the slower decrease

in accidents with injuries as compared with accidents with fatalities? How can underreporting of slight and serious injuries be assessed? What relationships exist between road accident types, road user behavior, vehicle types, and injury types?

6. Safe road design. This research priority could answer questions such as

– How efficiently can safety assessments of the existing road and infrastructure be conducted? and

– Which education and training approaches are needed to implement all tools of the Infrastructure Safety Directive (e.g., road safety impact assessments, road safety audits, road safety inspections)?

7. Education and training of road users. Research could answer the question of what specific education and training are needed for different road users and groups, as well as what the most cost-effective training (or retraining) methods are (e.g., e-learning or simulations).

8. Behavioral change. This research priority relates to the philosophy that impaired drivers should be rehabilitated. The questions that arise are whether an improved theoretical basis is needed to initiate behavioral change and how key human factors such as attitudes and expectations can be adapted to improve safety in a sustainable way.

9. Road safety management. This priority examines what research topics are needed to improve road safety management and which components of the research programs should be conducted on an international level.

Discussion

Francesca La Torre framed seven objectives for the session's discussion:

1. Identify the gaps between research and implementation.
2. Identify the critical elements in current research approaches and funding policies that limit the implementation of research results.
3. Identify successful funding programs (e.g., SHRP 2).
4. Understand whether there are best practices that can be useful to enhance technology transfer, including transfer across continents.
5. Identify issues in the transferability of research results worldwide, that is, how knowledge can be exchanged systematically on a worldwide scale to avoid duplication.
6. Determine how to get end users' insights on how the outputs of the research could be improved to allow for easier implementation. End users are the final implementers, she said, so how can researchers incorporate their inputs into the research products they deliver so that those research products are what the end users wanted? SHRP 2 involved the implementers, but the European Commission's Horizon 2020 is not driven by the needs of implementers. There might be a process whereby the road authorities or contractors could say what they want some of the research outcomes to be.
7. Help researchers find a way to enhance the willingness of industry to be aware of the value of new solutions. La Torre encouraged researchers to make the extra effort to get user buy-in, sell the new solution, and evaluate the effectiveness of new solutions. An end user will not buy a solution just because the seller says it works; the message must be credible. Researchers can add credibility to a solution by evaluating its effectiveness.

Cristina Marolda wanted to clarify the confusion of "end user" as a term. The term is confusing because who the end user is changes over time along the chain of innovation. She suggested using the term "buyer of the result" to reflect the end user who funds the innovation. Research has to provide value to the buyer, and the buyer has to be convinced of that value. The value will change on the basis of who the buyer is. For example, to sell to industry, researchers need to make a business case. To sell to public authorities, researchers need to make a policy case that the research will help achieve policy targets. When you have a clear policy authority, you also have peer investment, she said. If you have that investment, you have a way to apply the result.

Marolda added that the funder breakout group mentioned the need to have a vision and a plan for what the researchers want and need. This can be achieved through a dialogue between the policy makers and the researchers, and the dialogue must take place both in the global context and also regionally, because one solution does not fit all. Northern European countries that have ice 8 months of the year have different issues than southern countries that have to deal with heat. Despite regional differences, the countries do share common goals, such as the desire for efficient infrastructure at a lower cost. When there is agreement on a common goal, countries can jointly fund the research effort and pool their money. "If you have political willingness to reach a goal, you can reach the policy targets," Marolda said. "In the European Commission, we are trying to fit all the topics of our research program to match policy drivers. We are committed to reach policy objectives and adapt the research to engage the right critical stakeholders."

John Munro suggested using the term "adopter" rather than "buyer," because some users adopt, but they don't necessarily buy.

Marolda commented that the term itself is less important than the concept of "buy-in," that is, investing so that there is buy-in.

Livia Pardi supported Marolda's comment on the importance of buyers, because going from research to implementation requires a greater investment of money in the demonstration phase of the project. That means strong commitment from industry in the results. The demonstration period is important to show the performance-based criteria. The demonstration period also offers the opportunity to show the advantages of the solution.

George Giannopoulos remarked on two points he heard. First, how can implementation be incorporated into the research work in a practical way? Being a researcher himself, he would like to hear an example of how that is done. He speculated that there are three types of actions. The first possible action is selecting the right partners from the start. The partners can include the transportation researchers as well as policy makers. Currently, policy makers only supervise the research and are not involved as partners. Second, the buyers of the research are industry partners, but more of them may need to be involved, perhaps through consortia with research partners. Third, there is a need for an evaluation process focused on implementation issues; there is a technical review and a financial review, but no review focused on implementation. There should be an implementation review, Giannopoulos suggested.

Giannopoulos' second point related to incentives. He suggested first that during the implementation review phase, an incentive could be offered, namely, tying the extension of the contract to implementation or funding issues such as intellectual property rights or commercialization. Bonuses could be given in the medium term and long term if implementation takes place. He noted that Trentacoste mentioned that the U.S. Department of Energy gives bonuses. Second, as Brach said, implementation must take account of the social and economic context in which the innovation will be introduced. ITF could do this given its worldwide membership. Finally, he posited that there was a need to conduct research on implementation issues, that is, to study how to implement research in a worldwide context as a way to enhance industry's willingness to implement the research. Research on this topic is needed, he said, because the process of implementation and uptake is so complex.

Urban Karlström said that for research to be implemented, researchers and implementers have to work closely together so that researchers do not have to "sell" their solutions. Rather, they present solutions to real problems; everyone then agrees on the problems to be solved. That is how to bring the problem owners and researchers closer together. Sweden has been doing this intensively, he said. When Sweden evaluated its transportation R&D, it realized that it was not getting enough out of its research money, both public and private. The conclusion was to bring both the public and private sectors together to identify common problems and see what research was needed or what regulations needed to be changed and to have a systematic approach to the implementation process. Sweden brought together 40 key organizations to participate, including research institutes, companies, and public agencies. The organizations decided what innovation was needed and wrote a common strategy on how to address the problems faced. They now have some strategies, and the different actors can see the results. The whole system is made more effective by a common but broad strategy that is not just organized by mode and that brings in people from outside the transportation sector. For example, car companies and shipping companies helped to identify alternative fuels. Similarly, telecommunications companies were included in traffic management issues. When different agencies work together, they can get more out of the research.

La Torre noted that Sweden's approach was user driven, in that the groups established the needs. She then posed the following two questions: What if an innovation is developed that is not part of the identified plan? How do you incorporate that blue-sky thinking? "You have to shout," as Terry Hill had said, to get attention. Similarly, La Torre said, in Italy she has to shout to get the attention of road administrators. Luckily, she is a professor in Italy that people listen to, but otherwise innovators have to prove with numbers to say, "If you do X, you will save Y lives," and that takes research.

Pam Hutton emphasized that she is not a researcher, but an implementer. She agreed with Karlström that research needs to solve a real problem. SHRP 2 started that way: not as solutions looking for a problem but as solutions to real, existing problems. Second, the SHRP 2 research started with a primer on how the research would be implemented. It was a "how-to" manual that was written when the research began and was used daily. Finally, SHRP 2 at the outset had an implementation budget to kick-start the implementation. When Congress passed legislation that required states to contribute money to implement the research, the states gained ownership. They became buyers. There was a pool of money, and SHRP 2 provided financial incentives that were significant in engaging the states and getting them to be aware of the tools and to care because they were buying them. The implementation budget had a specific line item for communication and training so that the messages communicated would be consistent and so that overall awareness would grow. At the local level, the peer exchanges were funded by this communication line item. SHRP 2 was a large program—$232 million over 9 years—and the implementation budget was another $160 million. The recommended amount for implementation is to be four times the research amount, so SHRP 2 got only one-eighth of the recommended amount; nonetheless, implementation was part of the budget.

Patrick Malléjacq referred back to the earlier question on commissioning research. France participated in a European research project in which the administration that was to commission the research did not have knowledge of the problem; the administration simply left it to the researchers to define the problem on their behalf. That is, there was a loop in which the buyer asked the supplier, "you do it on our behalf." There are also different types of users. "Why is there so much research on cancer?" Malléjacq posed. Because people fear dying of it. People figure they can deal with potholes, so fixing them is not as pressing, he said. Malléjacq suggested that it is important to engage with end users such as drivers, neighbors, and industry—the whole range of owners—on the demonstration of the research.

Stephen Andrle offered the reflection that more people die of potholes than die of the medical issues that are being funded, so there may be a societal disconnect. He referred back to a point that Horst Schulze raised, namely, framing the research in a way that ensures implementation. Joris Al, he noted, brought up the point that conflicting policy is a barrier to implementation. There may be too many conflicting policies. For example, solving a noise problem may conflict with a safety requirement, or dealing with flooding can conflict with a water quality policy. There are so many policy bodies that they may conflict. Who should be responsible for identifying the policy conflicts?

Harold Paul reflected back to Stephen Andrle's statement in his presentation that if one wants implementation of the research, one needs to consider implementation from the start. TRB does that, Paul said, by considering implementation of the products that will come out of the research and how those research products will be used. Government, academics, and industry are trying to solve the same problems, so involving them from the start is useful.

Paul said that he is a researcher, but he is also a funder and an implementer because, in his state, he is charged with putting his research into practice. He has reorganized his office because researchers do not know how to implement, he said. He reorganized and changed people's job descriptions so that some of them became accountable for implementation, and their jobs now have performance measures for putting research into practice.

Paul said that if one wants to track implementation, one must put that intention in the problem statement at the start. It is too hard to try to put it in after the fact, because one needs to identify the data that have to be collected. Finally, on the point of selling the solution, Paul said that researchers do not need to sell the solution to the users if the users came up with the problem. However, researchers may have to sell the legislature on it if the legislature funds the research. In his case, the legislature funds Paul's research and his whole department. Therefore, Paul has to think about the value of the research, and that is the marketing piece—to express the value of what has been created.

La Torre noted that the last point may be a fundamental difference between EU member countries and the United States, in that much research in the European Union is not funded by end users such as AASHTO, who would require that the value of the research be established in the research proposal. In the Horizon 2020 project, the funding is not done by end users. "If you do only research that is funded by end users, you will not get blue-sky thinking," she said. "But if you do blue-sky thinking, how will you get the research implemented?"

Beverly Scott mentioned that she is a funder as well as an implementer and has worked in organizations large and small. The back end differs, she said, as does people's and organizations' capacity. How research gets implemented depends on the back end, which is diversified. Scott manages a $5 billion capital program, but the R&D portion is very small. The people are very "get-it-done" oriented, she said, and she had to fight to get the R&D budget.

Barbara Harder has been looking at bringing accelerators from other domains into the transportation domain, and she has seen boundary-spanning activities dealing with the gap between researchers and end users. Harold Paul has taken staff to span the gap from research to the user, she noted. SHRP 2 has also done that by taking people who are great at connecting the dots. The U.S. Department of Agriculture has "partnership intermediary agreements," and the agency hires people who are experts at gap-spanning and getting the product used. The U.S. Department of Defense uses transition teams. Companies such as Dell and IBM use concepts such as "entrepreneur in residence" that look at the research being done internally with an eye toward the question "How could a business be built from the research being done?" In short, other domains have a role for people who know how to bridge the gap, and that concept is transferable to transportation.

Joris Al added another actor to the mix. Besides boundary-spanners who get research implemented, there is a need for universities to teach the new research concepts that have been identified. For example, in two cases he studied [(*a*) Sustainable and Advanced Materials for Road Infrastructure and (*b*) Assessment and Rehabilitation of Central European Highway Structures], he asked whether engineering concepts such as high-performance fiber had been implemented in Eastern Europe. That had been the ultimate goal of those programs—to transfer that knowledge to Eastern European countries. However, the cases stopped at proof of concept, and the concept did not get taken up in Eastern Europe. The lack of uptake was not due to a lack of funds but because the engineers did not know about the solution. It was not taught in the universities. Therefore, Al suggested that universities need to play a role in disseminating innovation. The time lag between research results and when that new knowledge gets taught in the curricula is too long.

Ángel Aparicio pointed out that the transportation sector may perhaps be unwilling to change, or unable to, because it is a closed sector that does not talk as much to society as other more innovative sectors do. He urged that more collaborative thinking take place.

La Torre agreed that much has been said about bringing together different perspectives but that the transportation sector is not there yet in achieving it.

Astrid Linder shared an example of how safety research was successfully implemented. In her case, two competing companies were working on the same research project. Having the dynamic of the two competing companies ensured that they would use what had been created in the research.

Terry Hill said that in the business arena, a key principle is to have the shortest line possible from research to market. Ten years ago, Hill closed his company's research department because it was losing touch with business. In its stead, he put R&D into each business line. That way, each business unit, such as high-rises, would be responsible for its own innovation. Hill appointed a director of research to coordinate the research projects, but the point was to put research into the business and make them hungry for the research, so that the end users demanded the research and the distance to implementation would thereby be as short as possible.

Pardi said that in her case, she had to document the economic impact of the research 2 years after her research project ended or give back the funding. This approach obliges the researcher to put the results of the research into practice. Such an approach may be a good one to emulate, she suggested.

José Viegas echoed what another participant had said: that "instead of TRB praising the results of TRB research, someone else should be praising it." He experienced a similar problem when he went to a mayor to discuss implementing his research, and the mayor asked, "Where else has this been done before?" Viegas replied that it had not been done elsewhere because it was a new idea. "Then how can I be sure it will work?" the mayor asked. "I have the research to prove that it will work," Viegas replied, but that proof was not enough for the mayor. Viegas noted that he was a Portuguese researcher and was going to a Portuguese mayor, but he still could not get his research implemented. "Should I go to the mayor of Paris?" he posed. But the Portuguese mayor persisted, "It's hard for me to be the first one to do it."

Following on the comment that universities should teach innovative research concepts, Viegas noted that professors can choose what they teach. His own classes are full because he teaches new concepts, but other colleagues do not; they may not even be reading the latest journals that describe the new research, and that is their choice. So if a professor chooses not to teach new research or concepts, there is no way to force him or her to do so.

La Torre added that many professors are simply professors, not designers. That is, they have never worked in the field they teach. If she could, she would forbid this. She believes that professors need to be involved in the R&D process and not just teach material that they have never practiced. Perhaps in the future, even if it is not possible to force professors to teach a particular idea, they could be forced to remain up-to-date and informed.

Andrle followed up on Linder's comment of the two competing companies being involved in the research. Andrle has done partnership procurements that stipulate that a public agency must be a partner to use the research. Thus, the research proposal includes the public agency, a university, and a consulting firm that together form a mini test bed that is then communicated to the transportation commission. Metrics are also important, because metrics such as travel time reliability add value to the research. The metrics used must be valid. Involving insiders in pilots provides feedback on those who are the first to implement the research idea, he said.

A participant who had worked at the World Bank added that anyone who does research without understanding the benefits and costs is missing a major point. He said that when he was chair of a TRB committee that looked at federal R&D, the committee would ask, "Why are you doing this research? Have you subjected it to a priority analysis?" The research must say who would buy it or what it will produce so that it can be compared with other research that could be done. He pointed out that more money is spent to prevent an aviation-related death than to prevent a highway death. Why? The key factor in highway deaths is driver behavior, the most important of which is alcohol use, so why not address that problem? Economic priorities should be addressed. A research project should be undertaken not because that particular research is cool, but because it can demonstrate real benefits. There is no business case for high-speed rail, but there is an economic case for high-speed rail, and that is the point. Businesses can evaluate research investments, but public research needs economics to prioritize research choices.

La Torre echoed that in the researchers' breakout group, many said that every research proposal should include a cost–benefit analysis.

Angela Miller added that in addition to the economic perspective, there should be a time perspective. She mentioned that in other industries the pace of innovation is faster, and that if the transportation industry cannot keep pace with change, then other industries will encroach into the industry without it having the context or nimbleness to respond. She mentioned the cybersecurity threat, now that cybervandals can make money from their nefarious actions and can jeopardize electronic vehicle control systems. The pace of research needs to be agile to stay ahead of such threats, she said.

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SESSION 4

Using Research Results in Effective Ways

Luis Fernando López Ruiz, *Administrator of Railway Infrastructures (ADIF), Madrid, Spain*
Allen Biehler, *Carnegie Mellon University, Pittsburgh, Pennsylvania, USA*
Christopher Martin, *Robert Bosch Corporate Research, Pittsburgh, Pennsylvania, USA*
Natalia de Estevan-Ubeda, *Transport for London, London, United Kingdom*

Jesús Rodríguez introduced the session by commenting that the company he works for, which has headquarters in Europe, has its main activities in Canada and the United States. Such cross-Atlantic corporate work points to the value of cross-Atlantic cooperation in research as well. He noted that research can cover different applications, but researchers can identify common inputs and outputs and can carry out the research in ways that make it more useful to buyers. The private sector wants to improve competitiveness, for example. Rodríguez explained that this session would cover four areas: railroads, roads, the interaction between modes and infrastructure, and, finally, the urban environment. For example, the Infravation program can serve as a guide for research proposals to involve industry, as well as the owners and operators of highway and roads, so as to demonstrate the potential impact of the project and the application of the demonstration results.

Implementation of R&D Results in Railway Infrastructure

Luis Fernando López Ruiz

Luis Fernando López Ruiz began by giving some background on his organization, Administrator of Railway Infrastructures (ADIF). ADIF is a public company under Spain's Ministry of Development and administers the Spanish railway infrastructure. Railway infrastructure administration involves overseeing railroad tracks, rail stations, and goods terminals. In particular, ADIF oversees rail traffic management, capacity allocation of rail to operators, and the royalties received for the use of rail infrastructure, stations, and goods terminals.

ADIF has almost 14,000 employees and manages 2,322 kilometers of high-speed rail and 13,000 kilometers of conventional rail. Fully 784 million travelers use the Spanish railway annually on 1.8 million trains that operate with 95% to 98% punctuality. ADIF's research facilities and labs are located in numerous areas within Spain.

ADIF's Research, Development, and Innovation Policy

ADIF's research, development, and innovation (R&D&I) policy is to bring developments into production. López commented that before he became director of R&D&I, he was responsible for operations; he noted the difference in mind-set between operational people who have to solve daily problems in the short term and researchers who work on long-term projects and do not have to face immediate problems. He pointed out that this difference in mind-set helps to explain why some projects fail and others succeed.

In 2006, ADIF evaluated whether, as a public company that manages tracks, it needed to have a specialized R&D department. Ultimately, the answer was yes, an R&D department was necessary, and the president issued a policy declaration outlining ADIF's R&D&I policy. Specifically, the policy called for R&D&I to

- Control and reduce technology risks,
- Give the company the ability to position itself at the forefront of technology,
- Develop and maintain a technology watch,
- Identify and prioritize the most appropriate mechanisms for protecting and exploiting research results, and
- Carry out the transfer of technological developments.

ADIF's R&D&I Process

López showed a chart of the R&D&I process at ADIF (Figure 1). The process starts with an idea and then moves to a prototype to evaluate technical feasibility. The next steps involve protection of intellectual property (IP), implementation of the technology within ADIF, incorporation of the technology into ADIF's production process through a marketing agreement, and documentation of the experience of its use and improvement, where applicable. The final step of the process is a transfer of the technology to third parties.

Next, López showed a chart of R&D&I projects undertaken. The number of projects undertaken increased steadily from three in 2005 to a high of 47 in 2011 and 29 in 2013. López pointed out that there was a gap in the number of projects started and the number completed. For example, in 2010, 44 projects were started but only 11 were completed. In 2012, 29 projects were started and 21 were completed. López noted that projects that have clear objectives end within the allotted time, but when the objectives are not clear, the projects take longer.

ADIF's R&D&I projects are classified into one of five technical specialties and one of four strategic objectives, López said. The five technical specialties are

- Infrastructure,
- Energy,
- Control command and signaling,
- Telecommunications, and
- Rolling stock.

The four strategic objectives are

- Increasing the operational performance of the infrastructure;
- Improving energy efficiency;
- Increasing the reliability, availability, maintainability, or safety metrics that make up the railway transportation system; and
- Developing the railway of the future.

López next described the five-step life cycle of projects. The life cycle begins with planning the basic requirements of the research and deciding whether to undertake the project collaboratively or only internally. The second step is executing the project (from detailed requirements to design, prototype, testing, and validation). Finalizing the project is the third step and is accomplished by documenting the results achieved. The fourth step is undertaking an internal transfer within ADIF to pass the research results into the production cycle, and the last step is the transfer to third parties (Figure 2).

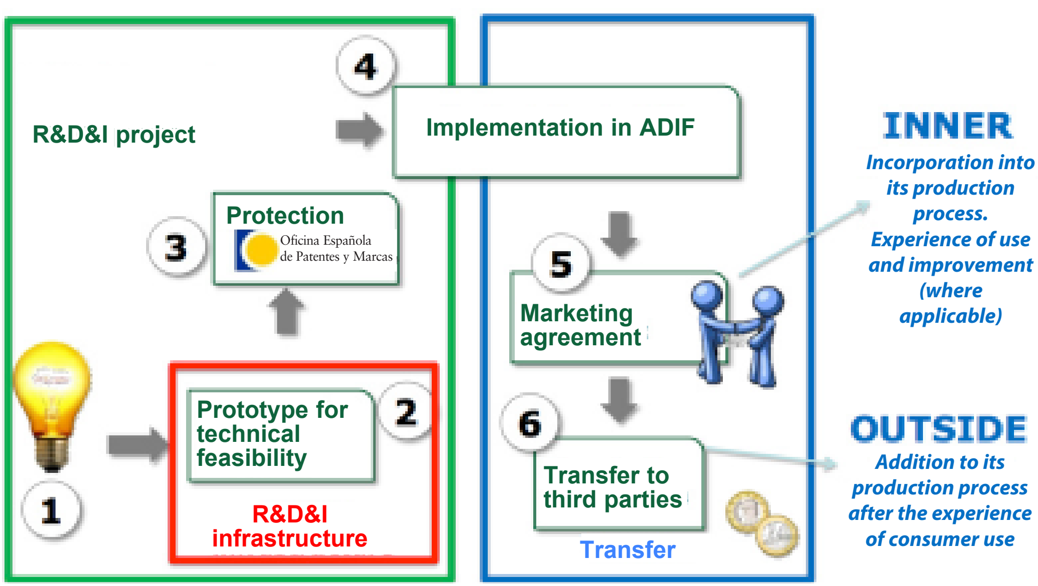


FIGURE 1 ADIF's R&D&I process. General direction of operations and construction. (Source: ADIF.)

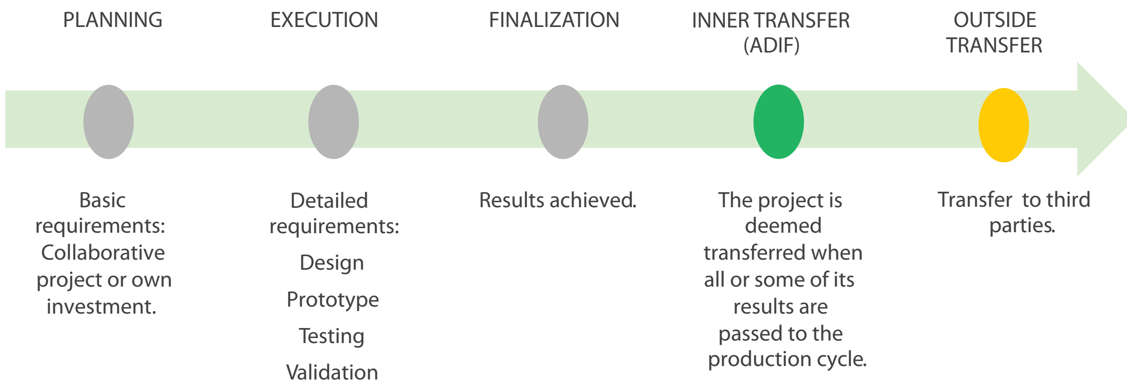


FIGURE 2 Life cycle of projects at ADIF. (Source: ADIF.)

Results of ADIF's Research Investments

Next, López discussed the results of ADIF's R&D&I investments. The overall budget of the R&D&I public–private partnership (PPP) projects as of May 2013 was €84 million, of which €57 million came from private partners, €20.9 million came from the science system, and €5.9 million came from ADIF. Thus, for every €1 that ADIF invests, the private sector invests €9.7 and the science system invests €3.5.

ADIF's research investments have yielded numerous intangible assets, including 25 national patents, 14 international extensions (Patent Cooperation Treaty, European Patent Office), seven licensed patents, 12 current licenses, seven national utility models, two licensed utility models, two current licenses, four national industrial designs, 34 national trademarks, six EU trademarks, three international trademarks, and six intellectual property licenses.

Commercialization Results

López concluded with a discussion of the successful commercialization results of ADIF's R&D&I, including the C-350 Contact Wire for railroad electrification, which was licensed to COBRA, SEMI, and ELECNOR and implemented on the international section of rail from Figueras, Spain, to Perpignan, France, and on the high-speed line between Mecca and Medina, Saudi Arabia.

What the successful cases had in common was that R&D&I identified a problem and then solved it. ADIF's production people have a say in what they want to improve so that R&D&I solves the right problems, López said. R&D&I makes prototypes and ensures they work and that the price and performance are better than before. All of the successful projects were collaborative projects.

Another successful commercialization project was the optical fiber falling objects sensor. The sensor detects whether something has fallen on the track, thereby providing high-reliability detection and early warning of problems. The system has a low maintenance cost. Another successful commercialization project was the lateral wind sensor, which detects high winds and reduces the speed of trains in response. The DaVinci traffic control system, another successful project, provides centralized telecontrol over multiple systems.

The reversible substation project, a fifth successful commercialization, increases energy efficiency by utilizing regenerative train braking. An electronic converter of direct current–alternating current recovers the electrical energy from braking trains and returns it to the supply network. Finally, the Ferrolinera 3.0 project was a sustainability project that developed and validated a system for charging electric vehicles by using the energy generated from the electric braking of trains. This project gives consumers an opportunity to recharge their electric vehicles at railway stations, which are abundant.

In conclusion, López said that the secret to implementation is close ties between people working in operations, research, universities, and supply.

Implementation of R&D Results in Operating Roads and Motorways

Allen Biehler

In contrast to López's focus on rail, Allen Biehler's presentation focused on roadways. Biehler described successful examples of implementation from research projects of four state departments of transportation (DOTs)—Arizona, Kentucky, Michigan, and Oregon—and identified common factors among them.

Arizona DOT Research

The project from the Arizona DOT examined wildlife–vehicle collisions that take place on Arizona roads. Vehicle collisions with elk or bighorn sheep are a serious problem in rural Arizona. Solving the problem is of interest not only to the Arizona DOT but also to the Arizona Game and Fish Department, which is why the Arizona DOT reached out to this sister agency to join the research team. Cooperation between the two agencies made use of their respective skills. The Arizona DOT could provide funding, project management, and implementation, whereas the Game and Fish Department could conduct the animal capture, GPS tracking, monitoring, and data gathering. The results of the research provided an interesting insight: elk will use underpasses, but bighorn sheep will only use overpasses, and the surface of the overpass matters to them as well. The Arizona DOT built overpasses and underpasses, which the wildlife is using regularly now.

The successful factors of the project included having engaged and involved sponsorship. Although the goals of the individual stakeholders differed (safe roads versus preserving animal species) the ultimate aim of both parties was the same: to eliminate wildlife–car collisions. Another success factor was positioning the project for implementation from the start.

Kentucky Transportation Cabinet Research

Biehler's second example came from the Kentucky Transportation Cabinet (KYTC), which for 25 years has had an exclusive relationship with the University of Kentucky. In particular, Biehler described the Cumberland Gap Tunnel floor settlement project. The tunnel is used by a major freeway that crosses Kentucky, but parts of the tunnel floor were sinking. This was a serious operating problem because detours around the tunnel were extremely long. The project used ground-penetrating radar to find voids and found 7,000 square feet of voids, an indication that this was a long-term problem. The voids were the result of the limestone subbase dissolving. The solution proposed filling the voids with inert granite material.

The lessons learned from this project were to keep the university involved in framing all the research and to have continuous collaboration between the university and the KYTC research team. Finally, implementation was woven into the capital program.

Michigan DOT Research

Biehler's third example, from the Michigan DOT, focused on longitudinal cracks in concrete box beams (i.e., cracking and joint problems). The Michigan DOT worked with researchers at Lawrence Technological University. The research delivered a series of transverse tensioning rods that used an alternative to steel—carbon fiber—as the tensioning material. The solution shows great promise in terms of less maintenance and significant cost savings, Biehler said. Indeed, Kirk Steudle, director of the Michigan DOT, reached out to work with a company in Japan that may now be doing an installation in Michigan.

The project is a long-term project that went through various test cases in Michigan. The challenge now is to develop specifications to implement the results, Biehler said. The keys to success were to solicit ideas from internal as well as external stakeholders; to develop effective research problem statements through collaboration of Michigan DOT experts, universities, and consultants; and to involve all levels of the Michigan DOT in the development and management of the research program. Finally, as with the Arizona DOT project, a focus on implementation from the start was vital.

Oregon DOT

Biehler's final example was the Oregon DOT's research-to-application process. The process involves three tiers of staff: an overarching Research Advisory Committee (RAC), Expert Task Groups (ETGs), and staff from the Oregon DOT research section who are experts in specialty areas. The ETGs comprise staff from the Oregon DOT—frontline practitioners, managers, and researchers—and from the U.S. Federal Highway Administration.

Each year, both the RAC and the ETGs set research priorities, with the RAC focusing on agency priorities and the ETGs focusing on topic area priorities. Examples of RAC priorities include improving employee safety, enhancing access and reliability, improving the environment, and reducing costs. ETG topic area priorities within the Traffic Safety and Human Factors ETG include urban–suburban design and features, continuing driver education to improve safety, and reducing the number of unsafe drivers.

After the research priorities are identified, there is a three-step solicitation, evaluation, and selection process. Research staff begin the process by working with the proposer to make sure the proposal is as good as possible, namely, that it addresses the priorities and includes an implementation plan. Then, the 90 to 100 projects are assigned to their respective ETGs, which narrow them down to the two to three best proposals in the topic area, which leaves 25 proposals. Those 25 proposals are then evaluated by the final section committee, which narrows them down to the final eight to 10 projects that will receive funding.

Common Factors of Successful DOT Projects

Biehler concluded by identifying the three factors that successful DOT projects had in common: a clear description of agency priorities and the research need, a continuous focus on implementation, and joint ownership by the agency and researchers.

Expediting R&D Results into Implementation

Biehler also offered three ideas for how to expedite R&D results into implementation. First, he urged drafting the implementation plan at the beginning so as to carefully think through what implementation means. The implementation plan also has to identify the funding and the time frame. Either of those may change, but defining them early on provides a rigor that positions the project for success. Second, defining the pilot test (in terms of both success and failure) was helpful, as was finalizing the implementation plan at the end of R&D. Finally, having a system for tracking the research program is also helpful. Biehler stressed this last point of having a tracking program. He acknowledged that some projects may fall by the wayside, but if most of them do, the agency is wasting effort.

User–Procurer's Approach to the Vehicle–Infrastructure Interaction

Christopher Martin

Christopher Martin's presentation looked at the challenges, opportunities, and success factors for bringing complex R&D to market. For Bosch, a successful outcome of research means that someone buys it.

Bosch Corporate Research

Bosch is the world's largest Tier 1 supplier of automotive products. Of 320,000 employees at Bosch, 38,500 are researchers and developers who work at 86 locations worldwide in a single network.

Each working day, Bosch files an average of 16 patents, which makes it one of the world's leading companies for patent applications and the one that has the most applications of any company in Germany. Bosch has invested more than €30 billion in research and development over the past 10 years. The research cuts across all sectors—transportation, energy, and consumer goods—and 80% of researchers' time is billable, so the research function is not an overhead expense. Bosch researchers are involved in 330 different engagements, and they work with academic institutions, so research is not just internal. Although researchers keep the consumer in mind when they execute research, the research organization is foremost a technology-driven organization, not a business-driven one.

Martin provided an example of Bosch's process for complex research using the example of vehicle-to-vehicle communication [and, more broadly, V2X (i.e., beyond vehicle-to vehicle and vehicle-to-infrastructure communication), because it can be vehicle-to-infrastructure, or to service providers, or to mobile phones]. Bosch is motivated to do this research because each year 5.4 million crashes occur on U.S. highways, resulting in 33,000 deaths and making traffic accidents the leading cause of death for people 4 to 34 years old. The annual cost to society of this problem is $260 billion. Besides addressing safety issues, V2X could also improve mobility issues. In the United States, the average driver is delayed more than 50 hours annually by traffic congestion. These delays amount to 2.9 billion gallons of gas wasted and an average congestion cost of $80 billion annually.

Automobile companies are working on V2X, as is the U.S. DOT. Together they have identified more than 100 V2X functions in the areas of safety, private-sector functions (e.g., electronic payments for services or for tolling), and public-sector functions (e.g., the optimization of traffic signal timing). These new functions have many complicated performance, safety, and security issues that involve a complex set of challenges and stakeholders, Martin said.

The overall challenges are how to design the solution and develop the surrounding system to address privacy and security issues. Addressing these challenges involves Tier 1 suppliers like Bosch and its customers (the original equipment manufacturers) as well as state DOTs, telecom providers, smartphone providers, and service providers. In short, it is a large, expanded ecosystem. In addition, users have changing and varied expectations.

Bosch's R&D Process

Martin next described Bosch's R&D process, which he offered as an example of how to implement innovation in such a complex ecosystem. He prefaced his description by saying that, like ADIF, Bosch uses a Stage-Gate approach. The first step at Bosch is to scout universities and consulting agencies to see if answers already exist. If not, then Bosch will execute the study, do market research, and develop prototypes; only after that will it do project engineering. Bosch Corporate Research then engages with specific Bosch business units that have specific domain expertise. That is, Bosch Corporate Research may be expert in battery storage, but the business unit would be able to translate that knowledge specifically into electric vehicles. In this way, the business units are involved as stakeholders. Researchers are supported by specific processes in which innovations are matched between Bosch Corporate Research and a Bosch business unit. Martin also said that Bosch has explicit transfer agreements, that is, "I will give you X, and you will do it in Way Y, and we can see if it paid off."

Project Management

Bosch R&D has a project management aspect to support the innovation process, Martin said. Project managers integrate the business side and the technology side. Bosch has high expectations of its project managers and does Project Management Professional certification. Project managers are evaluated not just on hitting their milestones, but on matching up what business units want, so that research delivers the right technology for the right issue. Bosch project managers understand concepts such as the "voice of the customer," so that research delivers what customers actually need, not just what they say they need. Project managers also do risk management, using tools such as failure mode and effects analysis, so that the innovation process is not a black box. Using such tools increases the chance of success from research to implementation, Martin said.

Martin then identified the top five challenges Bosch sees in the V2X world, which include the Internet and the world of connectivity. Bosch is expert in embedded systems, which has now expanded to mean the Internet of things. That expansion challenges Bosch's core competence. The expansion is a big challenge for Bosch and is forcing the company to change its culture. For example, what does safety mean in an Internet company? In the context of the Internet, safety is no longer just about the vehicle itself.

Martin discussed the complex stakeholder environment (Figure 3) and identified the challenge of prioritizing among all these stakeholders. In addition, as end users' expectations change (e.g., they want to bring the Internet with them into the car) and a new generation of drivers sees cars more as a burden than a right (and as something to share rather than own), Bosch has to change in response. It is an opportunity for Bosch, as a traditional embedded systems company, to engage in open, practical research and to open research test beds, partnerships, and business models that it did not have 10 years ago. Bosch is a global company, not a start-up, but it has a diversified competence base, in-house technology, and project managers who can be leveraged to rise to the challenge, Martin said.

Implementation of R&D Results in a Multimodal Urban Environment, Including Public Transport

Natalia de Estevan-Ubeda

Natalia de Estevan-Ubeda spoke from her experience at Transport for London (TfL), which commissions research from universities in the United Kingdom as well as from others that have transportation research labs, such as the Massachusetts Institute of Technology. Her goal for her presentation was to spark debate and pro-

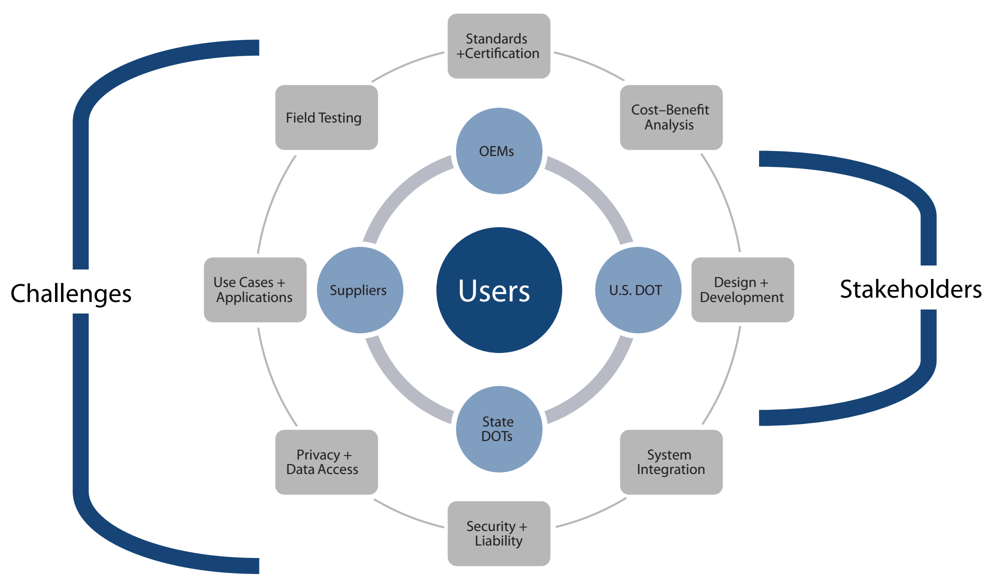


FIGURE 3 Challenge: Complex stakeholder environment (OEM = original equipment manufacturer). (Source: Bosch Research and Technology Center.)

voke a different perspective on how to have a conversation between end users (buyers) and researchers, such as through social media.

TfL Context

Estevan-Ubeda began by describing the context within which TfL operates. Specifically, TfL is responsible for managing all modes of transportation in London except airplanes. Roads, rail, bicycles, trams, cable cars, subways, pedestrians, barges, buses, and taxis all fall under TfL's purview. "Our job is to keep London moving," she said. Unlike cities such as New York City, which is laid out in straight lines, London has many winding, old roads. It also has 30 million visitors, so 30 million daily road journeys present a huge challenge. The £8 billion budget of TfL is funded by public money from the mayor of London, the government, and public transit fares. TfL must keep major highways running, as well as 6,000 sets of traffic signals, and it must integrate buses, light rail, and the subway. There is a great opportunity to make the most of all these modes and integrate transportation in a multimodal way, Estevan-Ubeda said.

Understanding Customer Needs

Achieving success, however, requires understanding what customers want, which raises the question of who TfL's customer is. TfL has two kinds of customers: traffic managers and travelers. When trying to get insight into what customers want, TfL discovered that the Olympic Games transformed TfL's reputation for the better, but that reputation is not rational; that is, people do not just experience TfL's service, they feel it. Their experience of the journey is not determined solely by reliability and journey time, but also includes the physical experience of comfort and convenience as well as an emotional experience, such as feeling safe or feeling crowded. Thus, TfL discovered from its customer research that it is not enough to provide a service, such as bus service; TfL must also support the customers' feelings of comfort and security during their journeys.

Examples of End User Involvement in Research and Implementation

Next, Estevan-Ubeda provided two examples of how TfL involved end users in research and implementation. Her first example was about innovation in road space management, namely pedestrian countdown timers at traffic signals (PCaTS).

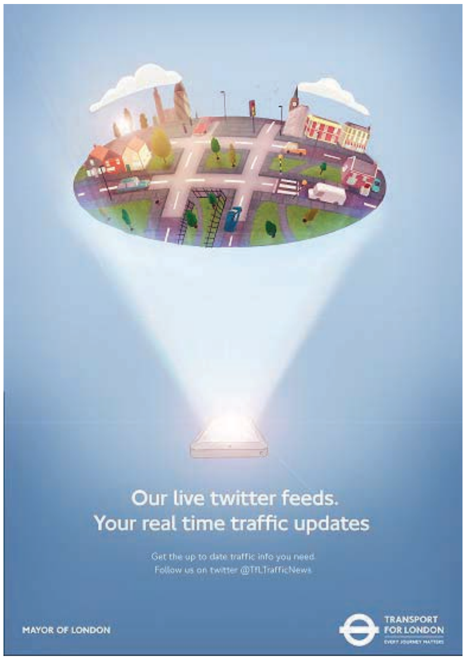
These timers are not a new concept, and companies have market-ready products, but that is not enough for TfL. TfL must ensure that the products will work in the London context. Being off-the-shelf does not mean a product is finished, Estevan-Ubeda said. Indeed, TfL's research showed that not all pedestrians understood that the green man on the traffic signal indicated an invitation to cross the street and that the black-out period showing neither the walking green man nor the stationary red man indicated that they should not cross the street. Therefore, TfL conducted off-street trials, testing a mock-up crossing with and without PCaTS.

The research involved more than 250 pedestrians, including groups of mobility-impaired pedestrians. Questionnaires were used to establish pedestrians' understanding and opinions of traffic signals, including PCaTS. After the off-street trials, TfL received approval to conduct on-street trials. TfL commissioned research to be done via face-to-face interviews as well as video analysis to assess pedestrian perceptions and behaviors. Sites were selected to ensure that a broad representation of pedestrians was included in the research. Results of the research showed that a clear majority of the pedestrians liked the countdown, that it reduced pedestrian uncertainty, and that it let them make more informed crossing choices. PCaTS have been introduced in London without a negative impact to safety, and the eight original trial sites have shown a 58% reduction in those who were killed or seriously injured 3 years after PCaTS introduction. In short, this example showed that TfL's research investment is not just in the product itself but also in the application of the product.

Using Social Media to Inform Implementation

Estevan-Ubeda's second example was on the use of social media to inform research implementation. A year ago, TfL did not use Twitter at all, but now it uses Twitter on a daily basis to engage with customers. Customer comments on Twitter do not guide TfL's capital program, but Twitter does provide a way to engage with customers (e.g., getting information that a traffic signal is not working or that there is a big pothole on a road). TfL has more than 210,000 followers on Twitter and uses Twitter to address reputational issues and foster engagement with the end user on the street. TfL puts out about 100 tweets a day, and 81% of its followers have changed their traffic plans as a result of TfL tweets about the congestion or delays at certain locations (Figure 4).

Results of TfL's Twitter customer satisfaction survey in 2013 showed that TfL's real-time twitter feeds were checked often (80% of users checked them at least once a day) and that people were most likely to look at the feeds when checking Twitter generally (78%), with half



24/7 operations

100 tweets per day

81% of followers have changed travel plans as a result

More than 210,000 followers

FIGURE 4 TfL's maximization of the use of social media. (Source: TfL.)

of users also referring to the feeds before they traveled or during their journey when they encountered a problem (47%). Fully 79% of TfL's Twitter followers changed their travel plans as a result of the information provided on the feeds, and most chose a different route (59%).

Applied Research

TfL had to rebrand its R&D as something that was not blue-sky, because taxpayers did not want to be funding blue-sky research, Estevan-Ubeda said. Rather, TfL's research focuses on trials and applied research. TfL research is business case driven. For there to be a business case, there must be an end user. Every research project undertaken at TfL must have a specific purpose to justify the investment.

A new area in which TfL is now investing is cooperative systems and vehicle-to-infrastructure. TfL needs to know what will hit it and be at the forefront of thinking, Estevan-Ubeda said. TfL realized it did not know the implications of technologies such as intelligent transportation systems (ITS) and sensors on vehicles, so through public procurement it invited public companies, manufacturers, academics, and suppliers to engage in scenarios: "If we did this, what would it look like? What would you do first? What partners would you engage?" TfL has now commissioned some research contracts with private companies and academics.

One of the obstacles that Estevan-Ubeda mentioned was that sometimes a vision is not understood in the same way by everyone. An ITS cooperative network may mean different things to different users. Similarly, the term "applied research" may have different meanings to different groups, so the question "what does it mean to me?" has to be addressed. TfL actively engages in budget prioritization and solves for tomorrow but not for the day after tomorrow, because TfL does not have a budget to look far forward.

Closing Remarks

In her closing remarks, Estevan-Ubeda offered five comments. First, she suggested involving the end user directly and indirectly (through trend data). TfL is a data-rich company and invests in translating that data into intelligence.

Second, research started by the public sector is different from external innovation. Sometimes TfL will tell the market what it needs, and other times external players will tell TfL, or TfL will just let it happen. For example, in cooperative networks, TfL engaged app developers. TfL did not tell the developers want it wanted; rather, it just told them the challenge and gave them access to the data. The mandate to the app developers was to "make life easier for end users." Thus, TfL's influence was not directive in that case.

Third, end users value tangible outcomes the most. Customers can see apps and the pedestrian countdowns. If TfL were to invest only in back office systems and business intelligence data fusion, customers would not see tangible outcomes. It is important for the research community to give end users some tangible benefits.

Fourth, research can change opinion through facts, Estevan-Ubeda said. Finally, TfL has had success with feedback loops. TfL plans for the whole life of the project but does sense-checking to see how it applies. TfL does not want to engage in a 2-year research project and find out at the end of the 2 years that the project does not work. Rather, TfL engages in constant communication with users and industry. TfL's Cooperative Network project, for example, began in 2012 and meets every month with both the public and private sectors.

Discussion

Raj Rajkumar reminded participants that the purpose of this discussion was to ensure the effective use of research results at the end user level. He then proceeded to ask a question of each of the session's presenters. First, he asked López whether his research projects are driven only by internal research activities or by external ones as well.

López answered that they have two kinds of projects. The first kind has a national or international goal, and the research projects usually come from a study by commissioners of different specialties who put the problems on the table and then select the most interesting projects to pursue. Sometimes it is an internal project and other times they ask for external input.

Rajkumar then asked Biehler, who was formerly secretary of the Pennsylvania DOT, to comment on how research outcomes can influence that state's DOT planning into 2040. **Biehler** replied that the Pennsylvania DOT commissioned Carnegie Mellon University (CMU) to help them understand what might happen by 2040. The year 2040 was chosen because it was far enough away that the Pennsylvania DOT thought connected vehicles would be ubiquitous, and the agency wanted to know what that would mean for it. In particular, the Pennsylvania DOT wondered how it should invest and how it should operate in that changed world, because autonomous vehicles would even change driver licensing. The research was a way to stretch everyone's thinking. Pennsylvania had recently passed a large gas tax to fund transportation expansion. However, if a $100 million transportation investment were to be made, some thought should be given to the future because traffic flow patterns will have changed in 25 years and because of the need to think multimodally. DOTs in the United States tend to think about highways first, but perhaps lanes should be set aside for autonomous vehicles or intermodal travel, Biehler said. The Pennsylvania DOT will be working in a continuous partnership with CMU researchers throughout the year-long project and meeting monthly to allow for course corrections. The research will challenge the agency to think differently about future actions as well as about workforce education.

Next, **Rajkumar** asked Martin the following question: since Bosch both creates and consumes its own research, how are research projects spawned? **Martin** answered that Bosch funds its own research but also funds research by universities, with Bosch R&D staffers being charged with making the research happen. The corporate R&D staff consists of researchers who then transition the research to business units. Every 2 years, the Bosch research staff is measured on the number of $100 million projects generated. Last year, Bosch's R&D budget was $250 million, so the return on investment (ROI) should be for six or seven $100 million projects to come out of that. The five to ten times ROI over the lifespan is aggressive, but not extremely aggressive, Martin said. The target ROI is likely to be more aggressive in the future because of the R&D options that Bosch has. Corporate R&D competes with start-ups and universities—all the different places where innovation lives—so Bosch R&D staff must deliver the most innovation bang for the research buck, even if doing so means extracting innovation from external sources like universities.

Finally, **Rajkumar** asked Estevan-Ubeda to talk about how researchers view outcomes that affect daily operations when things go bad. **Estevan-Ubeda** answered that the London Streets Traffic Control Center has a variety of tools that it uses for daily operations. To bring research into that Center, TfL researches software packages and has worked with operators in real time to change the way the system responds to what operators need. Through this deployment of people on the street to support engineers, research has been closely linked with daily operations. The researchers also believe that an intelligent client is a critical success factor in the implementation of research. That is, a company has to have the intelligence and know-how to operate the research, otherwise the research will not succeed.

Rajkumar then opened the floor to questions from the participants. **Steve Phillips** asked a question about using research to inform the public with facts. Trust is an important factor in decisions to implement research, but people tend not to trust facts as much as they trust the messenger. So, Phillips asked, how do TfL and Bosch make sure that the facts they convey are trusted?

Estevan-Ubeda answered that TfL has a big marketing budget, which may be unusual for research but which is needed to keep TfL's customers informed and involved in how TfL is delivering research for them.

When customers use the London subway or wait in a bus shelter, they see posters about what TfL has done. TfL influences customers in their travel choices and is responsible for telling them the status of transportation operations. Sometimes TfL is not believed. If TfL says there is no congestion someplace but customers experience a 5-minute delay, they may think that they were stuck for hours although it was only for 5 minutes. Customers see the status of the road network and where a delay is on the subway line. Marketing does not just give statistics; it also uses more appealing ways to show how research money is being invested. For example, TfL has a poster of a submarine with the TfL logo that says, "The technology that guides submarines tells you when your next bus will come." Perception is important, Estevan-Ubeda said. If customers think there was a delay, TfL cannot tell them that there was not.

Steve Andrle asked two questions of Martin: whether Bosch shares IP with university faculty and whether generating several $100 million products a year is based on forecasted sales. **Martin** answered that the $100 million is a measure of sales forecasts through transfer agreements with business units, so the business units work it into their sales projections. Those sales projections are then tracked by the board of directors, thereby closing the loop of tracking innovation and investing in innovation. Tracking innovation is now ingrained in the entire corporate culture and not just within R&D. A business unit says they got research from corporate R&D, and they track the resulting sales.

To Andrle's question about sharing IP versus funding university research outright, Martin explained that it varied. In some cases CMU got the IP, and in other cases the university got royalty value. Bosch has had a 25-year relationship with CMU going back to the late 1990s, when the two signed a master research agreement that defined IP rights, a gift, and sponsored research. The agreement is amended yearly. When Martin works with the University of California, Berkeley, on the other hand, the terms are different because the relationship with the university does not have a long history. Recognition of IP is bigger now, and starting from square one is hard. Most of the research is gifted research, in which one party gives X and the other keeps Y, Martin said.

Peter Sweatman of the University of Michigan referred to the test beds and demonstrations mentioned in the presentations and made a plea for researchers to "get their hands dirty" and do bigger deployments. For example, he gets 40 volunteers per day who come to the University of Michigan and leave with new beneficial technology in their cars. Because the university is known as a great research institution and innovation leader, it can get a deployment of beneficial technology in 20,000 vehicles. Another point Sweatman made is that, with ubiquitous sensors, there is a great deal of data at low cost that are available to anyone, not just to transportation researchers. Greater access to data and computing power means that now anyone can do data analysis. It is not just, "This is only for professionals; do not attempt to do this at home," Sweatman said. Researchers have to be implementers, demonstrators, and innovators.

Alasdair Cain said that researchers and funders are separated because of the impartiality demanded when taxpayer dollars are used; many protections are in place by legislation. How is it possible to work closely with end users without incurring the perception of favoritism or corruption?

Estevan-Ubeda answered that the perception of favoritism would be bad, so TfL makes sure that everything is done through a formal procurement process. TfL is a big entity, so the private sector wants to pitch TfL to buy X, but then TfL could be accused of providing unfair advantage to one player by not talking with other players. Therefore, TfL launched open communication events called notices of procurement. TfL hosts these public events, which describe what TfL is seeking to procure. Private-sector companies can register their interest and attend the events. In this way, all the companies receive the same message and budget figures and have the same time scale. After that event, the companies can come back and talk with TfL privately, because they might not want to share their IP at a public event. But the event is a way for companies to formally register their interest in working with TfL and then come back for one-on-one follow-up. This process provides for public engagement with everyone openly and offers a way for further follow-up privately.

Biehler answered that in Pennsylvania there is a law about PPPs. Twice a year, for a period of 30 days, there is an opportunity for anyone to submit unsolicited proposals to the Pennsylvania DOT. There is a review board that has a rigorous process for evaluating the proposals and that then publishes the responses of its deliberations publicly.

López answered that he likewise follows the laws for PPPs, so his company has to figure that separately from the rest of the company and put out a call or a contract that must be approved.

Jonathan McDonald asked about the role systems engineering plays in the implementation of research and where the dividing line is.

Martin replied that Bosch, right from the start of the project, has support processes for project management. At the start of a project, Bosch uses quality function deployment to scope out the work product and have discussions with the business units that ultimately own the system to which the research artifact is deployed. This process has changed over the past 25 years. The process formerly was a black box, but as the world has gotten more complex, there has been a need for more transparency so that the buyer or adopter can understand the process and the researchers, in turn, can understand the business unit's needs. Ultimately, Bosch is a systems company—it makes the subsystems that make up a car. Bosch not only integrates the technology but integrates it from a process and project management perspective.

La Torre asked whether, when expanding research to include not only the research itself but also its implementation, there was a structure for researchers to do the trials and the cost-effectiveness and feasibility studies. That is, does TfL have a research team and a separate implementation team? She remarked that in Europe they do not have implementation teams.

Estevan-Ubeda replied that it is a structured approach. Parts of TfL deal with the vision, scoping, and blueprint of the research; then that vision is taken up to further research (which can be internal or external). After that, TfL has systems engineering as part of its integration approach because TfL has grown to be a huge system over the years. Estevan-Ubeda offered an example of a research project done for the Oxford Circus area of London. That research was done by the teams who commissioned the research. The project had to have a business case in order for the research to get funding. Once the project was funded, it moved to the traffic infrastructure team, which did the research. Once the research was done, the project moved to the implementation team, who are experts in rolling out programs. Thus, there is a research team, but if the result is product based, then it will be deployed through the implementation team. TfL recently underwent a restructuring that resulted in separate outcomes and sponsorship teams. The sponsors generate the project, and the outcomes team ensures that the needs of the project are met. Finally, the operations team does the day-to-day running of the project.

A participant asked Biehler and Martin how each organization ensures that another part of the organization is not duplicating the research. For example, another state's DOT might be interested in knowing the solution to the problem of the elk on the road.

Biehler replied that states learn from TRB and from AASHTO, and that within AASHTO there are four different regions of the United States that get together. In addition, some states find it useful to be members of the American Public Transportation Association and read its journal. Nonetheless, in some cases there is such a blur of research that it is overwhelming. People wonder which projects had good research outcomes, so ways to share research by topic are still needed. The whole connected autonomous world changes so fast, Biehler said. In short, resources from AASHTO, TRB, and the U.S. DOT are ways to learn about research that has been done.

Martin answered that for Bosch it comes down to processes and people. First, the process in the six-stage chart Martin showed on one of his slides is generic compared with the actual process of doing the study, coordination, and funding. Bosch Corporate Research comprises 1,300 people around the globe. Given the way the process is coordinated and the latency of research, attempting to avoid duplication is a necessary evil and the process is not perfect. Thus, Bosch has some processes that might go slowly, but the goal is to be less wasteful.

Second, the percentage of people who are researchers within Bosch Corporate Research has decreased, while the number of project managers, controllers, and evaluators has increased. The evaluators quantify the value of the research being done. Thus, the controllers are nonresearchers who support the research. Bosch also uses more social media platforms internally to let colleagues build and maintain relationships, even though they are working in different countries. For example, Bosch has a social media platform that is like an internal Twitter. The company also uses Microsoft Lync as a virtual water cooler. There is a saying at Bosch that you always meet twice—virtually and in daily relationships.

Steve Andrle wondered whether, when Bosch links with other people's systems, they find new standards. Andrle remarked that these standards could be as important as the research itself.

Martin answered that yes, Bosch has a central function that engages with standards bodies and that Bosch is part of ISO 26262. Bosch has experts that participate in the standards bodies and also sends people from business units or corporate research to stay engaged. One surprise to Martin was that he never thought Bosch would be part of an Internet standards body, but now the company is participating in the Internet-related standards process of the Internet Engineering Task Force, although Bosch is not a member of it.

Ángel Aparicio was curious how a big organization such as Bosch manages incremental versus radical innovative research. For example, how does Bosch decide whether to do research on the development of electric cars or research related to conventional cars? Similarly, how does TfL allocate research among the competing modes of transport?

Estevan-Ubeda answered that addressing one mode may have an impact on another mode, so TfL has competing demands and conflicting targets. If TfL does a lot of promotion of pedestrians and cycling, what is the effect on traffic flow? TfL does give attention to "managing competing demands" and has outcomes shared between all transportation modes. There are layers of meetings, and TfL tries to avoid silos. Different boards look at cross issues and what they mean for investment and by-products, versus disruptive innovation like the submarine technology. TfL does more incremental change because it cannot afford to have something not working, but TfL can also use cooperative networks to look at more radical change further out, such as Horizon 2020. The Greater London Authority, TfL's parent organization, is looking at Horizon 2050 for big step changes.

Martin showed the innovation curve of incremental versus disruptive innovation that frames the question of incremental versus disruptive research as one of risk management (see Session 2, Figure 5). Where should a company make innovation investments? Disruption happens when a company has been focusing on X, but Y comes along, and Y is more important to customers. For example, Bosch could be focusing on reliability, which is incremental, but that reliability research could be disrupted by security. Cybersecurity has suddenly become a concern of customers because the linking of cars to the Internet makes customers vulnerable to cyber attacks or the Internet being down. Consumers now care more about security than reliability. The question is how much to invest in disruptive innovation and how to communicate the value of it. Bridging between disruptive and incremental innovation requires managing the risk portfolio, which is a big challenge.

Munro asked whether Bosch purchases licenses for commercializing a technology from a third party and, if so, what percentage of licenses were third-party licenses. **Martin** replied that the company does purchase licenses for commercializing a technology from third parties, but that the percentage is lower because of Bosch's large internal R&D.

Kevin Womack ended the session by requesting an additional discussion point for participants to consider in their breakout groups. A report that came out in December 2013 found that the U.S. DOT portfolio was overweighted with applied research and should focus more on advanced research. On the continuum from basic research to applied research is a middle ground of advanced research, which is more like blue-sky research. Womack said that, so far, the symposium discussions around the processes and successes of applied research programs have been great, but the discussion of blue-sky research has been sparse. How does one implement the results of blue-sky research? He asked individuals in breakout groups to discuss how blue-sky research can be sold to an adopter to ensure implementation of that advanced research. If the U.S. DOT were to get only research outputs but not the valuable research outcomes of blue-sky research, the program would not last. Bridging the valley of death is hard, but he would like to see more discussion of how to get the valuable outcomes of advanced research implemented.

Womack also referred back to Terry Hill's suggestion of writing a primer on how to do implementation of advanced and applied research. He asked that, as the participants looked at the three questions in the breakout groups, they also look at those questions through the lens of advanced research.

To Rajkumar's question about whether the U.S. DOT would be creating new programs of advanced research or redirecting existing ones, **Womack** replied that this new focus would apply to new research programs.

Hill added that he worried about where the big leaps will come from. He sits on the advisory board of Department of Engineering at the University of Cambridge, United Kingdom, and when he gets a tour of the labs and the research being done, he wonders how it will be used. What does one do with materials that are stable in two shapes? It is stunning, but what is it for?

Trentacoste added that 10% ($10 million) of the U.S. Federal Highway Administration's research budget is earmarked for advanced research. He, too, wonders how to get end users to implement the results of more exploratory research.

BREAKOUT SESSION 2

Identifying the Success Factors

Unlike Breakout Session 1, in which participants met in one of three groups, according to their professional affiliation (funder, implementer–user, researcher), the format of Breakout Session 2 randomly assigned all participants into three mixed groups.

Breakout Group 1

Martin Schroeder summarized the five key points that emerged from Group 1's discussion. The first point had to do with the definition of research and the different research types. Advanced research is defined as involving higher risk and is not necessarily tied to a product. Applied research, in contrast, is tied to a known problem or product.

The second key point was to connect advanced research with the end in mind. Even though advanced research does not have to be tied to a product, advanced research must be tied to a purpose. The purpose sets the context for the research. There has to be a concept of the purpose for the work and for the vision. For example, a mission statement such as "going to the moon" provided a clear vision and end goal.

The third point was the idea of using consortia to connect research needs to the end user. In the United States, for example, Technology Watch has the goal of identifying promising research. The identification goes both ways: the agency weighs in on the research topics and so do end users such as road system operators, who need to be aware of advanced research. The European Union has its own way of identifying promising research topics. In addition to being aware of advanced research in transportation, users such as those in transit systems and road systems also need to be aware of the advanced research in other disciplines, because it could be relevant to transportation.

The fourth point was awareness of the full funding requirements from advanced research through to product development. It is useful to know the cost estimate from the start, because that information could help in the decision of whether to do the research. It may not be feasible to undertake expensive research that would then require another tenfold investment to get the research to implementation. For example, a country will not undertake the replacement of all of its existing rail, so research that would lead to that end is not fruitful.

Finally, procurement practices need to encourage innovation. Currently, procurement is based on a lowest-bidder approach, which forces procurement of old solutions. The procurement system has to be restructured to provide incentives for innovation. An innovative solution may cost a bit more up front but will save much more in maintenance or over the entire life cycle.

Breakout Group 2

As in Group 1, the participants in Group 2 had an initial discussion about the different types of research and the aspects of vision, risk, implementation, and evaluation–financing of the different research types. **Urban Karlström** provided a recap of the discussion.

Types of Research and Their Implications

Several people in the group identified research on two ends of a continuum: advanced and applied. Advanced research is entirely driven by researchers. In contrast, applied research is driven by those who own the problem. Advanced research needs a vision, framework, or context under which it should be undertaken. It is essential to define the research so that it is focused but to give researchers the freedom to do what they want within that framework. The two types of research also vary in their risk profiles. Advanced research is high risk and long term in comparison with applied research. Finally, the more advanced the research is, the more interdisciplinary it should be. In advanced research, implementation might constitute the identification of the next steps of the research.

Applied and advanced research would be evaluated differently because each has different merits. Therefore, the criteria for funding should be different as well.

Likewise, different financing tools are needed for the different kinds of research. A portfolio is needed for both applied research and advanced research. Those portfolios will differ on the basis of the institutional situations of different countries.

Impediments to Application of Research

Individuals in the group identified six impediments to the application of research:

1. Lack of incentives to apply the research. From the point of view of the researcher, there is no incentive to work on the application of the research because doing so will yield neither academic recognition nor funding. The solution is either to provide academic recognition or to provide funding for implementation as an incentive for researchers.
2. Lack of understanding that research is a tool. In the public sector, few administrators or implementers understand that research is a tool that will help them solve their problems. Therefore, they are not looking at research and trying to apply it. Some members of the group thought that it would be beneficial to help these implementers–users to understand that research is a tool that can help them solve their problems, and that this could be done through communication.
3. Lack of cooperation between industry and academia. Industry and academia need to support each other and understand each other's processes.
4. Standards and regulations. Standards and regulations can both impede and enable implementation. In some cases, regulation can be an impediment to applying research, as when, for example, regulations or standards specifications do not allow new materials. In other cases, standards have been necessary to the application of research, as in the case of autonomous vehicles. Advanced research could identify the standards that would promote the operation of autonomous vehicles.
5. Communication. Although communication is vital, it is difficult and requires a skill set different from that of researchers. In addition, the communication must be ongoing. For example, the perfume industry continuously communicates that people need its product. Some in the group thought that continuous communication might be one way to increase the application of transportation research.
6. Culture. There is a need for a research-to-innovation culture, and this need boils down to leadership and people. People need to see the importance of research.

Karlström concluded by saying that the entire session could be distilled to one word: incentives. If the incentives are right for the system, it will work. If they are wrong, it will not work.

Breakout Group 3

Breakout Group 3, summarized by **Max Donath**, likewise distinguished between various kinds of research and then offered suggestions for tackling the impediments to applying research outcomes. On the continuum of research, advanced research pursues what he called "reach goals," such as the elimination of all roadway deaths. Applied research, in contrast, goes for the low-hanging fruit by examining standards, processes, or systems engineering. Some in the group offered the following suggestions:

- Regarding the driving elements that lead to deployment of innovative solutions:
  - Define and articulate the vision.
  - Set aside a percentage of all funds for advanced research that is different from applied research, so that the two do not compete with each other (suggestion for funders).
  - Reward innovation by giving a bonus to all partners who move the research forward.
  - Define success, because advanced research has different criteria for success. If researchers do not fail on occasion, they are not reaching high enough. It is not a failure but something to be learned from the process.
  - Conduct field operation tests under real-world conditions. Create the environment to test and deploy ideas in the field.
- Regarding impediments to the application of research outcomes:
  - Spread risk by teaming between partners, such as departments of transportation (DOTs) and agencies. State DOTs can pool their funds for research, but they have been funding applied research. They may also need advanced research. The same is true for different countries.
  - Foster a culture of innovation among DOTs and agencies. Deployers are risk averse.
  - Articulate a return on investment for investment in research and, perhaps, rebrand research and get it out there so that people understand it. The average person on the street does not know how research is connected to final deployment.
  - Target funding for advanced research and recognize that, regardless of whether research is technology pull or technology push, technology transfer

is still needed. Researchers need to go out and mingle with users to understand their environments.

- Regarding factors that inhibit deployment: Procurement rules need to move away from the low-bid model. Instead, these rules should reward innovation through incentives and by providing liability protection, because agencies are so averse to risk. Agencies should be protected from potential liability when they implement innovation. This means procurement rules should be based on functional performance and not on technical specifications.

SESSION 5

From Principles to Practice

Kirk Steudle, *Michigan Department of Transportation, Lansing, Michigan, USA, and Chair, Transportation Research Board Executive Committee*

Final Discussion

John Munro said that Chris Martin's perspective on how the private sector incentivizes research was missing; other participants, however, felt that this concept was captured under the "incentives" rubric.

Liam Breslin raised a question about the distinction between advanced research and other kinds of research, to which **Francesca La Torre** replied that advanced research was top-down research that was driven by researchers without end users asking for a product or asking directly for an outcome. She noted that implementing applied research was easy because end users help to frame the research question. On the other hand, basic research is not directly tied to an outcome; therefore, the question is how to get basic research implemented.

Patrick Malléjacq said that communication is important and that sometimes people's behavior does not seem rational. That is, people are presented with a solution that is cheaper and easy to implement, but they do not apply it because of disincentives. He thought that sociologists and economists should be involved in the process.

Alessandro Damiani mentioned that the role of venture capital as a bridge over the valley of death was overlooked in the recap.

Max Donath pointed out that public–private partnerships incentivize both parties and suggested creating bonuses for the two groups to work together. Research into understanding how to create successful partnerships would also be fruitful.

Chris Martin mentioned that he had research on how to use venture capital as a bridge over the valley of death and suggested some seminal articles on that for a bibliography. Martin invited any other participants to contribute to a bibliography of relevant materials on the topic.

Steve Phillips mentioned that there was a difference between advanced research and very innovative applied research. Innovative applied research is still applied research, and thus it has a very different process and research chain. He said it would be crazy for all funders to be mandated to set aside funding for advanced research, because some funders would not be good managers of advanced research. Rather, funders should focus on their core competencies. For example, road agencies should focus on applied research.

Bill Millar added that a mechanism should be put together to ensure that adequate advanced research is done. The key is having a mechanism in place for advanced research, he said, not that each funder has to conduct advanced research itself.

Phillips said that there is a big gap in trust. In the past, there was a good ecosystem of state departments of transportation (DOTs), national research labs, and universities, so that basic research was translated. That ecosystem has now been lost and needs to be recreated. The answer, however, is not that more funding of research is needed. Rather, current funding must be better spent.

Millar tied Phillips' comments back to the concepts of framework and context, and **Munro** linked them to the portfolio concept as well.

Cristina Marolda talked about the continuum of research and the difficulties in setting boundaries between the different phases. She felt that funding was the least of the problems. Rather, there are different competencies that are needed at each stage, and projects are concurrent. Sometimes basic research can deliver a solution, and sometimes an applied project can yield a new concept. Ideas on how to cross-fertilize the different stages and ensure communication across the continuum are needed. Citizens want value out of all research, not just pieces of it.

Damiani said it was important to keep in mind the dual EU–U.S. nature of this symposium. To say "we need more basic research" could be misleading because the EU framework program is 80% basic research, whereas in the United States the balance of basic to applied research is flipped. The United States is seeking more basic research, and the European Union is seeking more applied research. Thus, joint collaboration could help both parties.

Bob Skinner commented that the portfolio concept was useful, and he agreed that research organizations should play to their strengths and not be expected to do both applied and blue-sky research. Context dictates what the portfolio makeup should be, he said. For example, a developing country would likely do no blue-sky research but would instead scan the research that is already being done. Similarly, what one country in the European Union does or what one state does may differ from what its neighbor does.

Alasdair Cain saw three main areas of improvement: partnering, consortia, and procurement reform. What was missing was the idea of implementation agencies, which Breslin had raised on the first day. That is, some agencies should be responsible for the implementation stage and have the funding to do so, such as the U.S. Federal Highway Administration and the second Strategic Highway Research Program.

Millar concluded the discussion by summarizing the main points: the portfolio or continuum of research and risk sharing. He thought that researchers should frame the research and the context and the area of communication early on to connect researchers to the longer term as well as to the entity that has a particular need to be addressed.

Concluding Keynote Address

Kirk Steudle

Kirk Steudle said that the future is developed by research. Prior research has influenced society in big and small ways; research leads to what happens in society.

Over the 2 days, participants heard about many research perspectives that have many different angles: traditional research institutions, modified research institutions that focus on blue-sky research, and groups that focus on applied research. Participants also heard from industry and private R&D, which is driven by the need to improve productivity and the quest for competitive advantages.

In addition, participants heard about government-supported research at different levels: the national level (European Union or U.S. federal government), the state or EU country level, and cities and network operators. The EU country level and U.S. federal level focus on long-term research, and much of the process is driven by funding distribution and managing a big portfolio of research that has to happen across agencies.

There was discussion of the balance between advanced and applied research that happens at all levels. State–country and network operators focus closer to the end user and are more oriented toward customer demand. That group is also concerned about scalability. Research can demonstrate that something works on one bridge, but there is the question of how to scale it to several bridges and whether it can work on all bridges. The bottom line, as Bev Scott said, is about organizations, culture change, and people, people, people.

The world is changing and evolving, and disruptive technology and disruptive research are forcing change. At the same time, incremental research needs to respond faster to match the disruptive technology. Feedback loops are getting faster and shorter and will continue to do so.

Funding budgets are much tighter, and legislative bodies demand accountability. Particularly in the public sector, failure is not an option because failures will be used by political enemies. Therefore, failure must be managed, and administrators will be cautious about the risks.

Steudle called for a greater connection to outcomes. For example, the Michigan DOT will take risks if it is working toward certain specific outcomes. In those cases, a risk that does not produce a good result will be accepted.

In addition, investments need to focus on an expanded business case: why is the research being undertaken, and how does it impact the bottom line? There is intense competition for research funding, and new competitors are responding to requests for research.

He noted how Transport for London (TfL) is using social media and social interactions to connect with stakeholders and that stakeholders now expect much more involvement. Like TfL, the Michigan DOT conducts e-mail blasts and has two-way Twitter conversations; the agency asks for user feedback and uses social media as much as it can. Steudle suggested that others in the room use social media to its full advantage to tell their stories of what their research accomplished and how it changed people's lives and to get support for the next round of research.

Steudle ended with four conclusions. First, he supported Kevin Womack's idea of creating a research primer, especially for new employees. Second, connection to end users is paramount for the success and future of research. Third, innovation means implementing a result or a product that helps society evolve. Finally, he shared a relevant quote: "Imagination without implementation is hallucination."

Final Remarks by the Organizers

Bob Skinner thanked the participants for their high energy levels and engagement over the 2 days of the symposium. He felt enriched by the discussions and said he had learned not only about European methods but also about Americans engaged in the research process.

Kevin Womack thanked participants for their varied and important points of view and for helping in this endeavor. He said that he and Damiani would have much material that they could use. He also mentioned creating a primer of basic principles that apply to all types of research and that help to oversee the process from inception to implementation.

Alessandro Damiani remarked on the usefulness and applicability of the symposium discussions. The next steps are to reflect on how to follow up on them: What lessons can be extracted so that both the United States and the European Union put to use the investment of knowledge that was given here at the symposium? He was particularly grateful for the participants' willingness to share their knowledge and engage so actively. He acknowledged that each participant contributed a lot and that he and the European Commission appreciated it very much. He said the French have an apt, melodic phrase to describe the innovation process: *le savoir, le savoir-faire, et le faire-savoir*—knowledge, know-how, and outreach. He urged participants not to forget the importance of outreach and to communicate the richness of ideas that emerged from these symposia.

Jesús Rodríguez concluded the meeting, saying the collaboration would continue. He referred back to Breslin's comment about the two new EU–U.S. joint research projects that have developed from the first symposium and noted that the United States and the European Union are working together on Infravation. He said he sees that this kind of collaboration will be the future of research and that it should be the typical way that research is conducted. To do research within just the United States or the European Union makes no sense.

SYNTHESIS

Suggestions for Successful Implementation of Research

Andrea Meyer, *Working Knowledge, Boulder, Colorado, USA, Rapporteur*
Dana Meyer, *Working Knowledge, Boulder, Colorado, USA, Rapporteur*

Much of the symposium presented or discussed potential suggestions for how to improve the implementation of research to increase the long-term return on investment (ROI) from transportation research. During the 2 days of the symposium, presenters and participants offered ideas for making research more deployable and for breaking down barriers to deploying innovation in transportation systems.

This section contains a wide variety of suggestions for improving the efficacy of transportation research to produce successful implementations at scale. Broadly, the suggestions are as follows:

- Structure the research.
- Involve stakeholders.
- Disseminate research outcomes.
- Mitigate systemic impediments.
- Manage the double-edged swords (accelerators and impediments).
- Track research and implementation over the long term.

These suggestions, which form the structure of this synthesis, were harvested on an inclusive rather than consensual basis from the following sources during the conference:

- Two cycles of breakout group discussions;
- Two white paper presentations, including one of 13 case studies of successfully implemented research;
- Observations by the presenters; and
- Open discussion among all symposium participants, namely, researchers, funding agency representatives, infrastructure operators, and industry.

Context: Impediments to Innovation in a Risk-Averse System

Transportation research occurs in a multiparty context of mutual interdependence of the researchers who do the research, the companies that manufacture transport system products, and the public sector entities that fund research and deployment as well as operate transportation networks. To a first approximation, research flows along a chain from basic research to more applied research with prototyping and small-scale trials and then to broader implementation, with different parties playing different roles along that chain. Creating and maintaining the flow of new ideas and new implementations implies gaining the acceptance and ensuring the success of the multiple parties in the public, private, and academic sectors.

Transportation needs innovation to address pressing problems (e.g., emissions, congestion, costs, safety) but cannot tolerate the chance of failure that comes with trying new projects. Transportation system funders and operators want certainty, and yet the fundamental property of true research is that its outcome is uncertain. Thus, these suggestions occur within a risk-averse context. Improving the ROI of transportation research seems to face a systemic impediment. On one hand, increasing the productivity of research implies accelerating the deployment of innovations at scale in real transportation networks. On the other hand, the managers of these networks and the funders who might finance such deployments have a rational aversion to risk. Thus, the creators and promoters of innovation face the conundrum of trying to increase the adoption of research outcomes in a system that must meet the needs of end users.

The following impediments to research were discussed at the symposium: risk aversion due to resource limits, risk aversion due to operational priorities, and two valleys of death.

Impediment: Risk Aversion Due to Resource Limits

Many participants noted the constraints on funding for research and cited government austerity and overall budget pressures. Regardless of whether current research funding is sufficient or insufficient, justifying spending on research requires proving and improving the contribution of research to the cost–benefit performance of transportation networks.

Many transportation projects involve extremely large budgets. New or remediated infrastructure such as bridges, tunnels, highways, and rail facilities can cost billions of euros or dollars. These projects can take decades to come to fruition and, once built, have decades of impact on transportation operators and transportation system end users. The high cost, high visibility, and long-lived consequences of these projects contribute to risk aversion: failure is not an option during the design, build, and operational phases of the projects.

Impediment: Risk Aversion Due to Operational Priorities

Transportation system operators, being the managers of the literal network that underlies the everyday economy, naturally seek maximum uptime and minimum disturbance within their networks. Manufacturers, contractors, and operating entities also face potential legal liabilities, especially in the United States. Many aspects of transportation systems impinge on safety and environmental outcomes. By definition, something new might have new side effects that are not readily apparent in the lab, during small-scale trials, or over short timescales. The potential that even small changes might have large consequences makes players in the transportation space hesitant to innovate.

Impediment: Two Valleys of Death

The gap between research and real-world deployment of transportation innovations includes two valleys of death. The first—the technological valley of death—occurs between the initial research phase and the initial implementation of the concept as a prototype or demonstration. The second—the commercialization valley of death—occurs between the demonstration phase and the broader deployment at scale. The result is that successful research either fails to get a trial test or never makes it to the market. Moreover, the long delays between initial research, follow-on development, and eventual deployment mean that valuable knowledge created at each stage is lost before the next stage.

In addition to the high cost of individual transportation projects is the fact that transportation networks operate at very large scale. A large urban or national network might encompass thousands or tens of thousands of bridges, signals, public transit conveyances, network nodes, and kilometers of road and rail. Thus, deployment of innovation becomes a complex exercise in commercialization at large scale, requiring the development of a network of suppliers, manufacturers, and contractors to mass-produce and deploy the innovation into a large network. A shortage of debt or equity funding or a lack of a clear commercial opportunity can prevent an invention from being brought to broader markets. Opposition by communities and environmentalists can also forestall deployment.

Suggestion: Structure the Research

One of the key suggestions from the symposium was the need for a primer on how to implement advanced and applied research. The primer would facilitate a more effective research process by providing a road map for researchers to follow in setting up their research in a way that positions it for implementation.

Much of the discussion during the symposium centered on the characteristics of successful research efforts (i.e., research efforts that led to successful real-world deployment). These characteristics of successful implementations can serve as helpful ideas. Several of these characteristics related to the structure and presentation of the research itself.

Context: Spectrum of Research

Suggestions for improving the deployment of research depend on the type of research being done. During the symposium, many participants discussed the full spectrum of research, including basic, advanced, and applied research. All three are needed, but different types of funders emphasized different types of research. For example, network operators seem most interested in short-term applied research that offers a guaranteed solution.

Others argued for greater funding of advanced research that could offer potential step changes in the performance of transportation systems. The European Union may be rebalancing its focus from advanced research to more applied research, while the U.S. federal government may be rebalancing from an applied focus by adding more advanced research. Although the boundaries between the different types are not clear-cut, some participants cited general dimensions that correlate with these different types of research and that affect how the research is done.

The first dimension is the locus of motivation, that is, the key party or stakeholder driving the research. In the case of applied research, end user demand creates a pull effect. The funder or commissioner of the research has a specific problem in mind and seeks a specific solution. In the case of advanced or basic research, the researcher supplies or pushes a novel solution in search of a potential application.

The second difference is in the breadth of thinking. Applied research tends to have a rubber-meets-the-road focus, whereas advanced research might include more open-ended, blue-sky thinking. To be sure, all types of research demand a high level of creativity, whether it be solution-seeking creativity for out-of-the-box ideas or the creative problem solving needed to make everything fit inside a box of complex technological, operational, and policy constraints.

The result is that applied research offers an anticipated incremental (plug-and-play) innovation, whereas advanced and basic research have the potential to create radical or disruptive innovation. The various types of research chain together. For example, basic research might lead to radical new materials or ideas that require advanced research to explore possible uses. Alternatively, advanced research might lead to more specific conclusions that may require applied research to refine. This chain takes time, which implies that the earlier stages of research need to look further into the future for likely applications. Along with this difference in timescale comes a difference in the level of risk: applied research is generally less speculative and less risky than advanced research.

Several presenters and commenters stressed that the overall progression from advanced research to applied research to demonstration pilot to eventual deployment was not linear. Instead, there may be retracement loops in which one stage may uncover problems or opportunities that call for more research or work of an early-stage type. In the broader context, the entire process creates a loop, as deployment of an innovation from one cycle of research may lead to new societal issues (e.g., higher vehicle usage creates higher fatalities, a development that spurs new research into safety) or may create new opportunities (e.g., recharging electric cars by using power from railway catenary systems).

The symposium identified the following suggestions for structuring research:

- Define a clear objective,
- Outline the implementation,
- Conduct a real-world pilot test or demonstration project, and
- Provide incentives to researchers.

Define a Clear Objective

Several presenters stressed the importance of clear objectives and metrics. Research projects that lacked goals appear to have had a lower chance of success. Applied research has objectives and metrics driven by end users and their specific applications. Advanced research should also have an objective, even if the focus is more open-ended. The goal of advanced research can be quite broad and blue-sky aspirational, for example, zero highway deaths.

Outline the Implementation

Outlining the implementation of a new idea, even at an early stage, can help establish the feasibility and economic merits of the intended results of the research. Although ongoing research often causes changes to these tentative plans, the exercise helps link the forward progress of the research to the eventual deployment. Communicating the outline of the implementation also reduces the perceived risk, because it shows more operationally focused stakeholders how the research can fit into real-world transport systems. Overall, sketching the implementation and its business case was part of a suggestion for more systems-level thinking about any research project, including the road map for postresearch activities and how those activities fit with the needs and trends in the transportation systems.

Conduct a Real-World Pilot Test or Demonstration Project

As research progresses toward application, the need for real-world testing rises. Real-world testing has two purposes. First, the testing helps uncover and mitigate risks by creating real-world knowledge of how to deploy the innovation and how the innovation performs. Second, demonstration projects provide tangible proof to funders, infrastructure operators, and citizens that the research is producing useful outcomes. Some presenters noted the unfortunate inadequacy of funding for these kinds of tests.

Provide Incentives to Researchers

Participants raised the idea of incentive payments to researchers. These incentives should be tied to deployment performance metrics, not just research outcomes. Incentives could help reduce the natural tendency for academic researchers to focus on academic measures of performance (e.g., published papers in respected journals), which do not directly improve society's return on the research investment. Negative incentives might include performance-linked final payments. Positive incentives might take the form of a financial bonus or some guarantee for funding of future research. The U.S. Department of Energy's program of contract performance bonuses was cited as a potential example of these kinds of incentives.

Suggestion: Involve the Stakeholders

Many of the presentations and discussions highlighted the crucial role of bidirectional involvement of researchers and stakeholders. Collaboration between researchers and stakeholders early in the research phase helps both to shape the results and to give the stakeholders a sense of ownership. With stakeholder involvement, the research is more applicable and more likely to be accepted for deployment.

The symposium identified the following suggestions for involving stakeholders:

- Deepen researcher–stakeholder relations,
- Identify key stakeholders,
- Pool stakeholder resources, and
- Understand the limitations of researcher–stakeholder relationships.

Deepen Researcher–Stakeholder Relations

Many participants' presentations, discussions, and comments focused on the importance of tighter relations between researchers and stakeholders. In particular, researchers need to stay involved after the research is done and when the implementation begins. This involvement would better leverage the tacit knowledge of the researcher to accelerate the implementation of the idea. Similarly, involvement of stakeholders early in the research can help guide the innovation process in more useful directions. Stakeholder involvement thus changes the research from a bounded-duration, black-box project to a more open-ended, white-box process. In the future, researchers may be coproducers of implementation rather than just arms-length suppliers of the seeds of innovations.

With this increased connection between researchers and implementers come some ideas on changes in the framing of research. The first is the need to tie research to implementers' specific goals, priorities, vision, or policies. Doing so implies the need for some form of business case, with the potential costs and potential benefits that deploying the research could bring. That is, researchers need to communicate the economic merits of the work as well as the scientific ones. Overall, researchers need to help sell their ideas and make transportation innovation more sexy—that is, interesting and appealing—so that citizens, operators, and funders will want more innovation.

Identify Key Stakeholders

Working with stakeholders requires understanding who those stakeholders are. The symposium's wide range of presentations and discussions uncovered a daunting number of potential stakeholders, which can be loosely grouped as follows:

1. Public stakeholders: transportation agencies, infrastructure operators, legislative bodies, the executive branch or ministries, and citizens;
2. Industrial stakeholders: suppliers, original equipment manufacturers, distributors, engineering firms, and construction contractors; and
3. Knowledge stakeholders: the research community, educators, the media, and standards bodies such as the International Organization for Standardization (ISO).

There was some debate over the exact term to use for the stakeholders with whom researchers should work the most. Common terms for these key players included "adopter," "buyer," and "end user." More generally, the key stakeholders included those with one or more of three roles with respect to the research and the implementation of research outcomes:

- Those who fund the research and its implementation,
- Those who will bear the risks if the deployment fails, and
- Those who have the authority to permit or prohibit implementation.

The suggestion was for researchers to be aware of key gatekeepers who affect the progression of research to large-scale deployment. This need to work with key stakeholders was part of the general suggestion for more systems thinking about research and implementation. That is, researchers need to think about who will most affect the chances of deployment and then engage those stakeholders at an early date to ensure that the research outcomes are useful (or palatable) to them.

A special emphasis was placed on finding early adopters. Within the innovation literature is the notion of a bell curve of adopters: some users are early adopters, while the bulk of deployment occurs later among more risk-averse, later-stage adopters. Although early adopters account for a very small fraction of deployments, they play a key role in implementation of pilots, demonstrations, and early small-scale deployments. By helping to turn unproven ideas into lower-risk ones, these early adopters help allay the fears of their more risk-averse peers.

Pool Stakeholder Resources

Relationships between stakeholders, especially the pooling of resources, could also accelerate the successful implementation of research. Part of the natural risk aversion of individual agencies and operators is that each entity has a limited research budget. The budget limitations create high pressure for the success of each and every research project. In contrast, pooling resources enables each entity to share in funding a broader portfolio of research efforts. Each entity's outlay per project is reduced and the risks across a wide range of efforts are aggregated. Being part of a larger group or using research vetted by a broader entity can provide political cover for local officials in the event of failure. Thus, pooling significantly reduces the perception of the riskiness of supporting a research effort or trying an innovation.

Pooling can occur on a regional, continental, or global basis. Although the European Union and the United States may have different legal and governmental structures, they share many common goals, such as reducing congestion, reducing the costs of infrastructure, improving safety, and maximizing the performance of transportation systems. Specific transportation issues and priorities may vary across geographic and political boundaries, but many entities share issues and priorities (e.g., snow in northern climes, hot road surfaces in southern ones, or urban traveler safety priorities). Moreover, vehicle companies, technology companies, materials companies, and infrastructure engineering companies have a global reach and look for global markets. Thus, pooling also encourages the participation of private companies, which see the pool as a more attractive market than any individual country, state, or locality might provide. Finally, pooling could reduce the duplication of research efforts and foster competition among alternative innovations that could address a given problem.

Understand the Limitations of Researcher–Stakeholder Relationships

Researcher–stakeholder relationships are not without risks. Some participants expressed concerns that deeper relationships between researchers and stakeholders or involvement of researchers in implementation were not a panacea, for two reasons. The first reason was in the potential gap between best-in-class research skills and best-in-class implementation skills. Although many advocated that researchers take greater responsibility in aiding in implementation, some wondered if researchers were really best suited for that role. Implementation of large-scale engineering projects is a skill unto itself, as are sales and marketing of innovation. Just as some end users might not be well suited for funding and managing advanced research, some researchers may not be well suited for implementation-related tasks.

The second concern was that deeper engagement between researchers and stakeholders made less sense for the more advanced types of research. Blue-sky, out-of-the-box varieties of research projects might not have a clear end user or buyer during the earlier phases. New materials, energy-saving devices, or innovations in network management might apply to any of the range of modes, infrastructure arenas, or governments. Worse, prematurely pinning research to a specific mode or application could limit the deployment and value of these potential radical step-change innovations. Finally, linking research to stakeholders can also inhibit more systemic innovations that might disrupt the existing stakeholders themselves.

Suggestion: Disseminate Research Outcomes

For better or worse, getting research into the real world may require shouting. Communication plays both an informative role and a persuasive role in bringing research to large-scale deployment. Communication informs engineers, builders, operators, and maintainers about how to deploy the research or innovation. Communication also helps sell the value of the research, builds interest in forthcoming innovations, and shows that transportation can be sexy. Success stories about research and its role in deployed systems help to nurture a culture of innovation among transportation stakeholders.

The symposium identified the following suggestions for disseminating research outcomes:

- Communicate via multiple channels,
- Create trust via peers, and
- Educate the next generation of engineers.

Communicate via Multiple Channels

Researchers and implementers should use many different channels to disseminate research and innovation. These channels include traditional media in the form of mainstream news articles, technical reports, and even coffeetable books that, for example, illustrate the beauty and grandeur of transportation systems. Marketing via traditional, online, or social media can show stakeholders and citizens that research is exciting and valuable. Publishing research results in languages other than English increases uptake in countries where English is not the dominant language. Travel to conferences, roundtables, meetings, and collaborative events helps build relationships through face-to-face communications, supports deeper sharing of ideas, and builds trust. Training (undergraduate, graduate, or continuing education) helps engineers, managers, and policy makers learn how to implement the latest technologies. Using all of these communications channels implies reserving some fraction of research and implementation budgets for publications, public relations, outreach, training, and travel.

Create Trust via Peers

Trust plays a crucial role in the efficacy of communication. Wary stakeholders may not accept the optimistic pronouncements of researchers or the sales staff of those who promote an innovation. Instead, information from peers (e.g., those in other transportation agencies) or neutral third parties may be viewed as more trustworthy sources of information. That was one of the rationales for seeking early adopters or champions among operators. If a real-world entity has successfully implemented an innovation, its reporting of the event may be considered more reliable than a laboratory test or researcher-run simulation.

Educate the Next Generation of Engineers

Creating widespread adoption of innovations in basic materials or systems implies educating the next generation of engineers in the respective new properties and design principles. Some symposium participants noted, however, that adoption is slowed if professors do not update their lectures to include the latest technologies. This seems to have occurred in the case of fiber-reinforced concrete. Moreover, the solution to this issue may be stymied by academic freedom and tenure policies. No one can mandate that professors teach the latest innovations, although anecdotal evidence suggests that students tend to select classes taught by more forward-thinking professors.

Suggestion: Mitigate Systemic Impediments

A number of obstacles fell outside the scope of what researchers, funders, and operators could accomplish on their own. Some of the impediments to implementing research come from legislative or regulatory mandates. Improving the return on investment on research may involve tackling more systemic institutional barriers.

The symposium identified the following suggestions for mitigating systemic impediments:

- Change low-bid and arms-length procurement policies;
- Overcome policy barriers such as mandates, conflicts, and long-term instability;
- Coordinate a systematic approach to research and innovation;
- Adapt to the fast pace of external change; and
- Match the scale of the implementer to that of the transportation system.

Change Low-Bid and Arms-Length Procurement Policies

Many participants bemoaned the use of low-bid procurement, especially low-bid procurement that only considered the initial costs of new construction or system acquisition. Often, innovative solutions may have higher up-front costs but offer significantly superior life-cycle costs or provide additional benefits not offered by the mainstream solutions. Life-cycle costs and performance-based procurement would enable funders to optimize bang-for-the-buck trade-offs.

The goal of fostering deeper, collaborative relationships between researchers and end users can run afoul of well-intended anticorruption and antifavoritism policies. Procurement policies are often designed so that the commissioner of a transportation project is not seen as having a preferential relationship with any one bidder, yet that policy makes deeper relationships between researchers and innovative companies more difficult. Funding agencies need well-designed, open, and transparent procurement processes that create a level playing field while still permitting closer collaboration between the bidder and requester. These processes may include some mechanisms to enable the sharing of proprietary information between the bidder and the funder within a closed but fair context. TfL's open procurement calls with follow-on private sessions were cited as an example of this.

Overcome Policy Barriers: Mandates, Conflicts, and Long-Term Instability

Other policy-related barriers concern specific technology mandates, conflicts between policies, and instability in the legislative or regulatory systems. Conflicting regulations create barriers to adoption. For example, if research finds a way to improve safety, but the innovation increases emissions, does it get stopped by legal environmental challenges? A clear calculus of trade-offs would help implementers know which gains are worth which costs. Legislative and regulatory uncertainties also inhibit development and implementation of new transportation ideas by increasing the uncertainty about the deployment of an innovation. The long-term nature of transportation infrastructure and systems calls for long-term stability in funding and regulation.

Coordinate a Systematic Approach to Research and Innovation

Overall, some participants argued for a much more systemic approach to research and its deployment. The current approach is like filling potholes one at a time. It creates only incremental improvements within individual transportation jurisdictions but not the kind of paradigmatic change needed to cope with larger-scale problems such as megacity congestion, greenhouse gas emissions, or safety. The current approach is also not coordinated across modes, which is a mistake, because almost every journey taken by a person or piece of freight involves multiple modes.

What may be needed is a more systemic and coordinated approach to transportation research, transportation innovation demonstrations projects, and transportation system deployments. A more coordinated approach might start with high-level societal priorities and a better understanding of the systemic gaps between the as-built environment and the as-desired transportation fabric of the economy. It might include awareness of timescales of when new transportation research might be needed to deliver innovations in time for when new transportation systems might be needed. The result would be a much more interlocking pattern of research and implementation programs across time, modes, and issues that delivers systems solutions to systems problems.

Adapt to the Fast Pace of External Change

The fast pace of external technological change threatens to overtake transportation research results. For example, decades of research have gone into vehicle-to-vehicle and vehicle-to-infrastructure communication architectures based on dedicated radios on vehicles. Yet the rising prevalence of smartphones seems to obviate the need for dedicated radios and make the original architecture obsolete before it has even been implemented. Similarly, rapid demographic changes in attitudes about transportation (e.g., attitudes about the merits of personal car ownership) imply that transportation research might solve last year's perceived problem but not next year's actual needs.

These rapid changes seemed to motivate a greater acceleration of transportation research and the implementation of that research. One suggestion was that the transportation industry look more closely at industries that have higher rates of innovation and an accelerated pace of bringing research into the real world, with an eye to learning from these industries. It may be that these industries, which include aerospace, pharmaceuticals, and electronics, are doing what has been suggested at this symposium, namely, engaging in closer communication based on deeper trust between the different players in their research area. Good flow of information will improve implementation, and it will also update the players about what is going on and what the short- and long-term R&D needs will be.

Match the Scale of the Implementer to That of the Transportation System

One impediment to implementation of step-change innovation has been the gap between the scale of the implementation and the scale of the companies typically found in the transportation infrastructure industry. If an infrastructure operator has 3,000 bridges and a proposed sensing system needs 300 sensors per span, then deploying that innovation requires a manufacturer and associated suppliers to make millions of very cost-effective sensor units. Similarly, adoption of new materials such as warm-mix asphalt requires investment by material suppliers and paving contractors. Unfortunately, the transportation infrastructure industry is extremely fragmented; for instance, the United Kingdom alone has about 300,000 construction firms. These small and medium enterprises do not have the resources for large-scale R&D and implementation.

In contrast, other research-driven industries—such as biotechnology, aerospace, and electronics—have very large players that can afford to invest in scale. Aerospace, for example, has only two dominant manufacturers of passenger airliners. These manufacturers have the scale to invest billions in extremely large innovation projects such as designing and building a new airliner. Solving this problem in transportation may entail greater public-sector funding for large-scale development consortium-building efforts to pool development budgets or some form of private-sector consolidation to create players of sufficient scale.

Suggestion: Manage the Double-Edged Swords: Accelerators and Impediments

Some elements seem to have contradictory influences on the implementation of research. These elements were seen as potentially both improving the deployment of innovation as well as sometimes being an impediment. These double-edged swords generated some debate over whether these elements were good or bad for getting research implemented in the real world. Both were thought of as good ideas, but the discussions revealed some negative second-order consequences that might require other mitigations.

The symposium identified two double-edged swords: standards and intellectual property.

Standards: Encouraging Adoption Versus Discouraging Innovation

On one hand, standards such as those managed by ISO, the European Committee for Standardization, or the American Association of State Highway and Transportation Officials can provide a crucial channel for the mass deployment of innovation. Many product makers, construction firms, and operating entities rely on published standards for specifications, which drive the adoption of standardized technologies. Risk-averse funders and operators feel safer if they can use standards. Thus, the sooner an idea can become a standard, the sooner it will be deployed.

On the other hand, reliance on standards can inhibit the testing and initial deployment of the newest innovations. Researchers or those wishing to implement an innovation must convince funders, procurement organizations, and operators to accept a nonstandard design or product. The time lag between invention and the release of a standard referencing the invention can delay deployment. Also, differences in standards in different countries can limit the deployment of innovation or create a fragmented market for new products. Some symposium participants suggested that standards should be more performance-based rather than prescriptive.

Intellectual Property: Private Incentives, Public Assets, and the Free Flow of Ideas

Intellectual property rights (IPR) were cited as a significant impediment but also as another double-edged sword. Many funding agencies feel that the results of publicly funded research should not be privately owned. That perspective may be especially tragic if a funding agency insists on retaining the rights to an invention but lacks the policies, processes, or funding needed to deploy it. IPR issues stymie private-sector investment in commercialization. Without clear rights or licenses to new inventions, companies are loath to invest in development of the results of transportation research. The challenge is in balancing public rights to the fruits of public funding against private incentives to bring ideas to market. The National Aeronautics and Space Administration, the National Cancer Institute, and the U.S. Department of Defense were cited as U.S. government entities that had successful plans for licensing government-funded intellectual property (IP) to private firms. In addition, universities were cited as examples of entities that have successfully centralized IP and found a way to manage it across sectors.

Increasing the use of IPR, however, may also have consequences that slow innovation. Some researchers saw IP as a potential impediment to the free flow of ideas in the research environment. The need for secrecy surrounding potential inventions delays dissemination and discussions. Time lags in the patent process create lags in the publication of results.

Suggestion: Track Research and Implementation over the Long Term

Despite the many case studies of successful research, much uncertainty remained about the efficacy of research. Did a given piece of research make it into deployment? Was the research efficient or successful? Which research projects contributed to which transportation innovation, new product, or major infrastructure project? None of these questions had good answers. Thus, better tracking of research outcomes and their contribution to deployment outcomes was a major missing piece.

Research may well be more effective than it appears, but its contribution can be invisible. The ultimate end users of transportation systems—commuters and freight shippers—do not see the technology embedded in the network and under their tires or feet. Better tracking of the relationship between research efforts and transportation system performance has three benefits. First, better tracking of the contribution of research helps ensure funding of research by documenting its value. Second, tracking is part of learning best practices and performing postmortems. Third, tracking is part of the research process, namely, finding follow-on research opportunities in unexpected outcomes during and after deployment.

The symposium identified the following suggestions for tracking research and implementation over the long term:

- Collect the right data,
- Match the duration of the research to the duration of implementation and life span, and
- Analyze the research process ROI, not the research project ROI.

Collect the Right Data

Several symposium participants mentioned four guidelines for collecting the proper data for tracking the contribution of research to real-world transport system performance:

- Harmonize data collection across locations and time to ensure that data were collected in the same way and with the same definitions.
- Track performance both before and after to establish the impact of a deployment or innovation.
- Document the actual costs (including overruns) and benefits (including unexpected effects) of the innovation over the long term.
- Include both objective and subjective data in the tracking.

Although objective data on velocities, punctuality, and fatality rates do matter, subjective opinions about delays, flow, and safety have a greater impact on end users' opinions about transportation systems.

Match the Duration of Research to the Duration of Implementation and Life Span

Several participants noted the gap between research project duration and transportation system life spans. Most of the research programs mentioned had durations under a decade, and many research projects have funding for only a couple of years. Infrastructure, land use, and fleets, however, persist for more than a decade. The long gestation periods for major infrastructure only exacerbate this problem. The value (or risks) of a given innovation (e.g., long-term changes in consumer–user behavior, unintended consequences) might take years to appear. Long-term tracking of research, its implementations, and the outcome would help mitigate this disconnect. In addition, research that is funded with government money could have a clause stipulating that the project must document how the research was used and what cost savings or cost efficiency was achieved. Tracking would help close the loop between initial research, initial deployment of innovations, and follow-on research to further refine the initial innovation.

Analyze the Research Process ROI, Not the Research Project ROI

Several participants suggested having some way to accept or accommodate failure. By its very nature of delving into the unknown, research has risk. Not all research projects lead to viable ideas. That is especially true of projects in the advanced research category. Yet it is these advanced projects that are the most likely to produce major step-change innovations if they are properly nurtured and given the leeway to succeed. Small, low-risk steps cannot bridge the valleys of death or produce the kinds of paradigmatic change needed to achieve big societal goals in emissions reduction, congestion mitigation, cost reduction, and safety. Yet these participants noted the painful challenge of convincing risk-averse organizations to become more accepting of the failures required by innovation.

In contrast, high-tech companies and venture capitalists willingly make very risky investments knowing that most will fail but that a few will produce returns so high that they will offset the investments that did not succeed. Blockbuster winners from groundbreaking research can offset the inevitable losers. Spreading the risk and sharing the gains across a portfolio can produce a very positive aggregate return.

Reconciling the paradox that failure is required to achieve success implies changing the unit of analysis. Moving the focus from the success or failure of each and every individual research project to the program or portfolio level is often best. Thus, a key rationale for more thorough, long-term tracking of research is in documenting that despite some failures at the project level, the portfolio or program generates adequate returns. By pooling funding resources, sharing the risks, and coordinating research efforts, collaborating transportation organizations in the United States and the European Union can develop a high-return portfolio of research efforts.

APPENDIX A: COMMISSIONED WHITE PAPER 1

Transportation Research Implementation in the European Union and the United States

Observations and Working Hypotheses

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> Technology transfer (or research implementation) is the process by which existing knowledge, facilities, or capabilities developed under [U.S.] federal research and development (R&D) funding are utilized to fulfill public and private needs.
>
> U.S. Federal Laboratory Consortium for Technology Transfer, 2014

> Fostering a culture of innovation, where the results of research are exploited for the benefit of EU citizens, is a tenet of the European Research Area.
>
> Joint Research Centre, European Commission, 2012

> It was the best of times, it was the worst of times, it was the age of wisdom, it was the age of foolishness, it was the epoch of belief, it was the epoch of incredulity.
>
> Charles Dickens, *A Tale of Two Cities*

This white paper provides a foundation for the Second EU-U.S. Transportation Research Symposium held April 10–11, 2014, in Paris, France. The paper takes its theme from one simple and inspiring statement found by the authors in one of the preparatory notes for the Symposium: "research has little value if its outcomes are not applied." Although this paper includes multiple examples of successful transportation research implementation activities, programs, and strategies on both sides of the Atlantic, its overarching thesis is that there are necessary core conditions for enhancing the implementation of transportation research in Europe and the United States that remain largely unrealized:

Condition 1. A process that provides sufficient funding for research implementation,

Condition 2. Centralized planning and coordination,

Condition 3. Effective data collection and analysis, and

Condition 4. Effective use of intellectual property tools.

Although there are a myriad of differences between Europe and the United States in planning activities, organizational features, policy frameworks, and on-the-ground facts, there is also significant evidence that unrealized conditions for effective transportation implementation are shared by these advanced political–economic structures. It is notable, however, that the European Union has made extensive progress in centralizing and coordinating its transportation research implementation activities through the mechanism of EU-wide framework research programs.

Additionally, it would be a mistake to ignore U.S. progress toward an integrated transportation planning and innovation management system through initiatives exemplified by the Every Day Counts program, which is breaking down historical barriers to the implementation of highway innovations. U.S. Secretary of Transportation Anthony Foxx's commitment to developing an integrated national plan for transportation will also help to promote integration and greater efficiencies throughout the U.S. transportation ecosystem as well as move the United States into closer alignment with the European framework research model.

This paper reviews specific myths about transportation research implementation that arguably work against constructive change, for example, "Government funding and involvement should decrease as research approaches commercialization." Unfortunately, this myth and others have constrained the implementation of innovation, particularly for small firms and other entities that lack the resources to successfully move through what technology transfer specialists call the valley of death. Notably, there is evidence that administrations on both sides of the Atlantic are introducing policies and programs that will provide new funding for research implementation.

The paper ends with a set of 12 hypotheses designed to promote discussion regarding possible steps for promoting enhanced research implementation.

1 Background and Scope

This paper provides a comparative assessment of how transportation research moves to implementation and commercialization, both in the United States and within the European Union. Underlying this paper is observation that research implementation–commercialization is less than optimal in the European Union and the United States and that there are unmet "necessary" conditions that are responsible for this situation. Equally true, there are significant opportunities to enhance research implementation on both sides of the Atlantic. By research implementation, the authors mean transportation research that has reached the end point of technology deployment, either through adoption of the innovation as broadly accepted practice by public funding agencies or through commercialization via customers, whether companies, public entities, or individual entrepreneurs. Notably, while the facts are different, the necessary conditions and opportunities for optimized implementation of transportation research in Europe and the United States are strikingly similar in terms of both causes and resultant effects. Figure 1 illustrates the research development and deployment cycle.

Indeed, the importance of government in research implementation has often been the missing step on both sides of the Atlantic. Many public officials may view their role (and funding) as appropriately receding the closer research findings get to commercialization,

FIGURE 1 Research development and deployment cycle.

because they want to avoid potential conflicts of interest and distortions in market competition. The metaphor of the valley of death is applied to signify the critical point when government funds vanish and the private entity faces the lonely prospect of moving research into the marketplace without adequate supporting funds (Figures 2 and 3). The U.S. Small Business Innovation Research (SBIR) program [sponsored by several modes within the U.S. Department of Transportation (DOT), including the Federal Highway Administration (FHWA), the Federal Transit Administration (FTA), and the Federal Aviation Administration (FAA)] is a good example of a U.S. program created to actively help small businesses develop innovative technologies.[1] Unfortunately, when compa-

[1] For information on the SBIR program, visit http://www.volpe.dot.gov/work-with-us/small-business-innovation-research.

Research Implementation

"Research implementation" is a vague term, and definitions and interpretations abound. Implementation can apply to any transition from one research phase to another phase, such as incorporating research in a publication or securing a patent. It can also pertain to technology transfer from one organization to another without actual use. This paper defines research implementation as moving research fully from a test bed, shelf, patent, or a research paper into broad commercialization in which multiple units are used in activities such as infrastructure, railroads, software, sensors, and so forth. One-time deployment or limited experimental use is not considered research implementation.

FIGURE 2 The valley of death.

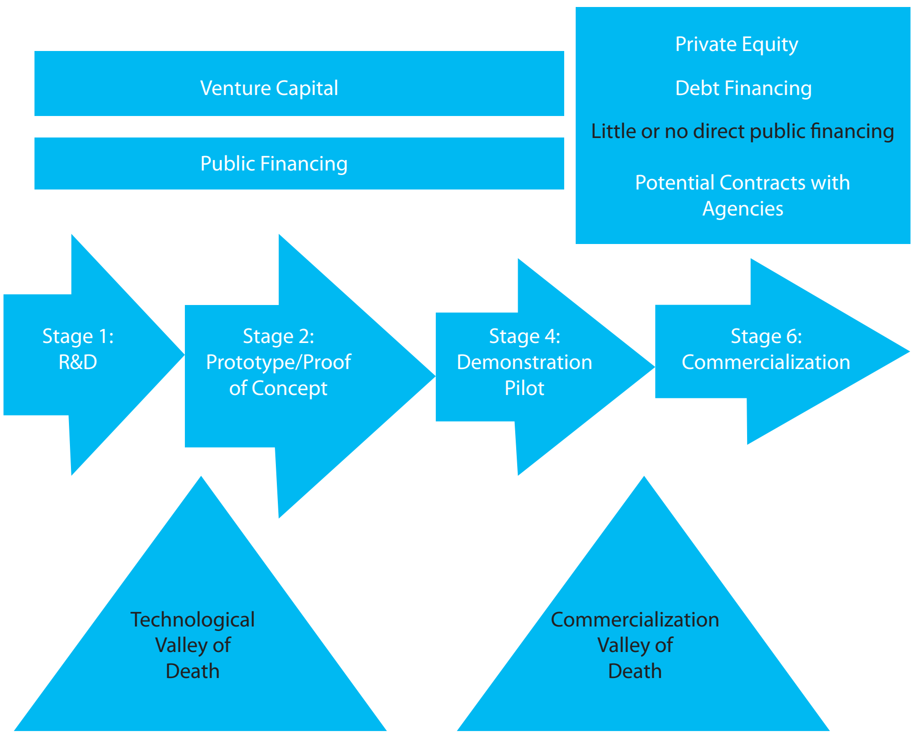

FIGURE 3 The U.S. Transportation innovation process and valleys of death. (Source: Adapted from Jenkins and Mansur 2011, Figure 1, p. 5.)

nies enter the third and final phase of the program, they may discover that there are no provisions for funding the commercialization process. Moreover, private capital is not always available to provide a bridge loan over the metaphorical valley of death.

A similar situation can be found in the EU Competitiveness and Innovation Framework Programme (CIP), which has a budget of €3.6 billion. CIP aimed at encouraging the competitiveness of European industry in the 2007–2013 budget period, with small and medium-sized enterprises (SME) as its main target. CIP has now been merged with the Framework Programme on Research and Development within the new Horizon 2020 concept for the current budget period (2014–2020); unfortunately, the limitations in supporting commercialization remain in place.

Innovators in Europe and the United States face this chasm equally. Despite the pervasive belief that the success rate for the implementation of new technologies in Europe is significantly greater than that in the United States because Europe trends toward the socialistic end of the political spectrum and the United States is more closely tied to laissez-faire capitalism (in which failures are an expected part of market processes), there are few hard data to support this conclusion. The effects of economic globalism may be operating to smooth both implementation success and failure rates in both jurisdictions.

This paper highlights the role of the private sector in transportation research implementation and commercialization; however, the central focus is on the role (and relative success) of the public sectors in Europe and the United States in supporting the implementation of transportation research. Section 2 of the paper describes current trends in publicly sponsored research implementation while discussing contrasts with certain elements of the private sector. Section 3 reviews the main elements of the transportation research ecosystem in the European Union and the United States and posits necessary conditions for optimizing research implementation: sufficient funding, organizational coordination, effective process analysis based on sound data collection, and the effective use of intellectual property tools. Section 4 gathers together some pervasive myths pertaining to transportation research implementation. Finally, to stimulate the discussions at the symposium, Section 5 proposes 12 working hypotheses on why the implementation of research results remains challenging.

Although the transportation sector will be considered in whole throughout the paper, significant differences in innovation paths and methods, research budgets, and stakeholder involvement are found while moving across transportation modes. Furthermore, the innovation cycle and the involvement of the private and public sectors are quite different with regard to vehicles and equipment, infrastructure, and transport service provision. Generally speaking, vehicles and related equipment constitute the area in which more investment is made and in which the involvement of the industry is particularly relevant (Wiesenthal et al. 2011). The financial support of the public sector is traditionally higher in the area of infrastructure and networks, and this is the area in which the industry seems to dedicate fewer resources to innovation. Socioeconomic research, frequently linked to regulations and policy choices, is another research area that has often been traditionally dependent on public funding.

2 State of Transportation Research Implementation in the United States and Europe

2.1 Current Trends in Transportation Research Implementation and Commercialization

2.1.1 United States

The Executive Committee of the Transportation Research Board (TRB) completed a list of critical issues in U.S. transportation for 2013 to stimulate awareness and debate and to focus research on the most pressing transportation issues facing the nation (TRB 2013). The Executive Committee observed that

- Performance of the U.S. transportation system is neither reliable nor resilient;
- Despite safety improvements, the United States suffers significant, avoidable deaths and injuries every year;
- Transportation exerts large-scale, unsustainable impacts on energy, the environment, and climate;
- Inadequate sources for infrastructure impede the performance and safety of the transportation system;
- Innovation in passenger mobility services and public-system infrastructure lags far behind that in the private sector (and Europe); and
- The R&D investment necessary for finding and adopting new solutions is declining.

The Executive Committee also observed that "uncertainty about the direction of federal policy and about funding shortfalls underscores the importance of research" (TRB 2013). Undeniably, research has played a critical role in sustaining U.S. leadership in transportation in both the 20th and 21st centuries. Most notable for highways are the Strategic Highway Research Program (SHRP), which originated in the 1990s, and its successor, SHRP 2. One of the major outcomes of SHRP was the Superpave® program, which has been implemented with great success across the United States. While the research results from SHRP 2 are just being completed in the areas of safety, renewal, reliability, and capacity, detailed plans are now being developed to ensure the rapid implementation of innovative practices and products. The SHRP 2 program provides multiple opportunities for rapid and effective implementation of transportation research in the United States.

U.S. Secretary of Transportation Anthony Foxx has adeptly identified opportunities for accelerating the implementation of research results. For example, at the 93rd Annual Meeting of the Transportation Research Board, the secretary announced his commitment to accelerating the deployment of best practices culled from recent studies that demonstrate that the costs of infrastructure improvements can be reduced by as much as 40%.[2] Paradoxically, while reduced funding is often a serious impediment to implementing transportation research, the effective implementation of research can enable public agencies to do more with less.

In the United States, institutions, programs, and policies continue to change and adapt to the evolving requirements of transportation research implementation, as exemplified by the establishment of the

[2] Remarks made at the Chairman's Luncheon, Washington, D.C., January 15, 2014.

Research and Innovative Technology Administration,[3] which is working successfully to coordinate research programs throughout the U.S. DOT, spur the implementation of intelligent transportation system technologies, and develop intellectual property for commercialization.

One past barrier to effective research implementation and commercialization was ambiguity in the guidance issued regarding the use of federal highway funds for projects using proprietary technologies. Recognizing the opportunities associated with the use of proprietary technologies, FHWA issued new guidance in 2011 that clarified existing regulations on the use of patented and proprietary products for federal aid highway projects. The guidance emphasizes that a state transportation agency may specify the use of proprietary products when the agency certifies that no suitable alternative product exists, as in the case of innovative products offering better performance, or that the product is needed for synchronization with existing highway facilities. These changes should accelerate the movement of innovations into the construction of highway infrastructure. Clarifying this guidance underscores FHWA's commitment to policy and programmatic changes that further the implementation of highway research (FHWA 2011). Nevertheless, simply clarifying existing guidance will not substitute for policies that incentivize the implementation of transportation research and technology transfer. In addition, as discussed further below, public policies and programs that build on past progress will go a long way toward ensuring that the U.S. transportation system remains robust and innovation based.

Within the private sector, it is evident that privately financed R&D and implementation–commercialization within the U.S. automobile industry are moving forward. Part of industry's commitment to innovation is of course the result of stiff competition, abundant intellectual property, government regulation, and profits.

To keep pace with ever-growing consumer demands for sophisticated new automobile technologies, automakers spend more than $100 billion annually on R&D, including $18 billion in the United States alone. Booz Allen found that auto industry spending on R&D climbed $7.4 billion to $102 billion in 2013. In comparison, the entire global aerospace and defense industry spent about $25.5 billion on R&D in 2013—one-quarter of what the auto industry spent. Another robust area of research is the conversion of vehicles to new, cleaner fuels such as abundant natural gas.

Westport Innovations Inc. and Delphi Automotive reported on March 3, 2014, that they have signed an agreement to develop high-pressure fuel injectors for heavy-duty truck engines that use natural gas. The first injector Westport and Delphi will develop together will be used in Westport's high-pressure direct-injection 2.0 technology. Combining technologies and facilities from the two companies will allow them to develop injectors that are simplified, have improved performance and reliability, and have lower costs compared with current injector technology, they said.

Moreover, sharing of intellectual property is a key aspect of implementing private research. David Demers, Chief Executive Officer (CEO) of Westport, said in a press statement that

> our agreement and investment with Delphi combines intellectual property with global production capacity at one of the world's most sophisticated injector facilities. . . . Delphi's support for natural gas fuel systems and Westport HPDI [high-pressure direct injection] components . . . will help create a landmark product with industry defining pricing, quality and performance characteristics for global engine OEMs [original equipment manufacturers]" (Alliance of Automobile Manufacturers 2014).

Nevertheless, the question remains whether public and private components of the transportation sector can provide the smart infrastructure necessary to support the timely optimization of the in-vehicle innovations provided by the automobile industry (Alliance of Automobile Manufacturers 2014). Part of the issue revolves around the enactment of regulatory frameworks that are accepted by both the European Union and the United States—owing to the international nature of the automobile industry—while enabling accelerated research implementation–commercialization on both sides of the Atlantic.

2.1.2 Europe

Lack of implementation of research results was identified as a significant barrier to achieving the Lisbon Strategy's (failed) vision of transforming Europe into "the world's largest knowledge-based economy" by 2010. The new strategy, Europe 2020, made a similar assessment and developed a flagship initiative, Innovation Union, to address this barrier. With this background, it is not surprising that the preparation of Horizon 2020, the new EU research Framework Programme for 2014–2020, included wide debates on how to better integrate European industry in European research programs and how to move research results forward toward implementation.

One of the key changes in the European research framework is that Horizon 2020 brings together all exist-

[3] Now the Office of the Assistant Secretary for Research and Technology.

ing Union research and innovation funding, with some new features, including "the integration of research and innovation by providing seamless and coherent funding from idea to market" and "more support for innovation and activities close to the market, leading to a direct economic stimulus"; one of the priorities where resources are focused is "smart, green and integrated transport" (European Commission 2011).

The new approach of Horizon 2020 can be seen as a confirmation of the growing concerns about the lack of delivery of research products in terms of enhanced economic performance and competitiveness. These concerns are shared across economic sectors and are certainly not an exclusive feature of the transportation community. Horizon 2020 includes new instruments to support implementation (mainly the new call, Small Business and Fast Track Innovation for Transport) and provides expanded resources for the involvement of the industry in research activities aiming at implementation of a public–private partnership (PPP) platform (such as the Joint Research Initiatives). Last but not least, interaction with the research services of the European Commission and industry for setting up the research agenda has been steadily increasing since the mid-2000s through the European Technology Platforms (ETPs).

In spite of these efforts, implementation of transport research results remains a significant challenge in Europe. It is worth noting that there are enormous differences within the transport sector in terms of the size of the research effort made by industry and the paths toward implementation. As in the United States, the context and the research cultures and practices are completely different in the areas of vehicle and equipment manufacturing, infrastructure construction and maintenance, and transport service provision. The European automotive industry evolves in a context of global competition and performance-based regulations, whereas infrastructure design, construction, and maintenance are prone to be largely regulated by procedural standards and guidelines, as is in part also the case for the provision of transport services. It is not surprising to find a wide variety of situations when analyzing innovation in the transport sector. In some areas, the industry is heavily investing in research; in others, the public sector is providing a far larger share of the resources. The parallel between what is happening in Europe and the current situation in the United States is striking.

A review by the European Commission's Joint Research Centre (Wiesenthal et al. 2011) partially substitutes for the lack of systematic statistics and information on the research funding in Europe. Some of the review's key findings clarify the respective importance of private and public funding of transport research and their main respective areas of interest, and, within the public sector, the relative importance of European compared with national funding. Taking various data sources for 2008, the report draws the following conclusions:

- Public R&D investments from EU member states were some €3.6 billion in 2008. Public R&D investments were at that time largely concentrated in seven member states: Germany, France, Sweden, the United Kingdom, Spain, Italy, and the Netherlands. The EU funds added another €0.6 billion per year (Figure 4).
- Private involvement is particularly focused on the vehicle dimension of transportation research. In the road sector, private investment is particularly relevant: public funds (2007 figures) from EU member states would reach €1.4 billion, or around only 4% of the total, and EU funds would provide some additional €100 million. Corporate funding provides the bulk of the research budget (Wiesenthal et al. 2011, p. 92).[4]
- The situation is the opposite for infrastructure and networks, in all transport modes. Public funding in this area would account for two-thirds of the total research effort. This would also indicate a crucial difference in research intensity between the automotive industry and the relatively conservative construction industry in the transport sector.

2.2 Key Participants in the Implementation of Transportation Research

2.2.1 United States

The United States has a federal system of governance with a core commitment to markets and partnering with the private sector; therefore, it is not surprising that transportation research, development, and implementation are performed by a diverse set of public, quasi-public, and private entities. This multilayered system is conducive to innovation, with many states and localities acting as test beds for new transportation technologies. The following sample of entities involved directly or indirectly in transportation research implementation–commercialization suggests the diversity and complexity of the U.S. transportation research implementation ecosystem:

- Organizations such as the American Association of State Highway and Transportation Officials (AASHTO),[5] the American Public Transportation Association (APTA),[6] and the Association of American Rail-

[4] This observation is based on conclusions from the 2010 research project Evaluations to Realise a Common Approach to Self-Explaining European Roads (ERASER).

[5] For more information on AASHTO, visit http://www.transportation.org/.

[6] For information on APTA, visit http://www.apta.com.

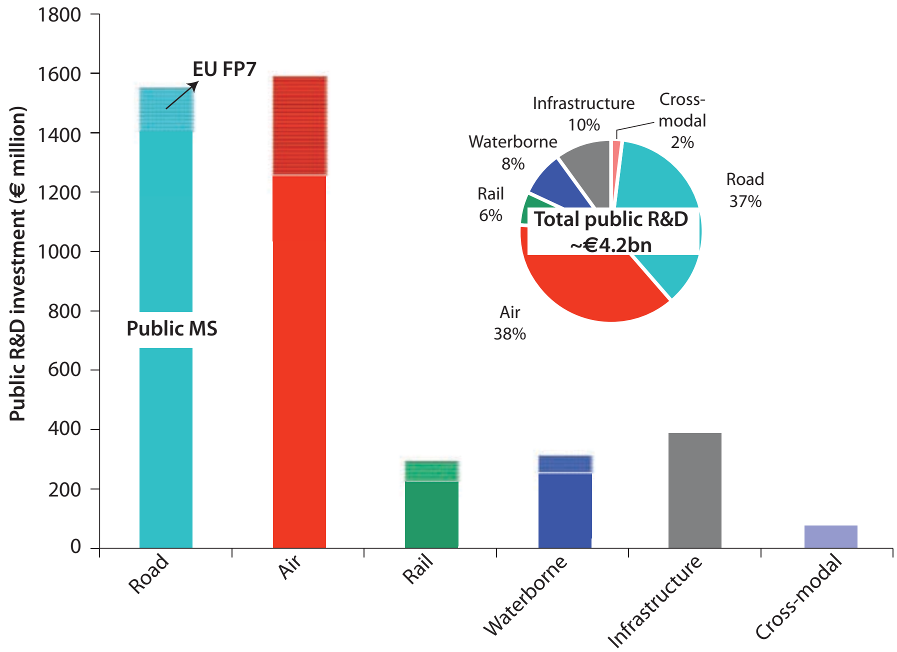

FIGURE 4 Estimate of annualized public EU R&D investments (FP7 = 7th Framework Programme for Research and Technological Development; MS = member states; bn = billion.) (Source: Wiesenthal et al. 2011.)

roads (AAR)[7] represent the owners and operators of U.S. transportation systems. These organizations not only represent the end-user community but are also often the source of research needs.

- A significant portion of research and research implementation technology transfer is performed by university transportation centers (UTCs), which are under the administration of the Office of the Assistant Secretary for Research and Technology (OST-R).[8] Research at these centers ranges from congestion relief to safer driving, innovations in multimodal freight transportation, railroad safety, and durable infrastructure. Research is done by faculty and students.
- Federal and state transportation organizations oversee much of the transportation innovation process. In addition to their own research programs, they have programwide responsibilities, including leadership roles in funding and staffing efforts (e.g., the FHWA Resource Center) and the definition of long-term research roadmaps.
- Quasi-public entities such as TRB are major contributors to transportation research implementation. TRB is a unique organization formed by federal law under the National Academy of Sciences. In addition to its role in bringing together researchers and practitioners in all modes, TRB is also the home of the National Cooperative Highway Research Program (NCHRP), wherein states and other organizations pool their funds to address national research issues.
- Small businesses often have specific scientific and modeling capabilities needed by the U.S. DOT and its modes as well as by the state DOTs. The SBIR program is specifically designed to enable small businesses to participate in the development of technological innovations. U.S. DOT modes such as FTA and FHWA have active SBIR programs. The amount of funding allocated to the SBIR program is based on a percentage of the extramural research budget of the mode.
- Dedicated modal research centers funded by the transportation research modes, which generally have fewer employees than federally funded research and development centers, include FAA's William J. Hughes Research Center in Atlantic City, New Jersey; FHWA's Turner–Fairbank Highway Research Center in McLean, Virginia; OST-R's Volpe National Transportation Research Systems Center in Cambridge, Massachusetts; and the Federal Railroad Administration's (FRA's)

[7] For more information on AAR, visit http://www.aar.org.

[8] OST-R, formerly the Research and Innovative Technology Administration (RITA), coordinates the U.S. DOT's research programs and is charged with advancing the deployment of cross-cutting technologies to improve the U.S. transportation system. As directed by Congress in its founding legislation, OST-R leads DOT in (*a*) coordinating, facilitating, and reviewing the department's R&D programs and activities; (*b*) advancing innovative technologies, including intelligent transportation systems; (*c*) performing comprehensive transportation statistics research, analysis, and reporting; and (*d*) providing education and training in transportation and transportation-related fields.

Transportation Technology Center (TTC), which is operated by AAR.

• Private-sector investment in research, often directed toward the development of proprietary products, is also a key source of innovation and research implementation–commercialization. Automobile manufacturers, for example, expend billions annually on research, both domestically and abroad, including R&D on automobiles, automobile bodies, trailers, and parts. Many major automobile manufacturers in the United States partner with U.S. public and private universities, such as the Georgia Institute of Technology and the Massachusetts Institute of Technology, on a variety of high-technology projects, including solar vehicles.

• The important role of university departments and associated research institutes is exemplified by the symbiotic relationship between the California DOT (Caltrans) and the University of California, Berkeley. Smooth and timely transfer of research funds is possible because both entities are under the California State Government.

• Some states with significant transportation budgets, such as California and New York, are key players in the funding and implementation of transportation research. Some of the funds originate with the federal government, while other funding comes directly out of state government budgets.

• Private sector contracts with private and public research organizations, which often include universities and colleges such as the Massachusetts Institute of Technology; the University of California, Berkeley; and the University of California, Davis, are used to fund international researchers who are prohibited from directly receiving U.S. government funds.

• Other cabinet-level departments and agencies that sponsor transportation research implementation include the U.S. Department of Energy and the U.S. Environmental Protection Agency. This funding has been especially important to various modes, such as the Maritime Administration, that do not receive R&D funds from the U.S. DOT.

Despite the major role played by the federal government in funding the diverse entities that make up the U.S. transportation research and research implementation ecosystem, the U.S. DOT does not have a top-down (hegemonic) management role. As noted, groups such as TRB and AASHTO provide a channel for obtaining a bottom-up understanding of the problems that need research attention, and the U.S. DOT often uses these groups to help prioritize and coordinate the overall national research program. The U.S. DOT, through OST-R, does exercise a more proactive role in defining the focus of research conducted at the UTCs as well as some of the research conducted by modal organizations.

Although OST-R is a logical coordinator of research and technology activities across the U.S. DOT, it is not currently mandated to do so. Modes such as FHWA have their own authorization legislation and, therefore, the authority to set their own research agendas.

This transportation ecosystem is best described as mixed, with elements of centralized research agenda setting and other elements that are clearly decentralized and represented by a diverse compound of private and public stakeholders and state and local governments. It is a system that is robust but difficult to coordinate. For instance, it is been said that when working with state DOTs, you are really working with 50 separate governments, each with its own priorities and laws. In some states, such as Arizona, the state DOT is prohibited from pursuing intellectual property through patents and exclusive licenses. In other states, the pursuit of intellectual property is encouraged.[9]

By virtue of the sheer number of private and public organizations involved in transportation research implementation–commercialization in the United States, it is logical to assume that research implementation is taking place on a massive scale. Indeed, a review of the diversity of programs involved in research implementation–commercialization shows that virtually every technique of effective technology transfer is currently in play, with additional methods under development. Table 1 cross-references a selection of the major research implementation–commercialization methods used by major U.S. transportation public organizations and stakeholders.

Intellectual property tools such as patents, cooperative research and development agreements (CRADAs), and exclusive licensing are the only mechanism that is not used broadly in public transportation research implementation–commercialization in the United States. As discussed in more detail below, some modal administrations at the federal and state levels appear to be reluctant to use intellectual property as a research implementation–commercialization tool and view such activities as contrary to the public good and the proper role of government.

Many modes have found effective research dissemination mechanisms that are consistent with their mission, the composition of their stakeholders, and the specific characteristics of the U.S. marketplace.

[9] The highway system is owned, operated, and maintained by a highly decentralized group of mostly public agencies. More than 35,000 public agencies in the United States have highway transportation responsibilities. These agencies rely on the private sector, traditionally for materials and construction and increasingly for design, construction management, and maintenance. The private sector of the highway industry, which consists of tens of thousands of private firms that provide materials and services, is decentralized and geographically diverse. See *Special Report 261: The Federal Role in Highway Research and Technology* (TRB 2001).

TABLE 1 Representative Selection of U.S Transportation Research Implementation Methods

Organization	Technology Push Programs	Existence of Champions	Pilots, Demon-strations, and Test Beds	Senior Management Support for Priority Technologies	Effective Marketing Through Publications and Conference Participation	Public–Private Partnerships	Commerciali-zation Funding	Patents and Licensing
DOT modes	+	+	+	+	+	~	X	X
State DOTs	~	~	~	~	~	~	X	X
OST-R and associated organizations	+	+	★	★	+	+	X	★
AASHTO	+	+	+	★	+	+	X	X
TRB	+	+	+	+	+	+	X	X
UTCs	+	+	+	+	+	+	X	X
Federal transportation labs[a]	+	+	+	+	+	+	X	~
Universities	+	+	+	+	+	+	+	+

NOTE: + = significant activity; ~ = variable activity; ★ = new activity; X = little or no activity.
[a]FAA's William H. Hughes Research Center is an active user of patents and licenses to disseminate research. In contrast, FHWA's Turner–Fairbanks Highway Research Center has not actively used intellectual property to promote research implementation.

For example, FTA announced on September 5, 2013, that $13.6 million in federal funding was available to advance the commercialization of American-made fuel cell buses for the transit industry.[10] Eight projects were selected to receive a share of FY 2012 funds through FTA's National Fuel Cell Bus Program. This program has provided nearly $90 million since 2006 to speed the development of fuel cell technology by tapping American innovation and enabling American manufacturers to avoid the valley of death discussed above.

FTA is also an active champion for American companies and technologies internationally and has participated in a number of international forums to promote commercialization. The International Public Transportation Program (IPTP) engages in the active championing of innovative U.S. research through international conferences and workshops that have the potential to increase U.S. global market share and further improvements in U.S. transit operations. Examples of recent international research implementation efforts include the following:

- Advanced propulsion vehicles. IPTP works with foreign countries to develop the next generation of vehicles powered by hydrogen fuel cells, battery electric vehicles, hybrid electric vehicles, and other alternative energy technologies.
- Standards. IPTP works to promote adoption of U.S. standards abroad. Harmonization of standards holds important benefits not only for increasing global market share but also for operational efficiency, safety, and security.
- Accessibility and mobility. Since the passage of the Americans with Disabilities Act and subsequent legislation, the United States has become a global leader on accessibility issues. IPTP shares this expertise with the international community and assists in improving mobility for persons with disabilities abroad.
- Sustainability and climate change. IPTP surveys and evaluates international policies and best practices related to the role of transit in lessening environmental impacts and promoting land use strategies that encourage public transit use.

For instance, FTA sponsored an international 2-day Workshop on Livable and Sustainable Communities in January 2011 with the French Ministry of Ecology, Energy, and Sustainable Development. A distinguished group of French officials met with high-level leaders from DOTs, APTA, and other transportation organizations to discuss cooperative programs. During this workshop, FTA championed the use of U.S. technologies.

The meeting was the result of a memorandum of cooperation signed in December 2009 by former U.S. Secretary of Transportation Ray LaHood and his counterpart Dominique Bussereau calling for the exchange of information and technology on topics such as congestion mitigation, climate change, livable communities, advanced vehicle technology, and improved intelligent transportation system applications.

FTA is not alone in implementing innovative programs to promote research dissemination over the valley of death and all the way to commercialization. FRA has also established an innovative mechanism for research implementation and technology transfer through the

[10] For information on FTA programs go to http://www.fta.dot.gov.

construction and operation of the Transportation Technology Center, Inc. (TTC), a major center for railroad technology testing and certification in Pueblo, Colorado.[11] The 52-square mile facility, which encompasses extensive track facilities and state-of-the-art research facilities, is operated by AAR. TTC enables isolated testing for all categories of freight and passenger rolling stock, vehicle and track components, and safety devices. This facility is a major mechanism for the implementation of railroad-related research and represents a best practice for PPPs in the transportation research and commercialization sector. Once a technology is validated through TTC, it is virtually guaranteed to be widely used throughout the freight railroad sector.[12]

The railroad industry is increasingly ripe for innovation, given the growth in the natural resource component of its business. The industry as a whole grew by 800,000 units in 2013, half of which were handled by the Burlington Northern Santa Fe railroad (BNSF). Much of the growth has come from increased hauling of crude oil from the Bakken Shale formation in North Dakota. BNSF expects to haul 1 million barrels of crude oil per day by the end of 2014. BNSF also announced plans to spend a record $5 billion in capital in 2014, $1 billion more than it spent the previous year. Growing safety concerns related to the transport of petroleum will likely accelerate the implementation of safety innovations and practices.

The U.S. railroad industry has long been inaccurately portrayed as the caboose of the innovation transportation train. Nothing could be further from the truth. For instance, both sides of tracks were once lubricated to reduce wear and tear on wheels and locomotives, but sometimes when a train was chugging up a steep hill, the lubricant would cause the wheels to spin and stall. The innovative solution: solar-powered dispensers pump a different substance—a friction modifier—on the tracks as a train approaches. "This new technique reduces wear but also provides adequate friction so the wheels don't slip," explains Wick Moorman, CEO of Norfolk Southern Corporation, one of the nation's largest freight railroads.

There are technology projects—big and small—in the freight rail industry that are contributing to more and more efficiency, making the United States the world leader in the transportation of freight by trains. The rail industry has been a pioneer of the digital age and a leader in technological advances, such as sensors that can detect when wheels and tracks are about to give out from stress. Railroads were an early adopter of technologies such as radio frequency identification, which uses tags and radio waves to track the flow of trains and cargo. The industry is now adopting wireless sensors to provide better information on train movements to improve efficiency and safety while reducing greenhouse emissions (Mulloch 2014).

Much innovation in the railroad industry is driven by information technology and the ability to have better planning tools by using real-time information. For example, locomotive engineers can now turn to an onboard, GPS-based computer system that tells them the optimum throttle, speed, and brake settings to achieve maximum fuel efficiency. This system takes into account the train's length and weight and provides recommendations on how to operate the train based on hilly terrain, curves, and other track conditions. FTA's use of GPS parallels FHWA's deployment of GPS technology under the SHRP 2 program.

Finally, it is important to consider the RailEdge Movement Planner, the railroad industry's version of a next-generation air traffic control system. The planner gathers data about train schedules, traffic control systems, and the movement of trains relative to each other over a huge span of tracks. By analyzing all that information in real time, the system can optimize travel plans for the train, down to telling the engineer the best speed to travel at any given moment to keep the best overall flow and ensure safe operations. This system will be instrumental in maintain public confidence as the U.S. rail industry transports increasing supplies of domestic petroleum.

The railroad industry's research outcomes are truly amazing: non-petroleum-carrying freight trains are increasing their average speed as much as 4 miles per hour. While that might seem a trivial amount, in the freight world, every 1-mile-per-hour translates into $200 million a year in capital and expense savings. In another way of looking at it, a railroad running 20 trains per day between New York and Washington, D.C., could increase that frequency to 23 trains per day with RailEdge simply by utilizing the existing track more efficiently.

Not all innovations in rail are technological, however. As in all industries and transportation sectors, solutions often rely on instituting common-sense ideas. For example, trains that transport paper products from mills have historically returned to the mills empty. A Norfolk Southern pilot project found a cost-effective, eco-friendly way to make better use of those returning trains: loading them with scrap paper that the mills use in their recycled paper (Mulloch 2014).

With regard to the highway sector, it must be emphasized that FHWA is constantly seeking new methods for enlarging its implementation–commercialization successes. FHWA recently announced that it has made roughly $30 million in incentive funding available to state transportation departments under its new Accelerated Innovation Deployment (AID) Demonstration program.

The purpose of the AID Demonstration funding is to incentivize state DOTs and other agencies to implement and

[11] For information on FRA research dissemination activities go to http://www.fra.dot.gov.

[12] For information on TTC, visit http://www.aar.com/.

adopt innovations in highway transportation. The program encourages the use of AID Demonstrations under the Every Day Counts initiative,[13] which provides opportunities for improving the work of highway infrastructure planning, design, construction, and operation. The AID program is one aspect of the Technology and Innovation Deployment Program under the present surface transportation bill, the Moving Ahead for Progress in the 21st Century Act (MAP-21),[14] which enables SHRP 2 implementation activities and the accelerated deployment of pavement technologies. Again, FHWA is discovering and implementing policies and practices that enable transportation innovations to traverse the valley of death.

2.2.2 *European Union*

Excluding vehicle design and construction, surface transportation research in the European Union is strongly dependent on public programs particularly for disruptive (as opposed to incremental) innovation concepts (Aparicio et al. 2012). Research activities are usually financed by programs at both the EU level and the national (and eventually regional) level. In some countries (e.g., Germany, France, and the United Kingdom), national programs on transport research provide substantial funding opportunities; in other countries (e.g., Greece, Hungary, and Poland), research institutes rely mainly on EU programs, as national funding opportunities are modest. Indeed, it is doubtful that any level of significant transportation research would occur in Greece without EU funding.

The network of entities involved in transportation research and technology transfer at the European level includes

- ETPs, active in the various transport modes, with national correspondents in some countries;[15]
- International transport organizations of European or global character that help to structure joint research projects of transnational nature [e.g., the International Union of Railways (UIC), the Community of European Railways (CER), the European Conference of Transport Research Institutes (ECTRI), the Forum of European National Highway Research Laboratories (FEHRL)];
- Dedicated national transport research centers, most of a public character and increasingly federated at the EU level through different networks such as FEHRL, the Forum of European Road Safety Research Institutes (FERSI), or ECTRI;[16]
- Universities, many of which have specialized transport research centers;
- A variety of stakeholders, such as operators of transport services for passengers and freight; and
- A wide realm of industries of all sizes (e.g., manufacturers of transport equipment, construction companies), many of which are organized through European networks such as the European Automobile Manufacturers Association (ACEA), the Association of the Euro-

Disruptive Technology

"Disruptive technology" is a term coined by Harvard Business School professor Clayton M. Christensen to describe a new technology that unexpectedly displaces an established technology. In his 1997 best-selling book, *The Innovator's Dilemma,* Christensen separates new technology into two categories: sustaining and disruptive. Sustaining technology relies on incremental improvements to an already established technology. Disruptive technology lacks refinement, often has performance problems because it is new, appeals to a limited audience, and may not yet have a proven practical application (such was the case with Alexander Graham Bell's "electrical speech machine," now known as the telephone).

In his book, Christensen points out that large corporations (as well as many government agencies) are designed to work with sustaining technologies. They excel at knowing their market, staying close to their customers, and having a mechanism in place to develop existing technology. Conversely, they have trouble capitalizing on the potential efficiencies, cost savings, or new marketing opportunities created by initially low-margin disruptive technologies. Using real-world examples to illustrate his point, Christensen demonstrates how it is not unusual for a big corporation to dismiss the value of a disruptive technology because it does not reinforce current company goals, only to be blindsided as the technology matures, gains a larger audience and market share, and threatens the status quo.

[13] For information on the Every Day Counts initiative, go to www.fhwa.dot.gov/everydaycounts/.

[14] For information on current surface transport funding, go to www.fhwa.dot.gov/map21/.

[15] Examples include the Advisory Council for Aviation Research and Innovation in Europe (ACARE), the European Rail Research Advisory Council (ERRAC), the European Road Transport Research Advisory Council (ERTRAC), the Waterborne ETP, and the European Construction Technology Platform (ECTP).

[16] Although the bulk of the research activities of the national transport research centers frequently focuses on national research needs, with strong interaction with their respective governments (e.g., ministries of transport and associated agencies), their participation in European research programs has always been substantial.

TABLE 2 Representative Selection of EU Transportation Research Implementation Methods

Organization	Technology Push Programs	Existence of Champions	Pilots, Demon-strations, and Test Beds	Senior Management Support for Priority Technologies	Effective Marketing Through Publications and Conference Participation	Public–Private Partnerships	Commerciali-zation Funding	Patents and Licensing
European Commission Directorate-General for Research and Innovation	+	X	~	X	+	+	X	+
European Commission Directorate-General for Mobility and Transport	+	+	+	+	+	~	X	X
National govern-ments	+	+	+	+	+	+	~	~
National transporta-tion research centers	+	+	+	~	~	~	X	+
European Technological Platforms	X	+	~	X	+	+	X	X
Modal European organizations	X	+	~	X	+	★	X	X
Regional and local governments	~	X	+	~	~	X	X	X
Joint Research Centre, European Commission	X	X	~	~	~	X	X	X
Universities	+	~	~	+	+	~	~	~

NOTE: + = significant activity; ~ = variable activity; ★ = new activity; X = little or no activity.

pean Rail Industry (UNIFE), the European Network of Construction Companies for Research and Development (ENCORD) and the European Construction Industry Federation (FIEC).

Table 2 cross references a selection of the major research implementation methods used in EU transportation research.

The European transport research agenda has been materialized through the priorities established in the Framework Programmes (every 7 years) and their annual working programs, which include the description of topics to be financed. These have been closely linked to the policy priorities of the European Union (the so-called Transport White Papers, published every 10 years).

However, since 2005, the working programs have increasingly accommodated the priorities of European industry, as set up by the ETPs for each transport mode. Furthermore, an effort has been made to increase cooperation with national programs: the European Research Area–Network (ERA-NET) structures were intended to create a pool of financial resources for research by combining national and European budgets. In the case of road transport, the ERA-NET structure has evolved to produce the first transnational research program, with the support of the Conference of European Directors of Roads (CEDR). Furthermore, the original top-down approach for research priorities has evolved toward a more flexible structure, so that researchers can have more freedom in defining topics and even apply for financing by using bottom-up proposals.

In spite of regular efforts to reduce red tape, participants have periodically raised concerns about the increasing bureaucratic complexity of European programs and about the level of effort and resources needed to prepare a competitive proposal. Concomitantly, the chances for approval have been reduced as a result of increased concurrence as national funding has declined over the past years and researchers have tried to compensate for this decline by presenting proposals on a higher number of topics at each new European call.

Big organizational players could find a competitive advantage, as they could afford to dedicate more resources to the preparation of attractive proposals, whereas there would be a barrier to the entry of smaller research institutes and to newcomers. In the research institutes of some EU cohesion countries, as much as 40% to 60% of a young researcher's (postdoc's) time is spent preparing research proposals at certain critical points during the year instead of making progress in completing dissertations and educational plans, doing research, attending symposia, or participating in research implementation and technology transfer training (interviews with young European transportation researchers, personal communication, January 23 and February 28, 2014). The consequence has been an alienated, anxious universe of young researchers who are increasingly tempted to move to more lucrative research settings, the result being an accelerated national brain drain. A related controversial topic is the extent to which more elaborated proposals actually result in better research results.

European research programs typically require explicit dissemination and exploitation plans as a key part of the proposal. Projects are followed by assigned European Commission officials, and programs are subject to midterm and final evaluation. Although there are isolated monitoring efforts, particularly for topics that are being continued over time, there has not been a comprehensive effort at the EU level for assessing the level of actual implementation of research results. The lack of critical data is a systemic barrier to facilitating enhanced research implementation and technology transfer. The parallels between Europe and the United States could not be more obvious.

The involvement of the industry in the EU Framework Research Programme has received increasing attention from policy makers since the mid-2000s, and this attention increased in the first years of the economic crisis, as research and innovation were seen as key components for an economic recovery strategy. Since the early 2000s, the European research budget has financed PPP research efforts, known as Joint Research Initiatives or Joint Technology Initiatives. Aeronautics was the pioneering field for such PPP efforts (Clean Sky Joint Technology Initiative), and the concept was transferred afterward (in a slightly different format) to the automotive sector (the Green Cars Initiative). There are advanced plans within Horizon 2020 to launch similar concepts for rail (e.g., Shift^{2}Rail) and for waterborne transport.

The involvement of the private sector in transportation research in Europe is far from uniform across areas. Corporate research efforts are substantial in the development of new vehicles and equipment, whereas the research activity of construction firms and other companies active in infrastructure and network development and operations is significantly lower (Wiesenthal et al. 2011). The research activity funded by public budgets (European or national) is also different. In the case of European funds, this difference can be the result of the requirement to establish a multinational consortium with a variety of partners. In the area of vehicles and equipment, the private sector prefers to apply for European funding for activities at the basic or precommercialization stages, in which it can cooperate with otherwise competitive partners. For infrastructure and networks, many industries see the public sector as the final user of research results, as new practices and concepts usually need to be explicitly accepted in official standards and guidelines.

3 Optimal Implementation of Transportation Research

This section explores the critical conditions for optimal implementation of transportation research and looks at areas where opportunities may exist for the United States and Europe to achieve that status. It was earlier noted that there are numerous scientific implementation activities in the United States and the European Union at all levels and that there is evidence that changes are occurring that will enhance research implementation, including new funding for the accelerated deployment of highway technologies. Nevertheless, as recognized in the very focus of this EU-U.S. symposium and in recent statements by the TRB Executive Board, concerns about the rate and effectiveness of research implementation continue.

Rather than provide a laundry list of factors and symptoms that impair the effectiveness of the implementation of transportation research in the European Union and the United States, it is more productive to focus on four key conditions that, if realized, would support an optimized research implementation–commercialization process. These necessary (though not sufficient) conditions are as follows:

Condition 1. A process that provides sufficient funding for research implementation. Funding processes must provide sufficient resources to support both scientific research and research implementation–commercialization at all levels of government. The process would include predictable funding as well as a means to assure that funding is allocated in a way that supports bridges across the valley of death.

Condition 2. Centralized planning and coordination. The use of a comprehensive planning process that spans modes will ensure that research and implementation resources are coordinated and directed at high-priority transportation needs. Such a process would likely lead to the optimized setting of research agendas, allocating resources on a competitive basis, and ensuring the prioritization of research implementation activities on a national (United States) and transnational (European Union) scale. Again, Secretary Foxx's commitment to an integrated National Transportation Plan is a critical step in the right direction.

Condition 3. Effective data collection and analysis. Evaluation methods and mechanisms that can monitor the performance and effectiveness of research implementation strategies across and within modes must be instituted. Such systems would include a means to collect and analyze data on the monetized and the discounted benefits and costs of implementing new transportation research.

Condition 4. Effective use of intellectual property tools. A robust, integrated, and reinforcing research implementation portfolio that includes the use of intellectual property tools, when warranted, to promote the commercialization of transportation research should be established.

3.1 Condition 1. A Process That Provides Sufficient Funding for Research Implementation

3.1.1 United States

According to the TRB Executive Committee, with some major exceptions, "new technologies and innovations that promised more efficient and sustainable travel have been implemented haltingly and incompletely particularly in the public sector" (TRB 2013, p. 12).

The TRB Executive Board points to long-needed upgrades to air traffic control systems and technologies that are immersed in controversy over the sharing of costs between the private and public sectors and uncertain federal funding and the significant investments in information and communications technologies that have yet to produce dramatic changes in mobility, such as dynamic ride sharing and demand–response transit. Moreover, the effective management of congestion remains largely an intractable challenge despite large public investments in traffic management systems as well as real-world experiments (in both the United States and Europe) with congestion pricing systems. Moreover, there is an underlying issue of equity, in that these mechanisms do not account for the ability to pay.

One of the central factors that is increasingly responsible for the suboptimal implementation of transportation research is the significant decline in federal funding for transportation research, which, in turn, influences investments in implementation at all levels of government as well as by the private sector. When compared with other sectors, U.S. investments in transportation research are minimal. Although U.S. R&D has been increasing as a percentage of gross domestic product (GDP) and now approaches 3%, Figure 5 illustrates that transportation R&D has declined steadily in real terms to only 0.01% of GDP (TRB 2013, p. 14).

Funding uncertainties are reflected in the increasing reluctance of states to cosponsor research implementation activities with FHWA. For example, the Nevada State Transportation Board recently elected to delay a research program with FHWA that would have cost the agency $1 million over 4 years because of concerns about the availability of highway federal funds later in 2014. While the sum was relatively trivial, Governor Brian Sandoval stated that if the state was facing the potential of having to cut road projects later in the year because of a looming federal highway funding issue, the board had "to be cautious now about spending scarce funds on research" (Whaley 2014). This example underscores the vulnerability of research implementation to funding uncertainties. After all, research generates little public interest, while infrastructure problems, including an abundance of potholes, can jeopardize the reelection chances of state and local public officials.

Despite the reduction in transportation research funding as a percentage of GDP and uncertainties regarding future federal funding levels, innovations continue to make it from conception all the way to implementation, including electronic stability control devices that save lives by reducing rollover crashes. Moreover, real-time data on traffic and parking are now used to aid traveler decision making via electronic signs and cell phone messages. New vehicles, including trucks and locomotives (as reported earlier), are using sophisticated, energy-saving technologies. State-of-the-art logistics models are reducing shipping and inventory costs.

3.1.2 Europe

The availability of research funding remains scarce in many countries of the European Union and has been further reduced by austerity policies. Both insufficient resources and lack of long-term funding have jeopardized the balanced development of transport research across the European Union. Successful implementation can be seen as the tip of a pyramid; only a minor percentage of research results ultimately reaches the top.

This consequence is due to the myriad of half-anonymous efforts that served to pave the way by discarding alternative approaches that were provided by a much wider community of researchers. In fact, it could be said that research is always a high-risk investment; success stories are grounded on previous (and sometimes expensive) failures.

Lack of implementation of research results in Europe can be seen as an indicator of the lack of a sufficient number of researchers working in different but interconnected fields and geographical areas. From this perspective, it is uncertain that increased funding in Horizon 2020 will be able to compensate for the weakened research structure caused by national austerity policies.

Public funding is typically scarcer for demonstrations and pilots. As discussed earlier, a partial explanation for this scarcity is that demonstrations and pilots are closer to commercialization and raise concerns about intellectual property rights and the dedication of public funds in

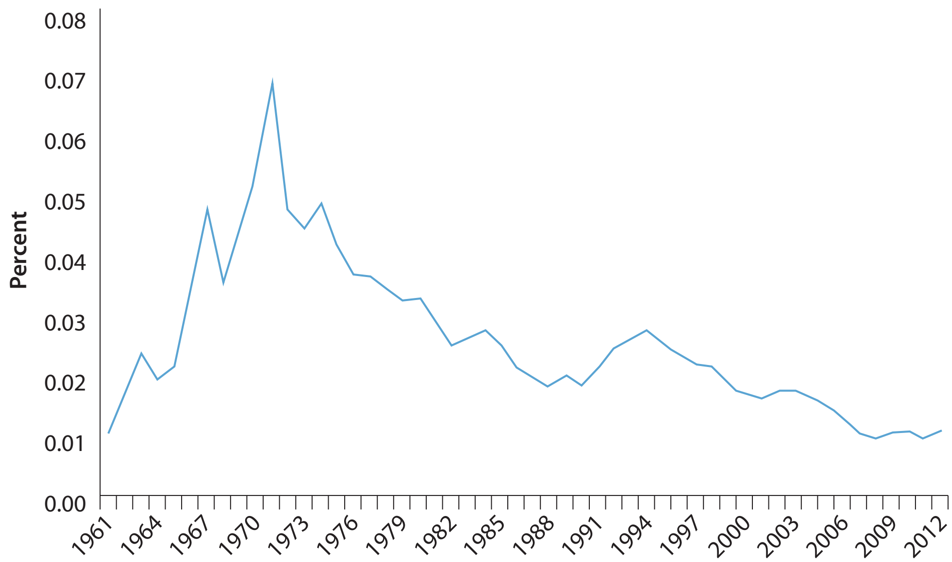

FIGURE 5 Transportation R&D as a percentage of GDP, 1961–2012. (Source: TRB 2013; used with permission.)

a way that can directly or indirectly support the market position of particular companies. Furthermore, transport demonstrations and pilots usually require substantial investments and have to be associated with already planned construction projects or service concepts, particularly when they relate to infrastructure. Again, parallels can be drawn between the European Union and the United States.

Transport, particularly in the area of infrastructures and networks, is a conservative environment subject to well-consolidated regulations and standards that inhibit the application of innovations or proprietary technology. A risk-avoidance culture that more often than not results in avoidance of innovation prevails. Furthermore, the transport sector is strongly influenced by public policies through regulations and through public investments, particularly in infrastructure. Thus, it is only natural for stakeholders to expect that decision makers in the public agencies will lead the innovation effort and establish goals for all the transport community.

In spite of the efforts of EU transport research programs to encourage broad research partnerships that include industrial partners and end users, the involvement of partners with actual commercial interest in the quick implementation of results remains rather unusual in research projects. Many exploitation and business plans are not detailed enough at the time a proposal is approved, so it is difficult for research officials to assess what can reasonably be expected for projects in terms of moving close enough to implementation.

Pooling of national and European funds has been seen as a promising way to optimize limited resources and to speed up the process toward implementation. Under the leadership of CEDR, the road sector has been particularly active in this process. The ERA-NET Road Research scheme was active between 2006 and 2012 and has been continued by another CEDR Transnational Road Research Programme call launched in 2013. A similar ERA-NET concept, Infravation EN+, has also been set up with participation of the United States and several European countries.

3.2 Condition 2. Centralized Planning and Coordination

3.2.1 United States

Although reduced funding has affected the rate at which transportation innovations are developed and implemented at both the federal and state levels, an additional obstacle to effective implementation of research is the organizational complexity associated with transportation research implementation. While there are literally hundreds of organizations involved in transportation research implementation, there is no one organization capable of coordinating the national (public) transportation agenda and the rigorous collection of data on implementation and commercialization.

Organizational complexity and redundancy can lead to the duplication of resource expenditures and the inability for one part of the organization to know what other parts are doing in the areas of research implementation. Whether the U.S. transportation sector as a whole knows what it does not know about research implementation is uncertain.

FHWA is an illustrative case study of how organizations cope with these complexities. The agency manages multiple organizations involved with different facets of highway transportation, of which research implementation is only one of many responsibilities.

This diversity and organizational complexity are understandable, given the complex set of public and private stakeholders FHWA serves (e.g., Congress, tribal governments, state and local governments, other federal agencies, contactors, universities, and private firms). This complexity is also a byproduct of managing the largest and most advanced highway system in the world. While the level of federal funding is uncertain, FHWA's responsibilities—including enhancing roadway safety, mobility, and reliability—have not disappeared.

The Turner–Fairbanks Highway Research Center has launched a series of initiatives to facilitate coordinated research implementation, including hosting FHWA's Office of Corporate Research, Technology, and Innovation Management (TRB 2005). This office develops and executes policy, budget, program management, and administrative mechanisms to enable a nationwide FHWA research, development, and technology program that is carried out in cooperation with public and private partners. The office develops and executes communications and outreach that support FHWA-wide research, development, and technology programs and innovation delivery needs. The office supports Turner–Fairbanks Highway Research Center staff, other FHWA offices, and the FHWA Resource Center in the planning and evaluation of programs and projects and is responsible for communicating the benefits of new, priority technologies. Finally, the office also oversees the establishment of partnerships with European transportation organizations.

Through the leadership of the Office of Corporate Research, Technology, and Innovation Management, FHWA has identified 24 priority market-ready technologies and innovations that the agency has designated as push technologies. Each month, the office's website profiles one of these technologies. The list of priority market-ready technologies changes periodically as new technologies are added and others reach a level of deployment that allows them to be removed from the priority list. However, the fatal flaw is that no system is in place to measure whether this process is producing concrete results and sufficient benefits relative to investment costs.

Despite the centralization of many research implementation activities, FHWA's overall technology transfer and research implementation efforts are likely hampered by virtue of the sheer number of organizations that are involved in research implementation and technology transfer. One former FHWA employee noted it is sometimes the case that "organizations across FHWA do not know what others are doing in technology transfer and commercialization" (personal communication, March 7, 2014).

Not only are multiple organizations within FHWA responsible for research implementation, but each of the major DOT modes [e.g., FTA and the Federal Motor Carrier Safety Administration (FMCSA)] has its own distinct processes for disseminating research. Coordination between modes is infrequent, if not random.

Questions and concerns regarding research coordination include the UTC program administered by OST-R. The program funds five national UTCs with funding of up to $3.0 million per center per fiscal year; 10 regional UTCs, one of which must be dedicated to comprehensive transportation safety, with up to $2.75 million in funding per center per fiscal year; and up to 20 Tier 1 UTCs, which are also key champions of technology transfer and the implementation of research results, with up to $1.5 million per center per fiscal year. Each UTC is required to focus its research and technology transfer activities around one of the U.S. DOT's strategic goals; however, there reportedly is insufficient coordination between the research activities of the UTCs and the priorities of the DOT modes, which also align their research with the DOT strategic plan. It is one thing to align research with general strategic goals; it is a more complicated task to ensure that the UTC research is supportive and reinforcing of modal priorities.

It is suggestive that those institutions that have centralized their activities in one organization have also realized increased commercialization successes. Emory University is representative of what universities have been doing for several decades to consolidate their intellectual property–related activities. Emory has one of the successful university one-stop shops for research implementation.

Likewise, those federal agencies that have built successful technology transfer programs such as the National Cancer Institute, the U.S. Department of Agriculture, and the National Aeronautics and Space Administration (NASA) have done so through the centralization of their technology transfer activities. Consequently, they offer best practices and organizational models for consideration by the entire transportation research community.

3.2.2 Europe

The EU Framework Programmes for transport research have played a significant role in promoting certain policy approaches and in increasing cooperation among researchers across the continent, but it is uncertain that they can claim to have been able to set main directions or coordinate research implementation efforts in Europe. In the key leading European countries, such as Germany, national research remains much more substantial in terms of resources. European research is seen by most of the big research players more as a helpful contributor in moving forward some particular concepts at a transnational level than as a leading reference for future research directions.

Nevertheless, the EU experience has provided consensual mechanisms among countries for agreement on common research topics of shared interest—a mechanism increasingly open to key stakeholders, such as industry and the research community. This mechanism is no guarantee, however, that the research topics selected will find a smoother path toward the implementation and commercialization of their results. On the contrary, it could be argued that the EU research agenda has mainly been open to exploratory research—an argument consistent with the nature of exploratory research being better suited to cooperation, whereas research closer to implementation can be seen more as a field for competition and poorly suited to cooperation.

European research programs have been influential, if not decisive, in setting up the research and policy agendas in certain areas, such as traffic safety, urban mobility, and multimodality, to cite a few examples. To strengthen more coordinated policies from governments, research topics in these fields have been generously financed through the Framework Programmes for exploring new policy approaches. Furthermore, European research programs in transport have encouraged close cooperation among the different directorates within the European Commission with responsibilities in transport, research and innovation, and industrial policy, among other sectors.

However, the experience in a few particular fields with a relatively low weight in the total research budget cannot change the general perception that it seems unlikely to expect the European Commission to undertake a relevant coordinating role in the future of transport research. Certainly, the consensual nature of agenda setting and decision making at the EU level can be further strengthened, and this collaborative

Centralizing Research Implementation Functions for Improved Commercialization Performance: Emory University's Office of Technology Transfer

The Office of Technology Transfer (OTT) supports the university's mission through comprehensive management of Emory innovations to maximize the benefit to the university and to humanity. OTT provides the following centralized services to the university community through a centralized and focused process:

- Educate researchers about intellectual property and technology transfer;
- Foster the identification of research results for disclosure of intellectual property;
- Evaluate research disclosures for commercial viability;
- Protect intellectual property and administer the protection process used (e.g., patent, trademark, copyright);
- Market intellectual property;
- Negotiate license arrangements for intellectual property;
- Monitor existing licenses for compliance with contractual obligations, including financial obligations;
- Collect and distribute all funds associated with licenses according to internal policies;
- Comply with federal or research sponsor guidelines for intellectual property;
- Administer the transfer (in or out) of research materials; and
- Facilitate the development of start-up companies based on Emory intellectual property.

effort can indirectly influence national agenda setting in leading European countries and the priorities of the key industrial players. Even so, there is no guarantee of increased implementation of results. At best, further coordination can be expected at the level of open access to research results and ex post assessments of research and dissemination efforts.

Public procurement can be seen as a powerful instrument for encouraging innovation. The European Commission has championed a sustained effort to stimulate innovation in environmental technologies since 2008 through the Green Public Procurement concept (European Commission 2008).[17] Since then, specific voluntary criteria for Green Public Procurement have been developed for some sectors, including transport equipment. The European Commission has also set up a platform on public procurement of innovation as a way to support public procurement authorities and stakeholders at large in their efforts to foster market uptake of innovative products.[18] Furthermore, the European Parliament passed a legislation package on public procurement in January 2014; this package introduced new provisions that allow for environmental social considerations and innovation to be taken into account when public contracts are awarded. Transport is one of the sectors targeted by this legislation.

3.3 Condition 3. Effective Data Collection and Analysis

3.3.1 United States

There are numerous examples of significant and successful advancements made by FHWA and others in implementing new technologies. Some of these include high-performance concrete, warm-mix asphalt, prefabricated bridges, the modern roundabout, and installation of rumble strips and median cables to improve safety. However, most of the information about these implementation efforts is more anecdotal than systematic. There is no question that the impact of these technologies has been significant; it is just difficult to measure the extent of that success and the overall investment that was needed to promote change.

As noted, the United States does not have strong centralized coordination of research implementation activities, and implementation is therefore often highly decentralized, with organizations all over the country playing a part in the cycle of research dissemination and commercialization. There also is no central source of implementation funding in the United States, which means that following the dollars as a means of tracking activities is harder. A notable exception mentioned earlier is the Every Day Counts program, which not only has centralized coordination of the implementation of specific market-ready technologies but also carefully tracks research implementation efforts across the nation.

In general, there is a lack of data on the implementation of transportation research. Most information is collected and stored by individual organizations. Many times, federal and state transportation organizations do not rigorously collect information on technologies developed and commercialized with public funds or on the economic value associated with a commercialized technology. Even the U.S. DOT's Bureau of Transportation Statistics lacks the mandate to collect data on transportation research implementation or technology transfer.

The lack of quantitative information (or useful metrics) on technology transfer and research implementation throughout the DOT and across the transportation modes prevents a fundamental assessment of whether the implementation of various research is resulting in widely used products. Again, it is irrefutable that there are significant research implementation activities in FHWA. Because of a lack of information, it is far less clear whether these activities are optimizing the transfer of transportation technologies.

The only cross-government source of data on technology transfer is provided by the National Institute of Standards and Technology, which produces the annual report *Federal Laboratory Technology Transfer* (see, for example, NIST 2013). Unfortunately, the information presented is usually about 2 years old when published and is largely restricted to activities associated with the development and deployment of intellectual property. The implementation of a state-of-the-art research implementation–commercialization tracking system that includes multiple modes would provide an opportunity for the enhanced management of hundreds of federal and state transportation research activities.

3.3.1 Europe

The European Union has deployed significant efforts in dissemination and evaluation of transport research results. Framework Programmes have followed midterm and final evaluations, most research projects have been followed by one European Commission technical official, and specific instruments have been put in place for public access to research results.

However, successful dissemination and implementation experiences are not easy to identify, even for stake-

[17] For more information on the European Commission's Green Public Procurement program, go to http://ec.europa.eu/environment/gpp/index_en.htm.

[18] For more information on the Procurement of Innovation Platform, go to https://www.innovation-procurement.org/.

holders actively involved in research projects. Once the research project is completed, most researchers move to another project and do not pay much attention to the potential implementation of their research results. There seems to be a pervasive divide between researchers and implementers. For example, it is not uncommon to find research leaders of EU projects unaware about the follow-ups of their project results. Furthermore, nonindustrial partners in research projects have little interest in exploitation plans. It seems there could be a missing actor, namely, some kind of facilitator who would review research results and actively look for opportunities for commercialization. In fact, little is known about the characteristics of implementation processes in the transport sector in Europe. There is an urgent need to improve systems for collecting data on implementation and to establish some monitoring of implementation processes with close cooperation between research administrations and industry.

The EU approach has consistently attempted to increase efforts made by researchers in the implementation and exploitation of their projects, with mixed results. Integrated PPP concepts such as the Joint Research Initiatives can be successful for specific topics with clear public interest but cannot be generalized without raising serious accountability concerns about the use of public funding. Although the ETPs have been instrumental in providing roadmaps for key topics from research to final implementation, they concern only a small part of the EU research agenda with a strong modal character and a short- to medium-term perspective.

Effective data collection and process analysis should also provide more insight on the traditional mismatch in European transport research between visions that are too ambitious and policies that are too cautious. Whereas transport research has worked hard to provide fresh technical and policy paradigms for fundamental transformations in the transport sector, aligned with the ambitious environmental policies set up by the European Union, policy making has been dominated by short-term concerns; lengthy discussions; and cautious, incremental changes. European industry cannot be asked to move fast into innovative concepts when the policy experience is that the actual path of change has moved rather slowly in the past.

3.4 Condition 4. Effective Use of Intellectual Property Tools

3.4.1 United States

On the one hand, the experience of the public sector of the U.S. transportation community with the use of intellectual property tools is, with some exceptions, limited. This limited experience stands in contrast to that of many other federal agencies. On the other hand, and when considered as a whole, the automobile and airline industries constitute a significant percentage of the total investment in transportation, and the companies that lead those sectors carefully protect their intellectual property assets domestically and internationally. This approach makes sense, considering the competitive value of their innovations and the importance of maintaining market position. In the United States, the approaches taken by the public and private sectors involved with transportation are clearly divergent.

The nature of the implementation of transportation research in the United States is to encourage the widest distribution and use of new technology to benefit the traveling public. Anything that might be viewed as an impediment to broad, open dissemination is usually discouraged or simply ignored. Much of the research that is being implemented is more process or specification oriented (as noted in the previous examples of Superpave and high-performance concrete) and is not particularly amenable to protection through intellectual property. Nevertheless, there are several highway-related inventions that have been patented by the federal government or its contractors.

As noted above, some within the public sector view the patenting and licensing of transportation technologies developed with federal funds as contrary to their view that the public interest requires these products to remain available equally to all to develop and commercialize. The potential flaw in the view that all should be public is that unless the private sector has a reasonable chance of making a profit on an innovation, it will not invest in research products. Nonexclusive technology licensing, therefore, can be a barrier to rather than an incentive for research implementation.

In addition, U.S. contracting processes are generally based on an arm's length relationship with the private sector, where collaborative efforts are fairly rare. (The exception to this are the relatively new PPPs being developed; however, those tend to focus more on infrastructure financing than on specific technologies). In contrast, at the National Cancer Institute, federal and private researchers typically work closely in the conduct of research.

Despite recent initiatives by OST-R to place greater emphasis on intellectual property, including patents, exclusive licenses, and the use of CRADAs, most federal and state transportation agencies still make little use of intellectual property tools or the tracking of patent applications by contractors under federal law.

Some states, including California, have tried to develop and commercialize research, with some notable failures. For example, the Mobile Work Zone Protection System, or Balsi Beam, developed and patented by Caltrans experienced several commercialization setbacks that soured some state transportation officials regarding the use of patents and licensing to commercialize technologies.

In contrast, other federal entities, such as the U.S. Department of Agriculture and NASA, have aggressively sought over the past 30 years to protect and commercialize intellectual property as well as to track patents sought by their contractors. In general, federal organizations that have supported intellectual property as an important mechanism for commercialization have a strong reputation as contributors to economic growth and innovation in the United States.

According to the most recent data provided by federal agencies, in FY 2011 there were 7,798 active CRADAs in place between federal laboratories and external partners, 5,294 new inventions disclosed at federal facilities, 13,940 active licenses associated with federal laboratory technologies, and approximately $167,543,000 in total licensing income associated with federal technology transfer activities (NIST 2013). As displayed in Table 3, the number of U.S. DOT active licenses, CRADAs, patent applications, and new invention disclosures constitutes a miniscule percentage of the total.

While intellectual property is infrequently used for promoting transportation research implementation–commercialization, it deserves additional consideration by federal and state transportation agencies as one among several possible deployment strategies (NIST 2013).

3.4.2 Europe

Intellectual property rights are negotiated between partners in European research projects within consortium agreements. There are no specific rules on the contents of these consortium agreements, and the bigger partners in the consortium usually impose their model agreements on the others. As the research activities funded are usually far from commercialization, consortium agreements have not been controversial. However, it could be argued that the European Commission could stimulate innovation by establishing clear rules for intellectual property rights concerning open access to research results, at least for projects that have been totally or substantially funded by public budgets (EUTRAIN 2013).

Another reason for the different approach of corporate research in the areas of vehicles and infrastructures is that transport infrastructure is probably a rather mature sector, in which the key research contributions were made decades ago. Large-scale demonstrators and real-scale test facilities were at the core of the research agenda 50 or 30 years ago, but research efforts are now focused on incremental improvements.

Of course, this could change in the future, as happened for rail infrastructure with the development of high-speed systems that required more stringent performance conditions; it could happen with climate change adaptation and smart infrastructure, which could again require a major review of traditional standards and guidelines. Furthermore, there is an increasing need for innovative maintenance for critical infrastructure in all transport modes, that is, for techniques for upgrading and retrofitting that can provide minimal operational disruptions, security, and no environmental damage.

Intellectual property rights can be adequately protected under the current regime in the EU framework research programs. However, in many areas of transport research, results are still considered to be public or collective property. This is particularly the case with infrastructure construction and maintenance, in which practices are largely established by official standards and guidelines regularly revised through collective action. Innovation is more the result of slow collective reflection than the contribution of particular agents driven by a commercial perspective.

Better protection of intellectual property rights may serve as a means to support innovation but should be coupled with a revision of current regulations to provide for more opportunities for testing and making use of alternative approaches. Performance-based standards and guidelines are being deployed and are creating a more favorable environment. They would need to be combined with clearer regulations on the responsibilities of the various agents charged with providing high-quality transport services to the community.

Ironically, a performance-based framework can stimulate both intellectual property rights and the generalization of open-access research results. From both perspectives, agents interested in commercialization can have secured access to research results and also to com-

TABLE 3 U.S. Department of Transportation Intellectual Property Statistics: FY 2011

Item	Department of Transportation	Total for 11 Federal Agencies with Significant R&D Budgets	DOT Percentage of Total
All active licenses	3	13,940	0.00021
All active CRADAs	25	7,798	0.0032
Patent applications	1	2,381	0.00041
New inventions	2	5,294	0.00037

SOURCE: NIST 2013.

mercializing innovative products on the basis of their actual performance.

4 Myths That Are Impeding Effective Research Implementation

The myths described below may refer to the United States, the European Union, or to both. They are intentionally presented in a summarized way to stimulate the discussions during the symposium.

4.1 Myth 1. Government funding and involvement should decrease as research approaches commercialization.

Financial needs and perceived risks often actually increase as the deployment stage is approached (i.e., the valley of death). In the United States there are unfortunately transport modes that have a distinct unwillingness to support any technology into commercialization. Requests for commercialization support would most likely result in claims that the government was exercising an unfair preference in supporting one company or technology over another. The question remains: What happens in cases where sufficient private-sector capital is not available or the creditworthiness demands are too severe?

In the United States, one possible solution would be a national infrastructure bank, as some in Congress are proposing. Such a bank would have the legal authority to fund promising transportation technologies all the way through commercialization.

As in the United States, in the European Union it is widely perceived that government funding should decrease as commercialization approaches. In fact, the percentage of public contribution is lower for demonstration than for pure research activities, and close-to-market activities are generally not funded by EU programs.

4.2 Myth 2. The use of intellectual property to promote the implementation of transportation research is contrary to the proper role of government; moreover, all research information and technologies developed by the federal government and paid for by taxpayers should remain open source.

Despite the pervasiveness of this belief throughout the public transportation sector, the U.S. federal government has actively promoted the use of intellectual property to promote technology transfer through legislation passed over the past 30 years. Moreover, the federal agencies most successful at technology transfer (National Cancer Institute, NASA) have centralized and fully resourced intellectual property programs. Likewise, the U.S. DOT's commitment to the development and commercialization of open source technologies has not always been successful. A process that enables systematic decisions for determining whether a proprietary or an open process should be used to implement research results should be established.

4.3 Myth 3. Current methods of transportation research implementation are sufficient.

Unfortunately, this hypothesis can be neither rigorously sustained nor rejected because of the lack of systematically collected information on outcomes rather than outputs. The collection of outcome information appears to be a problem for both federal and subfederal entities as well as an issue for both Europe and the United States. The U.S. Congress called for the development of better performance data in MAP-21.

Although European research programs include systematic midterm and final evaluations, the collection of factual information on actual project outcomes and implementation of results remains challenging. Evaluations are undertaken while research projects are still in progress or have just concluded; at those stages, implementation is quite unlikely to have occurred yet.

4.4 Myth 4. Research programs are mainly modal in character; therefore, research implementation should be left to modal agencies within the government.

Each U.S. federal agency has the discretion to develop the specific, detailed policies and procedures that guide how technology transfer works with its organization (FLC 2005). Nevertheless, there remains a question of whether the overall technology transfer policy of a cabinet-level department should be set by the secretary and secretary-level organizations or at the modal level.

Although there are no equivalent modal agencies within the European Commission and research programs and calls are administered in a unified way, the structure of research topics and the budget distribution remain largely influenced by the traditional borders between transport modes. Research implementation remains largely a modal-specific issue. Modal ETPs are expected to play a crucial role in the implementation of both intermodal and horizontal research results—an increasingly present outcome of European research. These ETPs face a more uncertain route toward implementation, with no particular champions or stakeholders to move the outcomes of their research forward.

4.5 Myth 5. The golden time for innovation in the transport sector was many years ago. Only incremental improvements should be expected in what is already a quite mature system.

The TRB Executive Committee suggests (in a strong although indirect way) a new process that should include innovative research implementation methods. Likewise, the European Commission has periodically highlighted the need for transport to enable fundamental technological changes and the need to base these changes on sound research. The reality is that segments of the transportation community in the European Union and the United States do not make full use of research results and prefer to adopt a cautious approach based on incremental changes.

4.6 Myth 6. Public funding from European programs is instrumental in setting research priorities in Europe.

There is a widespread belief in Europe that most transport research is funded by the European Commission through the Framework Programmes. In fact, in transport as in other sectors, most of the research activities in Europe are funded by national budgets. Research projects eligible for EU funding are those that can claim European added value, but this concept is elusive and the borderline between national and European research remains unclear. There is a case for discussing whether the European Union should focus on basic research rather than on costly close-to-commercialization research because of the limited funds available as compared with many national programs. This is not to deny that the European research agenda may be leading the implementation process in some particular areas, such as traffic safety.

4.7 Myth 7. Implementation is mainly made by the industry.

Implementation in European and U.S. surface transport research is very much driven by public policy and regulations. In addition to getting the industry more involved, it seems necessary to revise current policy and regulations to provide an innovation-friendly perspective and to further clarify actual implementation objectives and roadmaps. Much about the innovation implementation processes in transport remains poorly known.

4.8 Summary

Comparing transport with information and communications technology, biotechnology, and so forth is in a certain way unfair: transport has quite different characteristics and its own path to innovation. Moreover, the policy process is driven largely by governments, and there are powerful public and private stakeholders that oppose any fundamental changes. Nevertheless, differences between transportation and other research sectors should not be used to excuse a visceral unwillingness to explore alternative approaches to research implementation, including commercialization of intellectual property.

Without more clear signs about the future vision (and funding) for the transport sector, disruptive innovation in Europe and the United States (i.e., beyond automobiles and other vehicles) will rightly be perceived by the private sector as a high-risk bid. At the same time, performance must be proven up front, before proprietary technologies are employed in publically funded projects. This is one among several key reasons why U.S. DOT Secretary Foxx's commitment to developing an integrated national transportation plan is so important to the future of transportation in the United States.

5 Hypotheses on the Current Transport Innovation Implementation System

The following hypotheses apply to both the United States and Europe:

Hypothesis 1. The lack of integrated intellectual property systems that track contractor inventions aimed at promoting commercialization through patents and licenses will jeopardize any major improvements in the implementation of research. A policy environment favoring increased use of intellectual property tools (patents, licenses) is necessary to increase the level of transportation research implementation in both the United States and Europe.

Hypothesis 2. The complex ecology of the transport system, particularly in the area of research and research implementation, impedes the efficient use of research funds and optimal research implementation, particularly under conditions of incomplete knowledge and strong regulation.

Hypothesis 3. Silo organizational structures that favor mode-based planning (Figure 6), such as those of the U.S. DOT, the European Commission, and many ministries of transport, jeopardize more effective research implementation.

Hypothesis 4. Reduced funding for transportation research in the European Union and the United States could significantly slow enhancements to the research implementation process. Reduced funding in Europe is particularly onerous for many cohesion countries in the European Union and some of the less economically robust states in the United States.

Hypothesis 5. Transport is misperceived as a mature sector in which innovation naturally makes progress at a slow pace. This misperception makes the transport sector unattractive to new generations of talented researchers, innovators, investors, and entrepreneurs. For both Europe and the United States, coordinated investments in training and education and measuring the return on investment of transportation innovations would be necessary to revitalize the knowledge triangle (education, research, innovation).

Hypothesis 6. Actual innovation in the transport sector usually follows an opportunistic approach that applies methodologies, solutions, and tools previously developed in other sectors. This approach jeopardizes any step or radical changes in the transport system independent of actions taking place in other sections. Blending the transport sector with emerging players to incorporate innovations from fields such as telecommunications, energy, and financial services would greatly accelerate research implementation and generate unique systems that could qualify for patents.

Hypothesis 7. In the absence of economic and regulatory incentives and changes (e.g., financial commercialization incentives, measurement and data collection tools, new regulatory frameworks, industrial targets, and voluntary commitments and coordination actions), the speed of implementation for innovative transportation solutions will not significantly increase.

Hypothesis 8. Because transport is a highly regulated sector, transport research implementation is, for many, closely embedded within standardization and strict guidelines for the approval and use of innovations and tied to governmental funding policies and decisions. The transportation governance framework plays a crucial role in facilitating or jeopardizing innovation, particularly in areas related to infrastructure and services.

Hypothesis 9. Both the European Union and the United States have multiple opportunities to develop more effective ways of collecting and analyzing information on the outcomes of transportation research implementation that is timely and includes the monetization of benefits and investments. The more effective collection and use of data would also improve greatly the management of the research implementation–technology transfer process.

Hypothesis 10. The implementation of research results needs a clear commitment from the United States and the European Union in favor of disruptive change—an option that must also be properly justified to the public. This option remains elusive for both Europe and the United States, and a preference for incremental changes continues to prevail.

FIGURE 6 Siloed organizational structure.

Hypothesis 11. Should an option for systemwide change be adopted, political leadership, buoyed by consumer support, could make a much more effective use of market forces (via the exploitation of intellectual property) to enhance the penetration of best-performing transportation systems and products.

Hypothesis 12. While the specific details are different for the European Union and the United States, both entities are facing similar obstacles to accelerating the implementation of transportation research. Thus, there is a significant opportunity for the European Union and the United States to collaborate in the identification and implementation of policies and programs that will accelerate transportation research implementation–commercialization.

Acknowledgments

The authors thank the European and U.S. members of the planning committee for the Second EU-U.S. Transportation Research Symposium as well as Joseph Toole, formerly of the U.S. Federal Highway Administration and now senior principal, Kittelson & Associates, Inc., for their in-depth comments, recommendations, and graphical and textual contributions. The authors also thank Frank Smit, Policy Officer, European Commission, who adeptly managed the process of developing the white papers, and Martine Micozzi, formerly of the Transportation Research Board, who played a critical role in the facilitation of initial activities pertaining to this white paper.

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Abbreviations

EUTRAIN	European Transport Research Area International Cooperation Activities
FHWA	Federal Highway Administration
FLC	Federal Laboratory Consortium for Technology Transfer
NIST	National Institute of Standards and Technology
TRB	Transportation Research Board

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APPENDIX B: COMMISSIONED WHITE PAPER 2

Lessons Learned from Case Studies of Successful Research Implementation in Europe and the United States

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Executive Summary

In preparation for the second in the series of EU–U.S. symposia on transportation research, several case studies illustrating the main factors that play a role in the successful implementation of research were evaluated. This paper presents 13 case studies that illustrate successes—and challenges—in implementing transportation research products, technologies, and practices. Seven of these examples are from countries in the European Union and six are from the United States. Each case was selected to highlight a particular aspect of the implementation process, but these cases also collectively present eight reoccurring themes or lessons learned that apply to both the U.S. and EU programs:

- **Stakeholder involvement.** Perhaps the most common factor noted in the case studies as a criterion for successful implementation efforts was early and continuous stakeholder involvement. Stakeholders clearly differ for each project, but they generally represent those that have experienced the problem that needs to be addressed and will therefore be the end users of the research. They also include those who will be responsible for moving the research products into and through implementation. When such stakeholders are involved in the definition of the research, and when they remain involved in ensuring that the research produces a solution that meets their needs, implementation tends to move far faster and more smoothly.
- **Resources for implementation.** Even in cases in which there had been a substantial investment in research, the funds programmed or available for implementation activities were often very limited. Part of this limitation appeared to be a result of the manner in which funds were allocated to different programs and sponsors and a lack of clarity regarding who was responsible for the implementation costs (e.g., the end user or the research sponsor?). However, some cases showed that even a small amount of funding can be a very strong incentive for implementation. Such funding helps to underwrite the risk, whether real or perceived, in using the new technology and often demonstrates an official endorsement of the products and practices. Staffing resources were equally important, particularly in ensuring that there was continuity throughout the process.
- **Development.** Several of the cases point to the challenges of trying to deploy research products that have not been fully developed or field tested. Aside from ensuring that the technology is ready for user applications, the development phase can also be the time in which additional data and evidence can be collected to substantiate the value of and need for the product. There are also cases that illustrate the success of building public–private partnerships during this time to ensure the research products will be commercially available for implementation.
- **Early adopters.** Successful cases highlighted the importance of having a champion that acted as an advocate for the innovation from research through implementation—a period that in some cases spanned more than a decade. Champions can be individuals, but more often are organizations with a specific interest. Champions that represent the end user community are particularly effective and often serve as one of the early

adopters of the technology or recruit other early adopters. Their involvement is critical because it provides a credible peer-to-peer basis for sharing knowledge with other end users.

- **Institutional barriers.** Many of the cases illustrate the multiple approvals and institutional actions often required to move a product from research into practice. These actions include everything from changes in standards or specifications to approvals of governing bodies or councils to the resolution of intellectual property issues. In particular, procurement rules and regulations can form a major obstacle to quick advancement of implementation efforts. Some of the cases illustrate the value of planning for those barriers and of ensuring that the key stakeholders that control those processes are included in the research from the beginning. Further, it is apparent that some organizations have made a concerted effort to streamline these institutional processes to accelerate the implementation process.
- **Governmental leadership.** Clearly the governmental structure of the United States and that of the European Union and its member nations differ greatly, but a number of the cases illustrate how leadership at that level can be a powerful catalyst and engine for change. As noted before, the government is often the source of funding for both research and implementation activities, and governmental leadership at the federal level or through the EU Commission can also help overcome institutional barriers. Ultimately, government leadership can also seek to use regulatory and standard-setting authorities to accelerate implementation of a product from state of the art to state of the practice. This kind of governmental support appears to be more prevalent when the subject of the research reflects a clearly felt societal issue, such as safety or congestion. Larger research programs that address broad technical issues may not attract the same support or sense of urgency for implementation by the public or politicians.
- **Communication.** Effective technology transfer is largely based on the sharing of knowledge, and consistent internal and external communication is a key to making technology transfer happen. Starting in the research phase, communication can build a pull for research results but can also establish realistic expectations about what may be coming from the research. There are several excellent examples in the case studies that show how continuous communication helped educate potential end users, inform decision makers, and, where appropriate, gain public support. The specifics of how the message is communicated are equally important. As an example, in the European context, language can be an issue. Although those conducting the research are usually fairly proficient in English as a working language, the decision makers responsible for implementation may not be.
- **Market readiness.** In the analogy of planting seeds, the seeds are more likely to sprout when the soil they are scattered on has already been tilled. Likewise, when the market is well informed and prepared, new ideas are likely to find an easier place in which to grow and mature. Many of the cases indicate that such efforts can greatly accelerate the implementation process and provide highway users with benefits faster. One question that surfaced was how today's college curricula could be changed to ensure that the next generation of transportation professionals would also be prepared to use these new technologies and practices.

Table 1 lists the 13 case studies and identifies the themes that apply to each. Table 2 summarizes the case studies according to the objective of the research and implementation, the role of research and development, the primary implementation strategies, and the lessons learned.

Introduction

The cases included in this report represent a broad range of topics and approaches to the implementation of research. They cover multiple surface transportation modes and vary considerably in the final outcome that was expected. The degree to which they were successful is, of course, open to debate, but each in its own way illustrates valuable lessons. As a group, they also provide some insights into the different challenges and opportunities that are found in the European Union and the United States. In general, these cases illustrate that there are likely more commonalities than differences in the way research is implemented on both sides of the Atlantic; however, in each region, specific practices and ideas can be found that could be applied to improve practices in many areas.

In the evaluation of these cases, several issues surfaced that may help shed light on why implementation is so challenging to address:

1. **Definition of research.** It is clear that there are many different definitions of research as well as multiple types of research ranging from "applied research" that responds to a specific problem, to very large, long-term research programs with a basis in fundamental scientific questions. Whereas the former are geared toward implementation-ready solutions, more-basic research may require several iterations to even begin to look into practical application, so that even the question "What is the purpose of research?" can have many answers.
2. **Definition of implementation.** There are also many different interpretations of the term "implementation." Some consider implementation to include everything that occurs after research, whereas other definitions make a distinction between development, implementation, and deployment. This difference points out the challenge

TABLE 1 Themes Exemplified in Each Case Study

Case Study	Stakeholder Involvement	Resources for Implementation	Development	Early Adopters and Champions	Overcoming Institutional Barriers	Governmental Leadership	Communication	Market Readiness
European Union								
Asset Management (the Netherlands)					X	X		X
ALJOIN					X			X
INNOTRACK	X		X				X	X
River Information Services	X		X	X	X			
SAMARIS, ARCHES, and CERTAIN		X	X				X	
Silent and Durable Road Expansion Joints (IPW, the Netherlands)		X	X		X			X
Climate Change	X			X		X		
United States								
Highway Safety Manual	X	X			X	X		X
Flashing Yellow Arrow Left-Turn Display					X	X		
Modern Roundabouts	X			X			X	
Warm-Mix Asphalt Pavements		X	X					
Heavy Rail Acoustic Bearing Detector			X	X				
Bus Rapid Transit				X		X		X

Note: ALJOIN = Crashworthiness of Joints in Aluminum Rail Vehicles; SAMARIS = Sustainable and Advanced Materials for Road Infrastructures; ARCHES = Assessment and Rehabilitation of Central European Highway Structures; CERTAIN = Central European Research in Road Infrastructure; IPW = Netherlands' Innovative Road Maintenance program.

even of defining when implementation should begin and when it is considered complete. For example, is it complete when the results have been translated into regulation or when the results have become daily practice?

3. Relationship between research and implementation. Although there is no shortage of literature on the research process and the results of research, information about implementation is generally more difficult to find, and when it is available, there is often no direct or systematic link back to the underlying research. This observation seems to point to the fact that often the sponsor of the research is different from the owner of the practical problem that the research is intended to solve. Little documentation that linked the two or described the process from the initial question to the applied solution could be found.

4. Innovation versus research. There is a distinction between research leading innovation and innovation leading research. In some of the case studies, it was clear that the research itself resulted in innovation (e.g., new analytical methods, products, applications or policy). In other case studies, innovation created interest in a particular topic that spurred research (e.g., finding new applications for ground-penetrating radar). That research then became the catalyst for broader implementation. Special attention may have to be given to the position of innovation and how it affects the subject of implementation.

It is also apparent that there are several constants that must be a part of any value-driven implementation effort, specifically, communication, governance, and finance and capacity. Having a clear understanding of who is in charge and how the initiative will be funded and staffed are simply core elements in the planning of any implementation process. Likewise, participation of stakeholders in all phases of this process and early and continuous communication are fundamental building blocks to any successful implementation effort. As noted in the executive summary, the cases pointed to the value that comes from focusing on each of these elements.

As illustrated in Figure 1, it is also apparent that the pathway to implementation is not necessarily linear. As a research effort moves from its origin as a problem to research execution, there needs to be continual checking in to ensure that what is being done in research does, in fact, address the initial problem. It is not uncommon

TABLE 2 Summary of Case Studies

Case Study	Objective of the Research and Implementation	Role of Research and Development
European Union		
Asset Management (the Netherlands)	Provide the basis for a quantitative and qualitative risk-based performance management of the National Road Administration.	Develop risk assessment and management tools such as life-cycle costing, systems engineering, and key performance indicators.
ALJOIN	Following accidents resulting in deaths, improve the material and construction of rail vehicles to minimize fatalities during crashes.	Provide a quantitative basis for the standards on joints and welds of vehicles, including modeling of vehicle impact.
INNOTRACK	Increase the competitiveness of the sector in a period of growing demand and environmental constraints by reducing track-related life-cycle costs.	Identify the cost drivers of railway track construction and maintenance and provide a quantitative and methodological basis for cost reduction.
River Information Services	Raise the status of inland navigation to a full-scale alternative to road transport through upgrading and harmonizing information services.	Identify organizational requirements for improved information systems and develop new standardized technologies and applications.
SAMARIS, ARCHES, and CERTAIN	Bring the former Eastern European countries to a more advanced infrastructure quality through own and assisted experiences with new technology.	Develop methodologies, testing, technical guides, and field trials of improved technology for pavements and structures.
Silent and Durable Road Expansion Joints (IPW, the Netherlands)	Solve the problem of noisy and short-lived expansion joints in an otherwise relatively silent and durable road infrastructure.	Prove feasibility of new generation of silent and durable joints through an innovation program in the shape of a contest and supported by research.
Climate Change	Provide road authorities with concrete models and instruments to tackle effects of climate change on infrastructure (adaptation strategies).	Provide (modeling) tools for predicting and assessing effects and a sound risk-based approach for (local) adaptation or evacuation measures.
United States		
Highway Safety Manual	Implement a new, quantitatively based approach to analyzing the benefits of safety countermeasures and improvements.	Create these new methodologies and continue to address additional issues.
Flashing Yellow Arrow Left-Turn Display	Put into practice a new approach to signal display to improve safety and operations for left-turn movements.	Develop the technology and demonstrate the practicality and benefits of the approach.
Modern Roundabouts	Encourage use of modern roundabouts by state and local government as a means of improving safety and operations.	Develop a guide for engineers on how to design roundabouts in a way compatible with U.S. standards and expectations.
Warm-Mix Asphalt Pavements	Encourage greater use of WMA to improve air quality, worker health, hauling distances, and a variety of other factors.	Show the durability and cost-effectiveness of WMA.
Heavy Rail Acoustic Bearing Detector	Implement a tool to help identify faulty rail wheel bearings before they fail.	Design, test, and commercially manufacture a practical device so that the concept could be implemented.
Bus Rapid Transit	Provide regions with a practical alternative that will enhance transit service and passenger throughput.	Develop practical guides to assist cities in (*a*) deciding what they actually needed and (*b*) how to implement that approach.

NOTE: PIANC = World Association for Waterborne Transport Infrastructure; NRA = national roads authority; CEDR = Conference of European Directors of Roads; WMA = warm-mix asphalt.

Primary Implementation Strategies	Lessons Learned
Comprehensive implementation plan, pilot projects and training, and gradual adaptation of service level agreement.	Translating research language into operator language is important, as is training. Stakeholder involvement, including (top) management, is essential. Translating output in guidelines and procedures fixates results.
Translation of research results into international standards and publication of the research results.	Bringing together all stakeholders helped in creating a solid solution. Societal impact of crashes and impact on sector provided urgency. Standards make for quicker and more general implementation.
Establishing an implementation group, achieving dissemination through communication and training, and making technical report and databases available.	Incentives for implementation of innovations (e.g. through procurement) are necessary. Local differences prevent general implementation; a common language is required. Stakeholder involvement gives stakeholders a competitive advantage.
Structured dissemination and support activities, ministerial support, and forced implementation via EU directive.	Championship on the political level overcomes barriers. Broad stakeholder participation and continuity in expert staffing are important. PIANC organization provided a strong neutral expert platform.
Dissemination through conferences (project), broad publication of field-test results, and translation of reports into national languages.	Involving experts from target countries eliminated the not-invented-here syndrome. Specific outreach program did reach research experts. Lack of funds, procurement barriers, and absence of standards prevent implementation.
Starting on the problem from the operations end, inviting the market to provide competing solutions, and introducing solutions via procurement strategy.	Market readiness of research was a condition for participation in the program–contest. Multidisciplinary teams reached a high level of technology readiness. The limited scope of the contest was an advantage because it led to quick results.
Research that was partly based on actual experience, NRAs' adoption of follow-up programs and research, and results that provided a menu for NRAs to choose from.	Close involvement of stakeholders (e.g., in providing data) reduced the gap between research and operators. Champions from different countries for parts of the research created involvement. As an intermediate organization, CEDR provided a basis for discussion with road owners.
Broad stakeholder involvement, development and delivery of extensive training, and federal leadership.	Translating research into practical applications is a challenge. Implementation should begin while R&D is still under way. Funding for implementation activities is important.
User involvement in all phases, federal leadership and cooperation, and inclusion in national standards.	Changes to standards require extensive institutional coordination. Lead efforts and demonstrations were critical. Hard data are needed to make the case.
Federal leadership, provision of tools and training, and leveraging of early adopters.	Lead states provided a showcase for others. Guidelines or standards can expedite deployment. Public outreach and acceptance can be important.
Participation of lead states that served as champions, addressing of issues directly and quickly, and hands-on demonstrations and training.	Change the technology in implementation if problems surface. Develop the support of industry. Federal leadership can help reduce the perception of risks.
Commercialization of the research and identification of early adopters.	Lack of funding for implementation can be a major barrier. Finding a commercial partner to manufacture the technology can be critical and challenging.
Early adopters, development of guidelines, and flexibility in implementation for users.	Users need to have flexibility to fit the innovation to meet their own needs (i.e., one size does not fit all). Having actual working applications is a huge incentive for others to join in implementation.

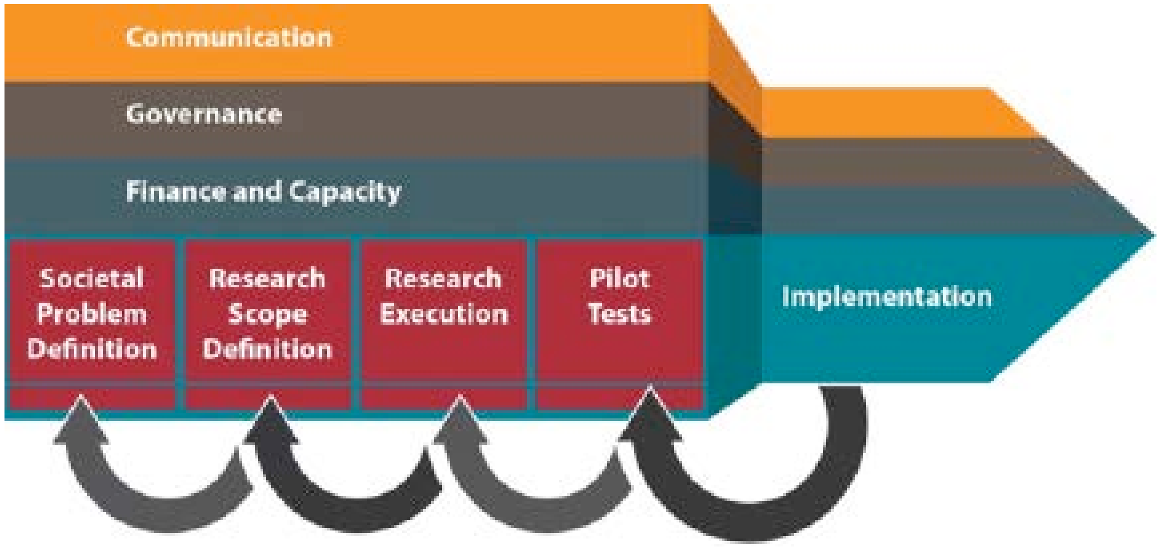


FIGURE 1 Pathway to implementation.

that as understanding of possible solutions evolves, so too may the scope of the research itself be refined. This refinement can be particularly true as a research product is developed and field tested and as the realities of what is needed for full implementation become more apparent. Accepting the need for this continuous process of evolution can help both in planning for implementation and in ensuring that the right stakeholders are always involved in the process.

These case studies present an extremely broad range of different implementation strategies. Therefore, one challenge is how to determine which strategy best fits the particular audience the research hopes to reach, the technology that is being implemented, and the available resources. One method for looking at these different strategies is to consider the following two aspects of implementation:

- **Mandatory versus volunteer.** In many cases, the fastest way to implement a new technology is to mandate its use through regulation, specifications, or standards, assuming that the regulation process can also be expedited. Clearly, this option can be viewed as extreme, but when something like a matter of public safety is involved, it may well be justified [e.g., after the collapse of the Interstate bridge in Minnesota, the Federal Highway Administration (FHWA) very quickly issued new standards regarding gusset plates]. Simply making implementation of a new technology or practice voluntary may be more acceptable to the stakeholders but can lead to a prolonged implementation process. However, such an approach may be appropriate when users have other available options to choose from or when the benefits are incremental. In many ways, this is the approach many companies face in trying to bring their new products to the market.
- **Proactive versus passive.** Some of the cases illustrate a very aggressive push by the sponsoring organization to get a technology implemented. In other cases, there was greater dependency on the end user's taking the initiative to become informed about the product, perhaps out of sensitivity to the stakeholder group or simply because of a lack of resources for a full-scale deployment effort. Although both strategies may lead to the implementation of the research, the speed with which that happens, as well as the ultimate market penetration, can vary significantly.

Figure 2 is a representation of how different implementation strategies may fit within the context of these two sets of variables. This information is provided only for illustration purposes to help readers frame their own thinking about what might work in their own efforts to improve the implementation of research.

Finally, in putting together this paper it became clear, particularly for the European Union, that there is a general lack of structured information on the actual application of research results and, thus, the outcome of research. The information that is available tends to be fragmented at best. It would be most useful for researchers and for those responsible for implementation to have at their disposal a database with examples of implementation in several countries or states.

A very interesting effort at systematically looking at implementation is the European Rail Research Advisory Council (ERRAC) WP06 project, which aimed to evaluate the market uptake of past research project results in the rail sector. On the basis of that evaluation, projects are categorized as having strong market uptake (clear evidence of the use of products and services, dissemination of knowledge, and implementation of project objectives in several countries), medium uptake, and weak uptake

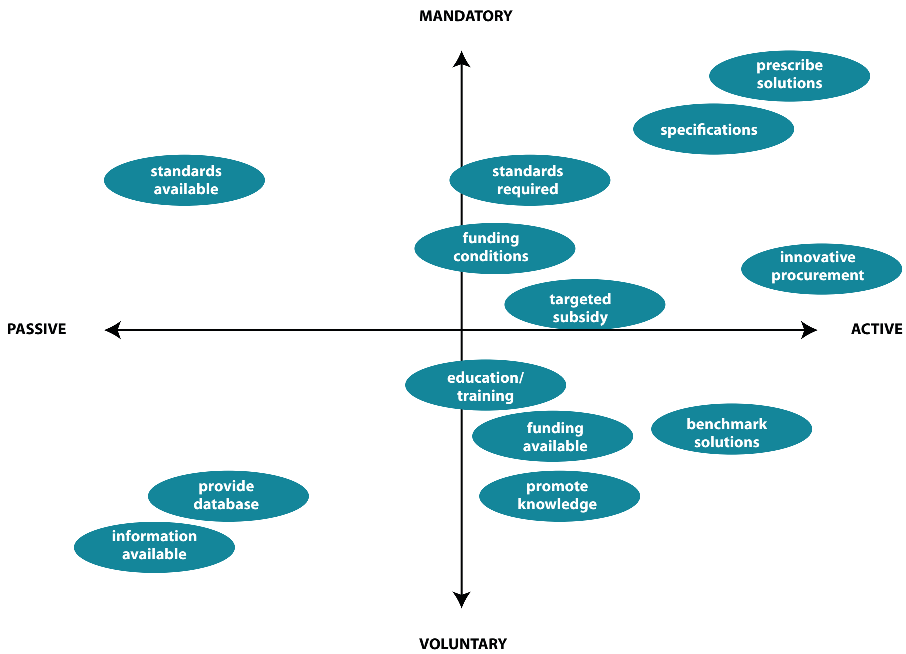


FIGURE 2 Implementation strategies: passive–active matrix.

(no known use of products and services, dissemination of knowledge, or implementation). In 2012, 59 projects had been evaluated, of which 15 were found to have strong market uptake, 16 medium, and 29 a weak uptake. A standard checklist for successful projects was developed in 2011 and is still being used. The lessons learned from this project are compared with the outcome of the case studies in another section of this paper. This database might be a good example for future applications. Such a database should include references to institutes, discussion platforms, implementing agencies, and organizations.

EU Case Studies

Asset Management in the Netherlands

Although this example of the implementation of asset management may not be representative of what is normally associated with research implementation, it does show that implementing research is feasible—even research that has not been directly commissioned by the problem owner himself. The implementation took time and effort, and without a strong sense of urgency would not have been successful.

Original Research Purpose and Need

Asset management is the profession of balancing cost, performance, and risk over the life cycle of an asset and takes into account the actual financial means, available human resources, information, and cultural aspects in an organization.

In 2006, the Netherlands executive agency for highways, waterways, and water management, Rijkswaterstaat (RWS), was in a fairly advanced state of disorder with regard to performance and management of infrastructure. The budget was more a sum of the wishes and plans of each regional directorate, often influenced by the local technical and political situation, than a consolidated priority of necessary works to uphold and improve the system. As availability of funds had not been a problem for many years, there was no clear incentive to change that situation. Management contracts diverged significantly between the regions. The whole funding system for maintenance and operations was not transparent to the outside world, including the Ministry of Transport and the general public. The condition of the assets could, in reality, be quite different from the existing documentation (if it existed), a situation that caused problems with contractors hired to perform maintenance and construction.

At the same time, the annual budget of the ministry had started to come under pressure. The funds for new construction were as yet undisputed, but maintenance did not receive as much political support, so that budget reductions in the Ministry of Transport were mostly translated into the reduction of operation and maintenance budgets.

As part of the condition for RWS to become a more independent agency in the field of operations and maintenance, it was decided in 2008 to set up a comprehensive Program for Asset Management (PAM) aimed at improving the situation not only in a few years, but as the program developed. There was too little time to establish a solid fundamental research program, although it was clear that the knowledge on the subject of asset management was still largely under development.

Research Process and Results

PAM started in December 2008 with a decision of the RWS board of directors. The four initial scope elements of the program were to

- Develop and implement a system for reliable and accurate asset data,
- Develop a stable long-term maintenance program,
- Define clear objectives and transparent requirements, and
- Improve procurement procedures for more transparency.

In 2009, a fifth element was added: introduce a system of life-cycle costing.

RWS realized that it would take many years to set up and implement asset management, but the first results in terms of process and procedure improvement were expected to be realized in about 2 or 3 years.

All of the scope elements required serious consideration from a practical point of view, and research was needed to fill the many knowledge gaps and design a systematic approach to the issue. Little information was readily available nationally in a suitable format. As the time requirements were quite strict, the decision was made to rely mainly on existing research programs; to benchmark in several European countries (notably the United Kingdom and Sweden) and in different sectors (such as the energy sector and drinking water sector); and to commission additional research for specific information.

The following European research programs and institutes played an important role in PAM:

- Next Generation Infrastructures Foundation. This research program began in 2004 and will be completed in 2014. About half of the program's funding is provided by the government. The research focuses on issues in asset management that crosscut all infrastructure sectors. The program started off as a traditional research program with the aim of bringing together researchers and research. Since 2008, it has put much more emphasis on stakeholder involvement, in part through an Asset Management Platform in which stakeholders and researchers participate. The program encompassed more than 40 doctoral research projects. Specific themes that were essential for the development of the RWS PAM were risk management [including the development of appropriate translation of methods as RAMS (reliability, availability, maintainability, and safety) or SHEEP (security, health, environment, economics and politics)], life-cycle costing (LCC), systems engineering, and probabilistic maintenance.
- Institute of Asset Management. The Institute of Asset Management is a professional institute in the United Kingdom that develops best practices for asset management. Publicly Available Specification (PAS) 55 provides clear definitions and specifications for establishing optimized asset management systems that align to a certifiable quality management system according to ISO 9001.
- Coordination and Implementation of Road Research in Europe (ERA-NET ROAD). Out of 20 proposals submitted for the 2010 call "Effective Asset Management Meeting Future Challenges," seven were selected. These seven proposals covered topics such as methods for assessment of service condition, key performance indicators, stakeholder involvement issues, and intervention strategies. The call finished in 2013 with a meeting in Copenhagen, Denmark. Many of the notions developed during the research were introduced in the PAM program as it went along.

RWS staff also gathered knowledge from several other institutes and participated in a scanning tour to the United Kingdom, Sweden, Australia, and New Zealand on this subject that was organized by FHWA and the American Association of State Highway and Transportation Officials (AASHTO).

Implementation Activities

The implementation of asset management research was done through the PAM program. The different research results had to be translated into action perspectives for the entire RWS staff, from higher and middle management down to the average staff member in the field. On the management level, it was important to bring all the different aspects of the asset management process together in a design scheme, distinguishing between the roles of the asset owner (the Ministry of Transport), the asset manager (RWS), and the market.

For the field staff, it was essential to understand the process of data collection and performance measurement, as this process would mostly dictate their daily priorities. For instance, the system of decomposition of data in order to fill the database on the maintenance situation had to be uniform throughout the whole organization of more than 1,000 staff. Most of the staff used to gather this data were familiar with their own database systems (if they existed), but making this change would require extensive education. Several internal guidelines were published (e.g., contracting requirements), some of which received mandatory status through the asset owner (e.g., the life-cycle costing system). The asset management process is shown in Figure 3.

The comprehensive implementation plan that was set up consisted of several key actions that could differ according to the scope elements mentioned earlier:

- A general action was an extensive communication program for all concerned. An essential aspect of this action was the heavy involvement of top management in the communication.
- Training sessions were organized for management and staff on the new system requirements and on how to handle the concrete material to implement the system (e.g., new format for regional asset management plans, data decomposition).
- Pilot projects were identified to speed up implementation, and sessions were organized to convey the results to colleagues.
- In the meantime, the existing service level agreement (SLA) between RWS and the Ministry was adapted, first on an experimental basis.

All these actions were organized and supported by a dedicated task force with strong support from the top managerial level. At the same time, outreach to external stakeholders (provinces, country officials, contractors) was organized to familiarize them with the new method of working.

As the project formally ended in 2012, the task force has now been disbanded and the standing organization has now explicitly taken over the responsibility for further implementation of the results. This responsibility is included in the management contract for the unit concerned.

Concrete results of the program started to come in as soon as April 2010, and new instruments for performance management were used in the contract negotiation on the SLA 2011. By then, the first regional asset management

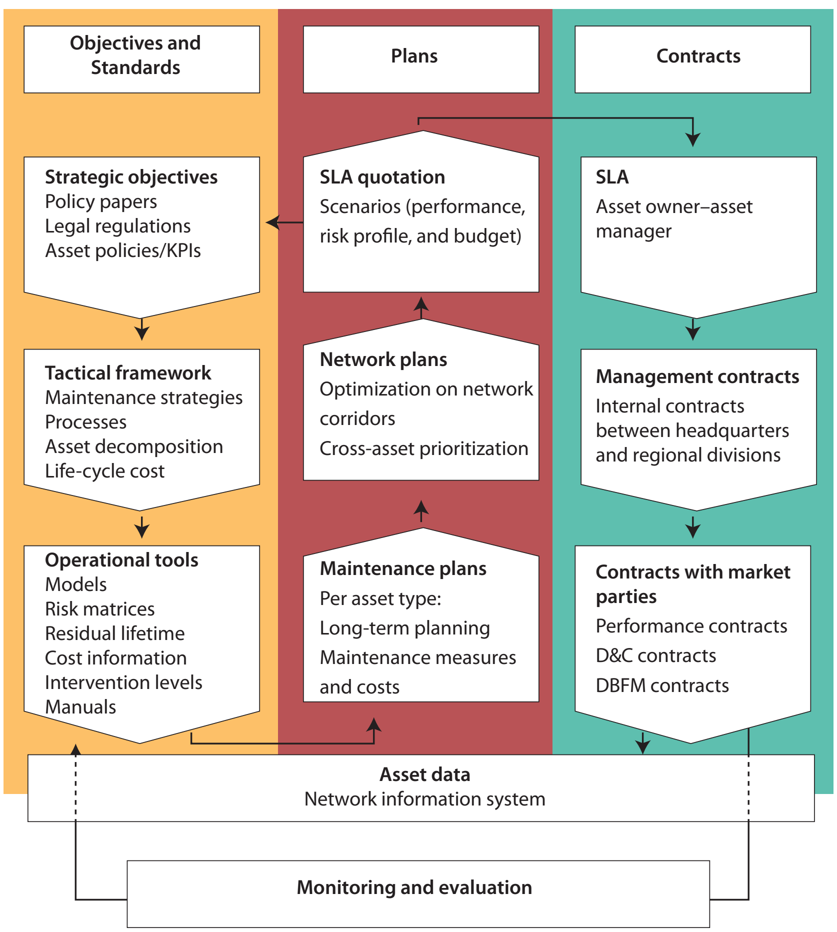


FIGURE 3 The asset management process (KPIs = key performance indicators; SLA = service level agreement; D&C = design and construct; DBFM = design, build, finance, and manage). (Source: Evaluation Programme Report.)

teams were being set up. Regional directorates that took the lead in using new work methods received awards, and a Corporate Asset Management Learning Center was established in 2011. The main results of the program are as follows:

- LCC (including maintenance) has been fully introduced, is mandatory (regulation) for the calculation of new construction, and is used on a regular basis for large rehabilitation projects.
- SLA for maintenance and operations has been fully revised and is mainly risk-driven.
- There is centralized (risk-based) programming.
- Procurement contracts are performance based.
- The underlying information system (NIS) has been revised and the quality of information has greatly improved.
- Asset management is a leading process for the organizational design of RWS.
- A number of research results (systems engineering, probabilistic planning) have been introduced over the whole range of construction works.

Barriers to Implementation

- Institutional decisions. Although there was a great sense of urgency to get to grips with diminishing funds for maintenance and the administrative situation was urgently in need of improvement, it took a relatively long time to come to a decision on starting PAM. The ongoing research of the Next Generation Infrastructures program was not formally related to the maintenance issue at the start. The two programs ran parallel for some time.
- Governance. The factor of power played an important role as well. It was clear from literature and examples elsewhere that proper asset management would highly influence the decision-making process and the daily planning and execution of maintenance priorities. All concerned did not necessarily welcome this development, especially as regional directorates were used to having large executive responsibility and being quite set in their ways. As early as 2005, proposals for introducing asset management were made and rejected. The size of the organization (more than 10,000 full-time employees at the time) was another complicating factor, as asset management, in essence, only functions when it is at the core of the work processes.

The pressure on RWS originated mainly outside the organization. Increased congestion resulting from lengthy maintenance projects had become a political risk. The combination of this risk with the financial situation had become an explosive mix. Setting up PAM helped to relieve some of the pressure, especially as the Ministry was informed about the plans and involved at a fairly early stage. As asset management is mainly an internal process, there was little formal regulation to contend with.

- Readiness. It must be recognized that, at the time, asset management was such a new instrument that the executive level of the organization could not easily see it as the solution of the existing problems. However, there was not enough time to start with what would have been a lengthy process for raising the awareness of the instrument.
- Resources. To a large extent, the research needed to develop asset management had already been commissioned via other financial mechanisms, and the program itself was mostly managed internally with the assistance of a limited number of consultants. The limited additional funds necessary to implement asset management were included in the SLA between RWS and the Ministry.

Lessons Learned

- Management involvement. Defining the research need and creating management support were key factors. At the outset, the involvement of the different management layers throughout the organization was too small. This led to slow decision making and a relatively slow start-up. A lot of effort had to be spent on broad management support for the program later on. Once the support had been realized by showing the potential for improvement, this support proved to be essential for success.
- Communication. The main condition for the success of asset management was the dedicated program itself. It was a concerted effort to translate the large amount of existing and new research and other experience into daily practice. As the program brought together the responsible people in RWS from the top to the lower level, it created

a direct forum for translating research into practice on the basis of the requirements of the Ministry.

- Organizational coordination. The research was only partly commissioned on the initiative of PAM. However, PAM played a crucial role in achieving the results. Since PAM had not been able to influence the research scope of the Next Generation Infrastructures program at the outset, it was necessary to create a support construction between the Next Generation Infrastructures research program and PAM, namely, the Asset Management Platform, which exists to this day. In this platform, research progress and support were discussed and additional queries were addressed during the process. The translation of research into practical application during the research phase also helped focus the research efforts.
- Stakeholders. Transparency of the process and broad communication with stakeholders—both internal (ministry, financial departments, own organization) and, later on, external (provinces, countries, construction sector, consultants)—proved to help in creating acceptance for a new way of risk-based planning and performance-based procurement. This included regularly celebrating successes that were achieved during the project.
- Training. Extensive training and support by peer groups, which is still going on after the termination of the program, was essential to anchor new ways of working in the organization and its immediate surroundings.
- Policies and guidelines. Translating new procedures and routines into the internal and external guidelines and regulations helped establish the results. Examples are the new format for the SLA, regulation on LCC (type: comply or explain), internal procurement guidelines, data requirements for constructors, and inspection.
- International aspects. PAM is a national program of RWS. It would probably have been introduced in some shape or another independently of international developments. The existence of similar international research and implementation programs was, however, essential in speeding up the process in the Netherlands. There was a lot of international exchange (some mentioned above) with other European countries, notably the Scandinavian countries, France, Italy, and the United Kingdom. PAM representatives participated in international conferences, where they both gave and gathered essential knowledge. Peer reviews were organized on certain issues.

ALJOIN

The Crashworthiness of Joints in Aluminum Rail Vehicles (ALJOIN) project illustrates how standards can be used as an effective tool for implementation of research, even throughout the European Union, particularly where public interest and focus are high.

Original Research Purpose and Need

Aluminum alloys are now in widespread use in Europe (and elsewhere) for rail vehicle construction, from commuter to express trains. The main contributor to the success of aluminum alloys as structural materials in rail transport was the development of closed-cell aluminum extrusions that can easily be welded together to form lightweight rail vehicles with high inherent rigidity, which could not be achieved with older designs. As rail transport is becoming more popular throughout Europe, there is an increased need to improve passenger safety by improving the crashworthiness of rail vehicles to minimize fatalities and injuries if an accident does occur. The strength, integrity, and performance of aluminum welds in rail vehicles contribute greatly to the overall body shell strength and crashworthiness. In collisions involving seam-welded aluminum rail coaches—among others, the 1999 Ladbroke Grove accident in the United Kingdom, in which 31 people lost their lives (Figure 4)—some of the longitudinal seam welds fractured for some meters beyond the zone of severe damage, the panels themselves generally being intact without significant distortion.

Research Process and Results

The aim of the project was to gain the knowledge needed to design cost-effective aluminum rail vehicle bodies that would not fail in the event of catastrophic joint failure under extreme loading. To achieve this overall goal, several objectives were addressed, including determining performance specifications for joints, testing the absorption capacity of welds and developing criteria for different kinds of joints, developing and validating models of material and joint failure, analyzing components and structures, and investigating alternative welding techniques.

The work was carried out in three phases. The first phase, a thorough investigation of existing joint designs and joining techniques, revealed shortcomings in existing designs. The second phase concentrated on the fundamental properties of aluminum weldments and on the performance of alternative welding techniques. Analytical models of failure were developed and validated with tests. The third phase concentrated on modeling rail vehicle impact with and without improved joints.

The results have improved the crashworthiness of aluminum rail vehicles and can contribute to a reduction of fatalities in potential future accidents. The cost of the research is less than the statistical value of one fatality. The scientific impact of the project was large, with 13 papers and a dedicated international conference in 2005.

The output has contributed directly to two European Standards (EN): EN 15085, Railway Applications—

FIGURE 4 Vehicle involved in the Ladbroke Grove accident. (Source: ALJOIN final technical report.)

Welding of Railway Vehicles and Components, and EN 15227, Crashworthiness Requirements for Railway Vehicle Bodies. Under the Fifth Research and Technological Development (RTD) Framework Programme, the ALJOIN project ran from 2002 to 2005. A European consortium (Denmark, Italy, Switzerland, and the United Kingdom) contracted the project. The cost of the project was approximately €2.2 million, of which €1.2 million was EU funded.

The ALJOIN project was continued with the ALJOIN PLUS project, which was commissioned to provide the necessary information to create a benchmark for joints in aluminum rail vehicles against which improvements in joint design are measured. The United Kingdom Railway Safety and Standards Board funded it with a contribution from Bombardier Transportation.

Implementation Activities

There was no specific implementation plan. However, the widely publicized accident in Ladbroke Grove and the ensuing investigation ensured the commitment of the stakeholders to addressing the identified safety-critical issues. The results were disseminated beyond the lifetime of the funding because of the interest generated and have led to EN standardization—thus, the results have become part of the regular body of standards of the European Union.

Lessons Learned

- ALJOIN addressed a specific technical problem that has concerned the rail manufacturing industry for many years by bringing together industry, academia, and research institutions in a joint effort to provide a solution.
- ALJOIN provided a significant contribution to the report to the Cullen inquiry with regard to the 1999 Ladbroke Grove rail crash.
- Industry recognition of a problem affecting the core of its business and its commitment to finding a solution can drive the success of the project. In this case, the safety concerns were particularly critical, as most modern rail vehicles are aluminum.
- A coordinated response to a research need identified as a consequence of a tragic event led to the understanding of fundamental issues related to aluminum joining technologies and their crashworthiness. This understanding emphasized that a strong need for research is beneficial to success.
- The quality of the work also contributed to the success of the project, as has the dissemination of its results beyond the lifetime of the funding. This is an important lesson that shows that results from research cannot be self-promoting and that appropriate postproject dissemination is critical to maximizing the benefits.

INNOTRACK

INNOTRACK (Innovative Track Systems) was an ambitious research effort directed at increasing the competitiveness of the railway sector. Its success was largely due to the extensive network of stakeholders

Examples of ALJOIN Implementation over Time, Including Early Adopters

- The main ALJOIN project outcomes have been the implementation of a joint design for extruded aluminum sections and an input to ENs for aluminum welded joints. These are being put into commercial operation.
- A 2009 ERRAC evaluation study showed confidence that the results were going to be used throughout Europe and supported by the EN standardization system. One of the reasons for this confidence was that safety is one of the competitive factors in the transport industry.
- The technical solutions developed through ALJOIN have been exploited by the European rail manufacturing industry and have already been implemented in the manufacture of rail vehicles.
- The results have been made available for the review of the future revisions of the relevant standards in the field of aluminum joint crashworthiness and for the construction of future aluminum railway car bodies.

that were engaged and to the advance planning done for implementation.

Original Research Purpose and Need

The European Commission founded the INNOTRACK research project under the Sixth Framework Programme. It was a joint response of the major stakeholders in the rail sector—infrastructure managers, the railway supply industry, and research bodies—to further develop a cost-effective, high-performance track infrastructure by providing innovative solutions toward significant reduction of both investments and maintenance-related infrastructure costs on a life-cycle basis. The final technical report states the objective in one sentence: "Increase the competitiveness of the railway sector by decreasing track-related life-cycle costs." The project contributed to the objectives of the European Commission White Paper on Transport 2002. The second major objective of INNOTRACK was to streamline the introduction of innovative solutions on a European scale.

The need for the research stemmed from the wish and necessity for railways to keep playing an increasingly important role in the transport of goods and persons. The railways were facing new demands regarding speed and axle loads, higher availability and reliability, and increased environmental and safety demands.

As the cost of track and substructure represents 50% to 60% of the maintenance and renewal cost of railways, a new approach to reducing life-cycle costs was necessary. Railways form a complex system. Originally built up from national perspective, rail is now an international system, the components of which are far from harmonized or standardized but still have to work together.

Much of the knowledge was empirical and fragmented, whereas many of the cost drivers were international; that is, the same cost drivers affected all systems. This led to an international research project in which eight European countries, more than 12 industrial partners, and nine research institutes participated.

Research Process and Results

The project ran from 2006 to 2010 and had a budget of about €20 million. It was organized in subprojects. To achieve a wider approach, a matrix organization was formed. Three vertical technical subprojects were developed to meet the technical demands:

- Track Support Structure (SP 2). This subproject studied track subgrade monitoring and assessment. Furthermore, evaluation and testing of superstructure innovations were carried out.
- Switches and Crossings (SP 3). This subproject studied optimized switch designs in which predictive modeling played a key role. Further standardization of driving and locking devices was a key elements, as was the development of switch monitoring equipment.
- Rails and Welding (SP 4). This subproject dealt with methods for establishing rail deterioration under varying operational conditions. It established maintenance criteria and methods. It further studied improved methods for the testing of rail materials, for rail inspection, and for welding.

These subprojects were supported by three cross-disciplinary (horizontal) subprojects created to verify and to give other aspects on technical solutions on the basis of the new demands mentioned above:

- Duty and Requirements (SP 1). The aim of this subproject was first to identify current problems and cost drivers for the existing infrastructure. After the root causes had been identified, the project proposed innovative solutions to mitigate the problems. At the end of the project, a technical verification of technical solutions that had not been validated in the technical subprojects was carried out. The aim was to deliver innovative solutions that were both technically and economically verified. Finally, this subproject also assessed the overall potential cost reduction derived from the INNOTRACK solutions.
- Life-Cycle Cost Assessment (SP 6). This subproject had two purposes. The first was to economically verify the innovative solutions to the technical problems. This task was carried out with LCC and RAMS analyses. The second purpose was to evaluate and develop a Europe-wide accepted process.
- Logistics (SP 5). In this subproject, the potential for logistic improvements was identified and proposals for promising areas of improvement were brought forward. Furthermore, the subproject was responsible for a logistics assessment of derived technical solutions. Logistics should be understood in a broad sense that incorporates aspects such as sourcing and contracting.

The result of the project overall was a toolbox comprising more than 140 reports with different deliverables: analyses, processes, methods, technical standards, and many innovative solutions.

The approach from the perspective of the cost drivers brought the research immediately very close to the actual practice of the infrastructure manager and the contractors, which was high on both the technical and the market-readiness levels. Cost drivers include improving subgrade, subsoil assessment, track stiffness, rail grades, corrugation (Figure 5), insulated joints, rail cracks, switches and crossings, and LCC methods. In the reports, each cost driver is analyzed and solutions are proposed. Some of these solutions are given in the shape of possible standards and have been submitted as such to the European standardization authorities.

The INNOTRACK project has been a unique opportunity to bring together rail infrastructure managers and industry suppliers and to concentrate on research issues that have a strong influence on the reduction of rail infrastructure life-cycle cost.

FIGURE 5 Short wave formation (corrugation control). (Source: INNOTRACK final report.)

Implementation Activities

The INNOTRACK project and final report, as well as other deliverables, devote a lot of attention to implementation. The *INNOTRACK Concluding Technical Report* notes that

> Many EU projects end when the project is formally finalised. . . . [I]t has been an ambition from the beginning to have a focus on implementation. This is the reason for the engagement and contribution with extra resources from the UIC [International Union of Railways].
>
> During and after the formal end of the project, extensive work has been carried out to prepare and support implementation of the results. This work has engaged many railways both inside and outside the consortium as well as several organizations and regulatory bodies.
>
> In addition, an implementation group has been established based on INNOTRACK Steering Committee and Coordination Group. The aim of this group is to promote and coordinate the Europe-wide implementation of INNOTRACK results.

Implementation activities were widespread but well designed, with the deliverables lying at the base of the implementation plan. One implementation stream included formulation of guidelines that have partly been submitted to standardization authorities (e.g., one on hollow sleepers). Also, seven databases were created for future R&D work.

The other implementation stream consisted of the final technical report, which is the key to the 140 underlying deliverables. From that report, top management information material has been deduced. Activities included conferences, publications, specific information for infrastructure managers, and training and industry events.

Although the INNOTRACK website is still available, it is not actualized any more. However, there are still active working groups, such as the Maintenance Working Group, and specific international projects that are follow-ups of INNOTRACK are still running.

Barriers to Implementation

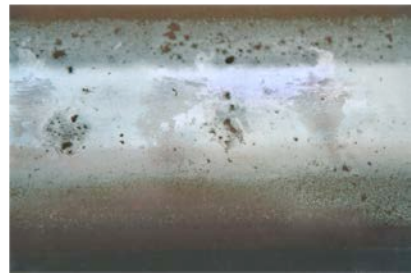
Although the project aimed for an overall cost reduction of 30%, and some examples show that good results have been obtained, it is hard to prove that this general reduction was actually realized. The main reason is that the problems, and also the technical solutions, are comparable internationally; the specific local situation differs too much to be able to guarantee full-scale implementation of all the possible improvements.

Differences exist in the local technical situation (infrastructure, moving material, regulation, labor cost, circumstances), but also in the political situation. For instance, there was agreement on the method for calculating life-cycle costs, but the local parameters in the actual calculation are predominant when the LCC instrument is used, so that it is difficult to compare results, let alone coordinate decision making on a European scale.

The reason for slow implementation is often that, for many participating members, there are no economic benefits to carrying on with the implementation work. However, the INNOTRACK project did set in motion an improvement process on a large scale, and this process

Examples of INNOTRACK Implementation over Time, Including Early Adopters

- One good example of the implementation of INNOTRACK is the treatment of rail cracks by grinding. Although this process had been known in Europe before 2006, the project proved to be the main catalyst for introducing this technology to Europe (and worldwide), even in countries that were skeptical at the beginning.
- The technology is relatively expensive in terms of investment (one grinding unit would cost more than €20 million), but in the Netherlands alone, the cost savings amount to €50 million per year. Extrapolated to the European scale, this savings would probably amount to more than €1 billion.
- Other implemented results from the projects are related to treating soil erosion in the substructure. Sweden is using lateral drilling and concrete insertion in locations where the substructure has weakened.
- In Austria, Sweden, and Switzerland, much effort has been put into reducing the length of rail joints to prevent train wheels from excavating the rail ends on the joint. Also other, more durable welding techniques are being applied.



Short-pitch corrugation on high-speed lines, an indication that grinding is required. (Source: INNOTRACK final report.)

offered the whole sector (not only the participants) much information and material with which to improve. The general direction of that improvement is convergence of the different systems, but it is slow going.

Finally the existing European procurement regulation does not make it easy to implement research and innovation results, as the parties involved in the earlier stages often find barriers to tendering in the implementation phase. Industrial partners and technical companies that take the initiative are sometimes punished for doing so, and therefore may be reticent when it comes to taking the lead in research and innovation.

Lessons Learned

INNOTRACK knew the following success factors for implementation:

- Implementation was part of the aim of the project from the outset. Implementation received structural attention in the setup of the project, and deliverables on implementation were foreseen from the start.
- Participants from all stakeholders were involved from the outset in defining the problem, doing the research, and discussing the answers. However, the total group was small enough to be able to work and coordinate efficiently.
- The definition of the problem and the research method (cost drivers as an essential starting point of the research for improvement) placed the project high on both the technology and the market-readiness levels. Therefore, deliverables were close to the work experience of the stakeholders.
- The existence of market parties that are able to offer grinding as a service to the rail infrastructure provider is a key success factor for the introduction of rail grinding, because the provider is saved from having to buy a very expensive device for a relatively small network.

INNOTRACK Policy and Regulatory Issues, Including Financial Issues

It is undeniable that implementation of many of the results from INNOTRACK would improve the business case of rail in comparison with other modes. In particular, the LCC instrument proves that many cost drivers can be handled more rationally.

The actual situation in many countries, however, may prevent full-scale implementation. Basically, the essential decisions about care for the rail infrastructure lie in political hands throughout Europe. Decisions on investment in improving the infrastructure lie with politically responsible people and are not always made on the basis of sound business cases. Public opinion also plays a big role in this process. There is simply no real market incentive for improvement.

The following lessons can be drawn from this case:

- Implementation of innovation will not come about without proper incentives, both for those responsible for maintenance and those responsible for the market. One of the incentives should be a reward (or, in any case, no punishment) for those involved in innovative research.
- Procurement rules should be considered (or reconsidered) to provide a bigger incentive for innovation.
- Local differences often stand in the way of Europe-wide implementation of evident improvements: the rail sector retains the basic characteristics of a quilt. There is as yet no common language for comparing business cases between countries and agencies.
- Close and intensive involvement of players in research projects such as INNOTRACK does give them a competitive advantage.

River Information Services

The case of River Information Services (RIS) is an example illustrating the possibility of full-scale implementation of European research in member states through best practice supported by regulation and the use of the time and energy that is needed to do that successfully.

Original Research Purpose and Need

The origin of RIS lies in the effort of the European Commission in the 1990s to raise the status of inland navigation to a full-scale alternative for transport by road and rail in Europe under the pressure of increasing congestion and safety concerns. At that time, several countries were working on information systems for inland shipping (more coordination had already been achieved in the maritime sector). As their work was not very coordinated, continuation could have led to the implementation of different technologies in each country. European research, particularly that funded through EU research programs, has played a very important role in harmonizing the development of RIS. The policy development went hand in hand with European research. The interest of a number of countries in participating in this effort, particularly countries in the Rhine and Danube basins, stemmed from the necessity to tackle economical, transport operational, environmental, and safety issues upstream and downstream.

Research Process and Results

From 1990 onward, RIS was developed through a number of research projects. The most influential of these were Efficient Inland Navigation Information System (INCARNATION), Inland Navigation Demonstrator for River Information Services (INDRIS), and Consortium Operational Management Platform River Information Services (COMPRIS), the last being mainly directed at implementation of RIS.

The projects resulted from research calls by the European Commission that were formulated in coordination with representatives from member states, the research industry, and the navigation sector. These were assembled in a platform Waterborne Support Group. Some of the consortia bidding for research already existed and had been involved in the European Cooperation in Science and Technology (COST) program.

The INCARNATION project aimed at identification of administrative and organizational barriers and the assessment of informational and organizational requirements and functionalities of an efficient inland navigation information system with special regard to transport capacity and goods flow, safety of traffic, and transport of dangerous goods. INCARNATION

- Covered 10 work packages that resulted in policy requirements, capacity and safety requirements, user requirements, and functional and technical specifications;
- Encompassed the demonstration project of an onboard radar tracking system; and
- Yielded recommendations on implementation in terms of further Europe-wide demonstration projects, introduction in national policies, legal aspects to consider, and the harmonization of reporting and communication procedures as well as standardization Europe-wide.

The INDRIS project ran from 1997 to 2000. The main aim of the project was to set specifications for and to demonstrate and assess communication technologies, management procedures, and information services for the RIS concept. The INDRIS project successfully demonstrated the technical realization of the RIS concept and many of its elements. Achievements included the following:

- Incorporation of new technologies in inland navigation [Automatic Identification System (AIS) transponders and the inland Electronic Chart Display and Information System (ECDIS)];
- Development of a framework for West European cooperation on RIS, standards, and harmonization (RIS guidelines, inland ECDIS standards, AIS standards); and
- Development of more user-oriented applications, not only for vessel traffic management and safety of navigation but oriented also to value-added services for the transport industry (vessel traffic management in large areas, onboard applications, and logistic and transport information exchange).

A special feature regarding RIS implementation was the key role of the World Association for Waterborne Transport Infrastructure (PIANC), which translated research into practical guidelines. The advantage was that PIANC, being a technical association, was further removed from the political stage than any committees the European Union might have set up. Moreover, because the Danube countries and Eastern European countries were members of PIANC, RIS had much broader support than the member countries of the European Union at that time could have had. The guidelines were published in 2002 and served as the basis for further implementation.

Implementation Activities

The COMPRIS project, which ran from 2002 to 2005, was intended to be the last stepping-stone before the full implementation of RIS across Europe. During the Pan-European Conference on Inland Waterway Transport in Rotterdam in September 2001, the European Ministers of Transport declared that RIS should be up and running on the main European rivers within 5 years. The main objective of COMPRIS, a research and development project, was to contribute to this implementation strategy and, thus, to make the RIS concept feasible throughout Europe. Therefore, COMPRIS was to be linked to existing and future initiatives in the participating European countries. Once the COMPRIS project had ended, the market forces were to be in a position to offer solutions and services on the basis of tested concepts and the specified standards. The project included creating an operational test platform, demonstrations to policy makers and operational responsible management (Figure 6), and developing guidelines and e-learning training modules. The steering committee consisted of government officials, but there was very open communication with market parties, especially in the pilots that were part of the project. The industry also participated financially in the pilots.

In 2004, the Central Commission on the Rhine updated and adopted the PIANC guidelines. With the adoption of the RIS Framework Directive in 2005, the scene was fully set for the implementation of RIS.

After the adoption of the European RIS directive, the pace of implementation seems to have diverged between countries. In its publication *River Information Services: Modernising Inland Shipping Through Advanced Information Technologies*, the European Commission gives a brief overview of the actual implementation of the RIS directive. Elements of the RIS solutions were implemented throughout the first decade, beginning in 2001. Although no single country seems to have implemented the entire range of RIS measures, Austria (which had already started implementation on the Danube early in 2001), the Netherlands, Germany, and Flanders had already implemented part of the available measures according to European standards in 2006. The first pan-European implementation had to wait until a few years after the publication and adoption of the RIS Framework Directive. At present, implementation in accordance with EU regulation is widespread in the European Union, in other European countries, and in many parts of the world, including the United States and China.

The implementation of RIS has been limited to issues concerning navigation traffic management. There are more aspects to RIS, such as logistics, that have remained unimplemented. The same goes for the development of the interfaces between navigation and road and rail transport. The relationship of RIS key technologies to RIS services is shown in Figure 7.

Barriers to Implementation

On the whole, the implementation of RIS must be considered as a success story. One must realize, though, that inland navigation is a niche market. It is small and, therefore, any innovation will need a long time to take hold because the return on investment on new products is slow. On one hand, being a small market helped in coming to agreements; on the other hand, the competition in that market is severe, and political influence could be (and was) used to speed up or decelerate certain developments. One example was the introduction of information systems that require privacy-sensitive information to be entered. This measure was held up for quite some time in the Netherlands by the lobby of the skippers' organization.

Along with being a niche market, inland navigation is not a wealthy sector. Any investment has a long payback time, and much of the capital in the sector is fixed in the assets (barges) themselves, which are mostly heavily

FIGURE 6 Demonstrator vessel *Ostarrichi*.

mortgaged. Another limiting factor was the small number of research institutes, including specialized research institutes, and the lack of transparency in the sector.

On a practical level, there was a certain lack of coordination of the many pilots. There was no central direction of these efforts at implementation. On the policy side, the RIS directive that came into force after 15 years of research and development was the breakthrough needed for widespread implementation. Even then it took a few years for the directive to be implemented. The positive aspect was that the preceding process had assembled most of the stakeholders, so that the directive as such was no surprise. From a political point of view, the inland navigation sector is not a strong key player, but it definitely has influence on the political decision makers.

Lessons Learned

The following factors played a key role for implementation:

- The European Commission took up a strong role at the outset of the process, coordinating and bringing parties together with a clear purpose.
- The sector was involved in the early stages of the problem definition and all along during the research itself.
- There was continuity in the institutes and persons involved. Although the projects ran for quite some time, changes in staffing were not very big. This continuity allowed for a certain trust to emerge between stakeholders. For the future, this same continuity poses another problem, as many key players are nearing the end of their active work.
- Involvement of PIANC as an expert but relatively outside agency proved to be a considerable success factor, in that it allowed separation of the political and technical streams.
- RIS generated a fairly strong expert platform that made it possible to discuss experiences from multiple pilots in different countries.
- Translation of the expert work into European regulation or directive was planned from the outset and the stakes were rather high for the stakeholders involved. This circumstance led to active participation.

SAMARIS, ARCHES, and CERTAIN

This case study considers three EU projects because they are interrelated. All three were strategically directed at diminishing the gap in the standard of highway infrastructure between the Central and Eastern European countries (CEECs) and the rest of the European Union. In terms of full-scale implementation, these projects, whether individually or together, did not quite meet the requirements of the supervisory panel for this study. However, these projects seem to be representative of quite a few research projects, and there are some useful lessons to be learned from them.

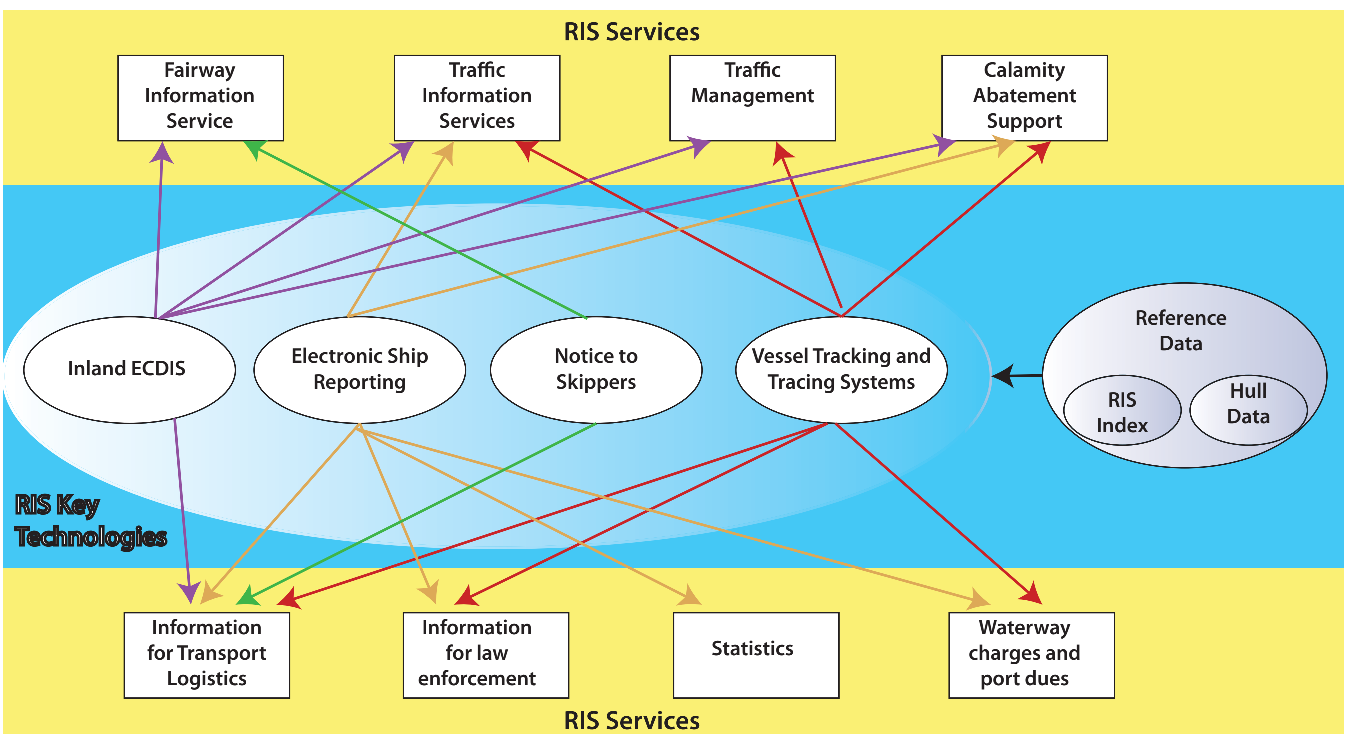


FIGURE 7 Relation between RIS key technologies and RIS services. (Source: PIANC Report 125-2011.)

The three projects are

- Sustainable and Advanced Materials for Road Infrastructures (SAMARIS),
- Assessment and Rehabilitation of Central European Highway Structures (ARCHES), and
- Central European Research in Road Infrastructure (CERTAIN).

SAMARIS and ARCHES were mainly concerned with the content of the research, whereas CERTAIN aimed at dissemination and implementation of the results.

Original Research Purpose and Need

The purpose of the research that was commissioned through SAMARIS, ARCHES, and some other projects was at least twofold. In the 1990s, it was felt that an effort should be made to develop a common European body of knowledge about infrastructure construction, both for bridges and for pavements. The background for this initiative was the common European problem of the deteriorating state of maintenance of the infrastructure assets and the shortage of funds for and political interest in that problem.

At the same time it was clear that the CEECs were building up a backlog in knowledge that had to be reduced if the European Commission were to remain justified in speaking about one trans-European network for roads. As some of the CEECs had recently joined the European Union, there needed to be a joint effort to reduce the distance.

Under the Competitive and Sustainable Growth program (GROWTH), one of the subprograms of the Fifth RTD Framework Programme, the issue of materials was addressed specifically. Materials was also one of the central issues addressed in the FEHRL Strategic European Road Research Program (SERRP II).

Research Process and Results

What became the SAMARIS project was originally proposed under two different proposals, one on road pavements (MAP) and one on structures (STRIM) in 2000. At the request of the European Commission, these proposals were merged and resubmitted under the name of SAMARIS 1 year later and contracted in 2003; the two research streams were retained.

The objective of the pavement stream was to encourage the sustainable use of recycled and secondary materials. The objective included preparation for the European Committee for Standardization (CEN) harmonization standards, which included developing guidelines for the use of recycled materials.

The objective of the structures stream was to radically improve efficiency and durability of repair methods by reducing the number of hours of disruptive road closures. At the same time, the aim was to reduce costs, improve safety, and pay special attention to the CEECs. The project plan called for research, demonstration, and interaction with national road administrations and with other road professionals through a professional network. The project ran through 2006.

The ARCHES project focused on structural assessment and monitoring, strategies for preventing deterioration, and the optimization of rehabilitation. It had four work packages, among which were the strengthening of bridges by bonded reinforcements and the hardening of structures with ultrahigh-performance fiber-reinforced concrete (UHPFRC). The project results were delivered in 2007.

Both projects yielded an impressive number of practical research findings. Examples from SAMARIS are

- A method for assessing alternative materials,
- Test procedures,
- Environmental annexes to road product standards in preparation for CEN standardization,
- Technical guides for recycling techniques,
- Methods for structure assessment,
- Field trials of corrosion inhibitors, and
- Full-scale application of UHPFRC for bridge rehabilitation and guidelines for use.

ARCHES yielded guidelines for nondestructive proof-load testing and corrosion testing, particularly with cathodic protection, and application of UHPFRC in a full-scale test in Slovenia.

Implementation Activities

To improve the chances of implementation, the SAMARIS project established an end user group to offer advice on prioritization of research issues, to review documents, and to discuss results. Meetings and newsletters were organized, and end users played the role of reviewers of the 17 main reports, mainly for practical relevance. In anticipation of difficulties with further implementation, the end user group was continued for some time after the formal end of the project.

Parallel to this, the CERTAIN project was started in 2006. This project aimed at facilitating the integration of CEECs and new member states into the EU road research community. CERTAIN was composed of four work packages: organizing workshops, project management training, facilitating secondments, and developing web tools for experts and for dissemination purposes. The project ran

Examples of Implementation of SAMARIS, ARCHES, and CERTAIN over Time, Including Early Adopters

As the aim of the research was primarily to bring the CEECs up to date, implementation in Poland and Slovenia was chosen as an example. In spite of the efforts to create optimal conditions, the actual implementation of the results of the research remained minimal in the CEECs. In other European countries, many of the technologies were already being used, in part independently of the two projects described in this paper. Such was the case in Switzerland, where more than 15 applications of UHPFRC are known. In Norway, the knowledge generated in the SAMARIS project was taken up and further developed [by the Norwegian Concrete Innovation Center (COIN), among others]. The construction sector is one of the main promoters of the fiber technology involved, which is considered a known technology that is sometimes prescribed in construction rehabilitation. In other European countries, as well as in North America, China, and Japan, the technology is also available and being used frequently. In the CEECs, the implementation mostly stopped after the realization of the pilots. As these were real-life pilots, the results, such as the Čezsoški Bridge in Slovenia, are still there. In fact, the pilot project for this bridge showed that applying new materials such as UHPFRC, though more expensive, even delivers a short-term benefit because of a shorter construction time, fewer labor costs, and less disruption over the whole project.

Čezsoški Bridge, Slovenia, after application of UHPFRC. (Source: ARCHES report.)

through 2010. Much attention was paid to the language barrier, which can be an obstacle for implementation in Europe. Courses, workshops, and the Internet platform were multilingual, and some documents were translated.

Barriers to Implementation

The SAMARIS report signaled the risk of lagging implementation in the final report:

> Some of the obstacles are systemic and very difficult to overcome from "below" or from "outside." Curiously, the very considerable economic "risk" of research and development is generally understood and accepted, but the much smaller risk involved in the implementation of the results of successful research is often seen as prohibitive. (Final Report, p. 8)

Continuation of the end users group for some time was not able to overcome this situation. There were several reasons for the lack of implementation:

- Lack of funds in general for maintenance and rehabilitation, a situation that led to increasing backlog and temporary solutions, some with large consequences for road users (e.g., closing off lanes on roads and bridges, detours, and speed limits);
- Lack of national technical standardization for rehabilitation work;
- Basing contract performance criteria on traditional experience more often than on the latest knowledge;
- Long-term performance not being a critical condition in design–build contracts (the lowest price wins contracts any time); and
- Uncertainty regarding whether universities took up project research results in their curriculums.

Basically, there was no structural or systematic follow-up of research on a national scale in terms of training, standardization, or procurement regulation.

Lessons Learned

There were some success factors in the three projects, though mainly with regard to the execution of the research and the theoretical possibilities for implementation:

- Aiming projects at gathering very practical knowledge and conducting research in target countries by bringing in experts from other EU countries can diminish the not-invented-here factor.

- When projects achieve clear short-term results on important issues (e.g., cost, less disruption, safety), the chances that they will result in implementation are higher.
- Involving end users in the discussion of the practicability of the research and reviewing results from that angle is beneficial.
- There should be specific outreach programs for target groups (e.g., national regulatory authorities, decision makers, the construction industry), and it is preferable to finance these programs along with the research.
- Translating information into the language of the end user overcomes the language barrier.
- Involving universities may lead to adaptation of the teaching curricula at high schools and universities; however, sometimes universities and research institutes are competitors (also in the eyes of the European Commission).
- The construction sector may be an important motor behind the implementation of solutions, given (or earning) enough funds to develop innovative solutions.
- Continuity of research staff leads to very good knowledge networks (although there is a risk of a shortage of experts over time).

Silent and Durable Road Expansion Joints

The Silent and Durable Road Expansion Joints project, which was part of the Netherlands' Innovative Road Maintenance (IPW) program, is a good example of how innovation-driven research can yield improvements (in this case, reducing the noise factor in pavement and bridge joints). However, the procurement conditions prevented the general introduction of the winning concepts.

Original Research Purpose and Need

The use of silent asphalt is widespread in the Netherlands, particularly in noise-sensitive areas. The relative contribution of expansion joints (Figure 8) increases with the application of silent asphalt. Silent expansion joints, usually bituminous, are used to reduce the noise of passing traffic. The average life span of the current silent expansion joints is too short: 3.5 years on average. This life span is much shorter than that of the adjacent silent asphalt, and this disparity causes both considerable additional costs for maintenance and traffic management and major disruption. The road authority, RWS, challenged the research and construction communities to develop silent expansion joints that would have the same life span as silent asphalt. These innovative joints were to be subjected to extensive laboratory testing and live trials (Figure 9).

FIGURE 8 Expansion joints.

Research Process and Results

The project did not take the shape of a traditional research project. It was part of the innovation program IPW and financed by that program. In 2007, RWS organized a contest for the market to come up with solutions that would be silent and have a life span of at least 10 years. In the first phase (2008), 15 proposals were submitted from different European countries. An independent jury of experts judged them according to published weighted criteria, which included noise reduction, cost, environmental aspects, and durability. Ten proposals survived the first phase of the contest and were subjected to extensive testing by three-dimensional finite element analysis with temperature and traffic load. The four proposals that remained after this phase were tested extensively in laboratory circumstances at the Netherlands Organisation for Applied Scientific Research (TNO), Delft, and in real-time pilots in both the Netherlands and Switzerland in 2010. Three proposals fully met the contest require-

FIGURE 9 LinTrack laboratory simulation. (Source: Delft University of Technology, the Netherlands.)

ments. Of these, two were selected as preferred standard solutions in the road construction manual (multiple choice matrix). The contest officially ended with a symposium in 2012.

The conclusion is that the contest yielded at least two scientifically proved solutions that are silent, last more than 10 years, are cost effective over the maintenance life span, and can be applied in practice.

Implementation Activities

Owing to the specific character of this innovation program, the research was very close to the implementing organization from the outset. The scope of the research was already defined in practical terms. The implementation plan consisted of including the research results in the existing construction manual to give both the client and the contractor all the information needed to specify the best solutions when contracting.

The national Platform Expansion Joints (PVO) center played a role in disseminating the information generated in the project. PVO is the knowledge center for this subject and assists construction companies and government organizations at all levels to come up with solutions. This knowledge center is cofunded by the public and private sectors. The platform organizes working groups, training, and meetings to share information.

Barriers to Implementation

The main barrier to standardized implementation of specific noise-reduction solutions lies in the procurement guidelines being used. In the Netherlands, the system of performance contracts is generally used for maintenance. LCC is not a standard requirement for performance-based maintenance contracts. For noise requirements in these contracts, any solution that meets the minimal requirement is accepted: those requirements dictate noise level and life span. Therefore, the contractor usually chooses the cheapest solution that meets the requirement. There are no concrete plans to change that situation, although it is expected that LCC will become a requirement in the near future, as it already is with new construction.

Lessons Learned

Although the specific expansion joints that won the contest are not (yet) being used as a standard, the process from research to implementation can be considered successful. In the past few years, developing and using silent joints has certainly gained momentum in both the Netherlands and some other European countries that use silent asphalt on a regular basis.

Specific success factors for this project were as follows:

- The issue of silent joints is widely recognized, particularly in urban and semiurban areas. The penalty for exceeding the noise standards is high, as building projects are being stopped because of it.
- The research on expansion joints started on a relatively high market-readiness level. The issue was defined from a practical point of view by the people who had to implement the solutions.

Examples of Implementation of Silent and Durable Road Expansion Joints Project over Time, Including Early Adopters

Although the research and innovation project on silent joints yielded concrete results in terms of design for a new generation of joints, none of the winning proposals has as yet been generally applied in practice. Two of the joint producers have a (small) market share, but application is not standard.

The construction companies have developed their own, often cheaper solutions, partly on the basis of the research that took place (and was made public). Some construction companies buy the joints or material from specialized companies. It is, however, not certain that, on a life-cycle basis, these are the best and most durable solutions.

The quality of the joints has greatly increased since the IPW project was initiated. There is increasing international interest in the technology, notably in Sweden and China, among other countries.

Policy and Regulatory Issues, Including Financial Issues, for the Silent and Durable Road Expansion Joints Project

The Silent and Durable Road Expansion Joints project was financed through the IPW Innovation Program and cost about €1 million. No direct return on investment was required. The market parties covered the development cost of the solutions; these were not refunded.

Although silent joints are a Europe-wide issue, especially for bridges spanning valleys with habitation in mountainous areas, there are currently no EU standards. Noise expertise in the European Union is rather fragmented.

• The contest brought together researchers, contractors, producers, and the clients concerned. There was much interaction between the different phases of the contest.

• The contest criteria and, therefore, the scope of the research were rather limited and quite clear to the participants.

• Through setting the criteria, multidisciplinary teams were necessary for a successful result. This reduced surprises at the end of the project and delivered acceptable and viable solutions.

• The whole project was monitored closely from the start, and deadlines and conditions were strict. Expertise on both content and process was available throughout the project.

• The existence of PVO made it possible to disseminate results widely. Communication with all stakeholders was good throughout the project.

Climate Change

There is likely no issue more controversial or extensive than climate change. This case study chronicles the step-by-step process of research that moved this project forward.

Original Research Purpose and Need

Climate change is one of today's big societal challenges. The effects of climate change have a huge impact on mobility and transport and, thus, on the economy and on the well-being of citizens everywhere. All transport infrastructure networks will suffer the results of increasing rainfall, more and more intense storms, and changes in temperature patterns. It is no wonder that, in many countries, research on climate change has reached a peak. The first priority was to understand the phenomenon of climate change. In the transport sector, however, the brunt of the research was directed at mitigation and adaptation strategies.

Research was, and is, being undertaken by individual countries. More and more collective international research has been initiated because the knowledge is widespread, increasing knowledge is expensive, and there is a risk of duplication.

In Europe, a research program was set up under the auspices of ERA-NET ROAD. This program was a coordination action funded by the Sixth Framework Programme of the European Commission. Within the framework of this action, the call "Road Owners Getting to Grips with Climate Change" was launched as the first cross-border-funded joint research program. Eleven national road administrations (Austria, Denmark, Finland, Germany, Ireland, the Netherlands, Norway, Poland, Spain, Sweden, and the United Kingdom) participated in the program and provided a total project budget of €1,350 million (Figure 10). Nineteen proposals from 18 different countries were submitted for the call.

The research program aimed at providing road authorities all across Europe with the knowledge and tools necessary to get to grips with climate change and its effects on all elements of road management by adapting design rules, updating and improving data collection, and developing risk management methods.

Research Process and Results

Four of the 19 submitted projects were selected for funding:

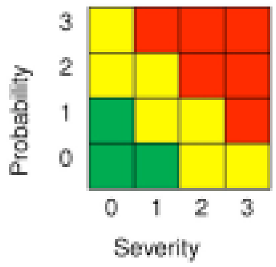
• Improved Local Winter Index to Assess Maintenance Needs and Adaptation Costs in Climate Change Scenarios (IRWIN),

• Pavement Performance and Remediation Requirements Following Climate Change (P2R2C2),

• Risk Management for Roads in a Changing Climate (RIMAROCC), and

• Storm Water Prevention—Methods to Predict Damage from Water Stream in and near Road Pavements in Lowland Areas: The Blue Spot Concept (SWAMP).

These projects, which constituted the research program, are discussed next.



	High temperatures		±0 temperatures		Wind		Storm		Rain intensity		Increased flow rates in rivers		Flood		Drought		Landslides		Avalanches		Snowfall intensity		Sea-level rise	
	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S
Norway	3	1	3		1		1		3	3	2	2	3	2	1	1	2	2	2	2	3	2	3	2
Finland	2	1	3	2	2	2	1	2	2	2	2	2	2	2	1	1	1	3	1	1	3	2	1	0
Sweden	2	2	3	2	1	2			3	3	2	2	3	2	1	1	3	3	1	1	1	2	2	2
Denmark	2	2	1	1	2	1	1	1	3	2	2	1	2	2	2	1	0	0	0	0	1	1	2	2
UK	3	1	1	0	1	1	2	2	3	2	3	1	3	2	2	1	1	0	0	0	1	1	2	1
Ireland	2	1	1	2	1	1	1	1	3	2	1	1	3	2	1	0	1	2	0	0	0	0	1	1
France	3	1	2	1	1	1	1	2	2	1	1	2	2	2	3	3	1	2	1	1	2	2	3	2
Austria	2	2	3	2	1	1	1	1	2	2	1	2	3	2	3	2	2	2	2	1	2	2	0	0
Hungary	3	2			2	1	3	2	3	2	3	2	3	2	3	1	2	1	0	0	3	2	0	0
Italy	3	2	2	2	1	1	2	1	2	2			2	2	1	1	2	2			2	2	1	1
Spain	3	2	2	1	1	1	2	1	2	1	2	1	2	1	3	2	2	1	2	1	2	1	2	1

FIGURE 10 Results from individual country surveys on the assessment of the probability of effects and severity of consequences resulting from changes in climate parameters (P = probability, S = severity).

IRWIN: Improved Local Winter Index to Assess Maintenance Needs and Adaptation Costs in Climate Change Scenarios

A winter index is a tool for planning and calculating winter maintenance work as compared with the present situation. It can also be used for evaluating road construction risks and construction dimensioning. However, winter indexes were not very detailed and did not take into account local climatic variations. Through the use of a dense network of stations, road weather information systems would improve winter index calculations because measurements would be taken close to the road and reveal short and local weather events. Swedish and Finnish data were used to improve the index.

The following benefits were realized: better linkage between weather and maintenance needs, better understanding of local weather variations, a user-friendly tool, and better coverage of extreme events such as heavy snowfall or strong winds. At the same time, the tool provides a better basis for assessing the financial implications of climate change for road owners.

P2R2C2: Pavement Performance and Remediation Requirements Following Climate Change

This project investigated the likely impacts of climate change in Europe, from the Alps northward, on the moisture and ice conditions in the pavement and the subgrade and the consequent behavior of the pavement material and pavement response to traffic over a 100-year timescale. The aims of the project were to

- Study the likely differences in moisture (water) condition in the pavements of roads in Europe as a consequence of climate change,
- Estimate the likely consequences for pavement and subgrade material behavior for a range of representative pavement types and climatic zones,
- Assess uncertainties so as to permit risk and vulnerability to be evaluated,
- Define options for responding to the changes, and
- Perform a cost-benefit analysis to allow road owners to determine the best options for their own situations.

The project was performed through a combination of literature review, laboratory evaluation of materials, computational studies of pavement structural and hydrological performance, and development of recommendations suitable for implementation by road owners. Although the life cycle of pavement is much less than the time span over which climate change will have an influence on pavement performance, the effects of these changes on pavement construction, management, and use will be better understood. This knowledge will yield recommendations for design and construction parameters in areas affected by changes.

RIMAROCC: Risk Management for Roads in a Changing Climate

The purpose of this study was to provide a systematic method for risk management on the basis of three questions: What can happen? How likely is it to happen? If it does happen, what are the consequences?

The RIMAROCC method was designed to meet the common needs of road owners and road administrators in Europe. The method seeks to present a framework for climate change adaptation for roads to help ensure that road networks will be more resilient to future climate change. The method is based on existing risk analysis and risk management tools for roads within the ERA-NET ROAD member states and others. It is designed to be compatible with and function in parallel with existing methods and to allow the maintenance of specific and functional methods for data collection, calculations, and cooperation. The method, which is also in line with ISO 31000 (risk management), consists of seven steps and is a cyclic process designed to continuously improve performance and capitalize on experiences.

The method has been tested in practical case studies in four countries and at different scales, including the network scale (a 100- to 1,000-km network of primary roads), the section scale (a 20- to 100-km road section), and the structure scale (a bridge). In addition to demonstrating the method and showing its scope and limitations, these case studies show in concrete terms how the method can be implemented and what the possible adaptations of the overall methodological framework could be.

SWAMP: Storm Water Prevention—Methods to Predict Damage from Water Stream in and near Road Pavements in Lowland Areas: The Blue Spot Concept

A greater frequency and intensity of flooding is expected to result from climate change in many parts of Europe, particularly central and northern Europe. Flooding poses a great threat to roads and traffic and damages the road structures themselves. In many countries, design guidelines for new road-related construction have changed in response to the anticipated future climate. Changing the entire existing road network would be very costly and most likely is not necessary. Identifying the weakest parts of the road network is the first and most important part of a climate adaptation strategy.

The SWAMP project addressed the critical issue of finding the parts of the road network that were most vulnerable to flooding by using a geographic information system. These parts are referred to as "blue spots." It was believed that most resources should, at least initially, be spent on relatively few blue spots. Additionally, one should perhaps think twice before rebuilding or upgrading structures. In many situations, the worst socioeconomic costs, which appear to be related to obstruction of traffic, may be avoided simply by using early warning systems combined with effective communication to the road users. The project dealt with the issue of how to limit the effects of flooding or, if possible, avoid flooding at blue spots.

The project aimed to present the crucial issues to consider in the creation of national or even regional guidelines for inspection and maintenance. The suggestions were geared toward lowland areas that are relatively flat and toward mildly undulating landscapes; steep, sloping areas were not explicitly covered. The project also provided the following:

- Guidance and instructions to engineers and people in charge of inspection, maintenance, and repair;

- Useful information to decision makers responsible for renewal of the drainage system, with the aim of reducing future flooding and damage of the road network; and
- Practical suggestions on how to perform field work in a systematic way over the season and also how to prepare the road system before, during, and after a heavy rain event.

Implementation Activities

At the conclusion of the program, a final event was organized by FEHRL and the German Federal Highway Research Institute (BASt) in 2010. The conference was organized around different workshops, reports, and presentations of the projects' results.

The output of this research program was a series of reports that facilitate the understanding of this research across the countries of Europe. These reports were presented as proposed guidelines.

The work of this research program has been taken up by the Conference of European Directors of Roads (CEDR) in its working groups on climate change mitigation and adaptation. This was possible because CEDR member states were already involved in the projects themselves. The implementation followed two lines:

- The program was used as a starting point for further applied research funded through the CEDR call funding mechanism under the responsibility of the Task Group Research. Examples of further research following from the CEDR call "Road Owners Adapting to Climate Change" are the projects Roads for Today, Adapted for Tomorrow (ROADAPT) and Climate Projection Database for Roads (CLiPDaR).
- Comparative studies on climate change mitigation and adaptation measures were initiated in CEDR member states under the responsibility of the respective task groups on climate change adaptation and mitigation. The road directors discussed these reports extensively in their meetings from 2011 to 2013. The working groups are being continued in the CEDR Strategic Plan and work program for 2013 to 2017.

Barriers to Implementation

During the 2010 conference held at the conclusion of the program, workshop participants identified several barriers to the development of the approaches and to their implementation in future. These barriers can be divided into two categories:

- Scientific uncertainty or imperfection, such as the quality of climate modeling (need for more robust risk assessment) and uncertainty in prediction of emissions (need for more consistent future scenarios) and
- Policy considerations, such as lack of funding for investment in necessary inspection and improvement of the networks and the difficulty of developing generic guidelines because local influences are so important.

Sometimes policies are counterproductive. An example is the EU Water Framework Directive, which limits the amount of water that can be removed preventatively from a flood risk site.

Lessons Learned

This research program yielded the following lessons on conducting a program:

- The projects were initiated rather individually and, therefore, developed a focus on specific climate risks and countries. This focus rendered the projects clearly applicable in specific circumstances but less interesting and less applicable for a larger number of stakeholders. Basically, SWAMP and RIMAROCC have been widely implemented, but the other two projects have not.
- Developing a robust database (in this case, on the impacts of climate change) could help road authorities apply the knowledge flexibly, depending on local circumstances.
- The workshop participants felt that more emphasis should have been placed on the implementation aspects of the results, either imbedded as part of the outcome of the projects or in a special call aimed specifically at implementation of results in selected places or countries in Europe. There was no defined strategy of how to proceed with the available results.
- The CEDR working group structure greatly assisted in translating research into practical recommendations and served as a catalyst for the involvement of road owners. Because much of the testing took place on the network itself, the results were directly recognizable.
- If research activity is directed at a specific goal (as opposed to knowledge development without implementation in mind) the scope should be accordingly specific, as should the indication of the geographical area for which the research is meant to offer solutions. This specificity saves a lot of energy in the evaluation of tender proposals.

These lessons have been input to the description of research needs for the CEDR call "Road Owners Adapting to Climate Change."

Examples of Implementation of the Climate Change Program over Time, Including Early Adopters

The CEDR working method includes an investigation among the members of possibilities for and concrete examples of implementation of the recommendations included in final working group reports. Thus, there is a sample of actual experiences with the implementation of research, although the research itself first has to be translated into a format that is manageable for road directors in actual practice. Thematic working groups therefore serve, on the one hand, as the initiator of research but on the other hand as the interpreter to the operational and responsible management.

In the case of climate change mitigation and adaptation, several examples of intended implementation were identified through a questionnaire. In the field of mitigation, these ranged from dissemination of the reports and underlying research to the taking up of results in government policy papers by experts in the respective agencies. The following recent information on adaptation is available:

- **Germany.** In Germany, the RIMAROCC method is elaborated at present in the currently running project Development of a Robust Generally Applicable Indicator System for Ecological Changes in Floodplain Systems (RIVA), which has resulted in a product that generates maps with climate risk locations. The SWAMP results could be used as a basis for an intermodal blue spot analysis in the future.
- **Denmark.** In Denmark, the SWAMP project was implemented in a pilot project. The results from this project were used as a founding model in 2013 to further develop a risk analysis model to identify roads of particular interest with regard to flood risks. This project was called the Blue Spot Project. The developed model, including subsequent cost–benefit analyses with the integration of socioeconomic calculations, is now (in 2014) being implemented on a national scale in Denmark.
- **Norway.** The Norwegian Public Roads Administration used RIMAROCC as a reference for developing a procedure for risk assessment of roads and road structures for climate-related events. The R&D program was called Climate and Transport. Standards and handbooks for stormwater trenches have been changed to address a precipitation probability of 200 years instead of 100 years. SWAMP was not implemented in Norway, but the methodology is well known and is under evaluation in a new R&D program on natural hazards. IRWIN has also been used as a reference in the Climate and Transport program in the study of winter operations. However, winter indices are not in use.
- **The Netherlands.** The Netherlands initiated a blue spot investigation following from the SWAMP project, and this investigation resulted in a report in 2012. The SWAMP method was custom fitted and further elaborated to the Dutch (flat) situation of polders and maintained water levels, which is different from hilly countries. Following the investigation, a risk investigation of blue spots with the RIMAROCC method was begun and is currently in progress. The resulting maps of locations that are at risk are a basis for the planning of measures, if necessary.
- **Ireland.** Ireland's National Roads Authority participated closely in the Climate Change program and implemented the SWAMP and RIMAROCC projects, which resulted in practicable solutions. SWAMP was integrated into the national strategic knowledge map and used in flood mapping through detailed surface modeling that employed a geographic information system. The findings resulted in a protocol for flood risk management. With the help of the RIMAROCC results, this protocol was then translated into a four-phase implementation plan that covered the establishment of a baseline database, detailed site-specific modeling (both in full use), and selection of mitigating measures and warning and evacuation systems.
- **Other countries.** Within the ROADAPT project, the RIMAROCC method is currently being elaborated and fit to use by European road authorities, generally for assessing all climate risks and not just flooding. Case studies are being done both in southern countries (Portugal) and in northern countries [the Denmark–Sweden Öresund region and the Netherlands–Germany Rotterdam–Ruhr corridor]. Other countries that were intending to implement (parts of) this research were Finland, France, Hungary, and Sweden.

U.S. Case Studies

Highway Safety Manual

The development of the *Highway Safety Manual* (HSM) represents the culmination of a decade-long research effort and demonstrates the importance of engaging a very broad range of stakeholders in the entire innovation process. This case study illustrates the institutional and resource challenges that a project of this magnitude must overcome.

Original Research Purpose and Need

With more than 30,000 fatalities per year occurring on U.S. roadways, it is clear that safety is and must continue to be the nation's number one priority. Significant resources have been dedicated to improving roadway safety, particularly through the leadership of FHWA. However, decisions regarding where to direct those resources and how they could be best used have often come down to a matter of professional judgment and past experience.

The development of the HSM was an outgrowth of recognition that safety practitioners lacked a quantitative basis for objectively estimating the number of expected crashes on a roadway segment or at an intersection, particularly after safety countermeasures were applied. Nor did a tool exist that was sensitive to different traffic volumes, geometric characteristics of the site, crash history, and the surrounding land uses. The ability of safety specialists not only to make informed decisions in the design of safety improvements but also to evaluate alternatives and priorities in the planning phase was, therefore, severely limited. What was needed was a tool that would provide science-based methods for evaluating past safety performance and estimating future safety performance as a means of reducing fatalities and severe injury crashes on the nation's 4 million miles of roadways.

Research Process and Results

It took approximately 11 years to produce the first edition of the HSM. The manual's complexity and importance were in many ways unprecedented in the field of highway safety, and the HSM would not have been developed without the very close cooperation and sustained support of three major players: the Transportation Research Board (TRB), AASHTO, and FHWA.

The idea of developing a comprehensive resource document on roadway safety originated at the 1999 TRB Annual Meeting, at which a special session on predicting highway safety was held. At that session, there was a collective realization that the profession lacked a single authoritative document on how to quantitatively estimate safety and that such a resource was badly needed. That same year, a workshop was held to develop an initial outline and plan for creating the HSM. The workshop was a joint effort of eight TRB standing committees and FHWA and led to the formation of the TRB Task Force for the Development of a Highway Safety Manual in the year 2000. The task force, which was composed of technical experts, academics, and representatives of the end user community, including the state departments of transportation (DOTs), played a key role in identifying specific research needs for the HSM and providing technical oversight to the ongoing research projects. Ultimately, the task force was one of the primary reviewing bodies of the HSM as the document moved to publication in 2010.

Once a plan was developed, research for the HSM was funded primarily through TRB's National Cooperative Highway Research Program (NCHRP). FHWA provided significant leadership and research support for the entire program and helped the project maintain momentum from start to finish. The first edition of the HSM was developed and produced from eight separate NCHRP projects. Some of these projects focused on compiling and developing material on past safety-related research, and others conducted original safety research to fill gaps in the current knowledge base. These eight NCHRP projects took place from 2001 to 2010.

Individual representatives of the state DOTs played a critical role in the entire project, as did AASHTO, the association that represents the collective interests of all the state DOTs. AASHTO took on the responsibility of publishing the first edition of the HSM, and in so doing formed a joint task force with representatives from AASHTO subcommittees on design, traffic engineering, and safety management. The joint task force was tasked with ensuring the HSM would meet the needs of state DOTs and also with promoting the use of the HSM upon publication.

Ultimately, all of these efforts resulted in the development of a comprehensive document that provides tools and methods for a qualitative and objective safety analysis of

- Existing and expected safety performance of different roadway segments and intersections;
- Alternative roadway projects and their potential effect on the severity and frequency of crashes;
- Design decisions and exceptions that often arise within a project's development and their corresponding effect on crash frequency and severity; and
- Relative improvement in safety performance resulting from projects or treatments that have been implemented (e.g., how effective a treatment was in reducing crashes).

Plans for the second edition of the HSM have started. Research has continued since 2010 to work to fill in the gaps in the roadway safety knowledge base. Currently, approximately 18 NCHRP projects are identified for inclusion in the second edition of the HSM. Some of these projects have been completed, some are ongoing, and some will be started in the near future. Each of the 18 projects is planned for integration into the second edition, which has a targeted publication year of 2020.

Implementation Activities

Because of the extensive involvement of so many stakeholders and end users in the entire research process, a lot of pull was created well before the HSM was published. FHWA in particular did a lot to inform the highway safety community about the HSM, even while the document was being developed, and this activity further built anticipation for the end product. Also, many plans for implementation activities, including the development of training and outreach materials, were well under way.

Training

One of the greatest challenges in implementing the HSM has simply been giving people the knowledge to use it. Therefore, training has been a cornerstone of the implementation efforts. Several different training initiatives targeted state DOTs and local agencies (e.g., counties and cities), many of which were organized and funded through government organizations. Following are some highlights:

- Highway Safety Manual Implementation and Training Materials (NCHRP 17-38). This NCHRP project was undertaken and completed in time for the initial publication of the first edition of the HSM. It produced spreadsheet tools for implementing the crash prediction methods of the HSM as well as training materials on how to use the HSM.
- Safety Management in a Data-Limited Environment Training. This course was developed by a subcommittee of the TRB Standing Committee on Highway Safety Performance, which was engaged throughout the entire development of the HSM. Materials produced included training materials and speakers' notes for use through the Local Technical Assistance Program and Tribal Technical Assistance Program to present a day-long course. These two programs work with local agencies and tribes on surface transportation issues and improvements.
- FHWA National Highway Institute HSM training courses. The National Highway Institute, which is housed within FHWA, was formed more than 30 years ago to provide training to state DOTs and other transportation professionals. Nine courses were developed as part of the HSM implementation, including online and webinar-based courses.[1]
- FHWA Resource Center training. FHWA's Resource Center is composed of national and international experts that provide technical assistance and training to the highway community to advance innovation in all fields. To supplement the direct assistance they provided in implementing the HSM, the Resource Center also developed three workshops, including "HSM for Local Officials."

Software and Tool Development

One of the primary hurdles to implementation of the HSM was the initial lack of software with which to implement the new network screening and crash prediction methods within the HSM. The level of effort necessary to implement the methods by hand is too great to make their routine use feasible. As a result, the following efforts were undertaken to make it easier for practitioners to use the methods, including spreadsheet tools (mentioned above) and new software:

- SafetyAnalyst software. FHWA initially funded the development of SafetyAnalyst software, which implements Part B of the HSM ("Roadway Safety Management Process"), at a large scale. The intent was to provide state DOTs with a tool they could use to help automate the network screening, diagnoses, countermeasure selection, and effectiveness evaluations. AASHTO has taken ownership of the software and now leads updates to it and deployment to states.
- Interactive Highway Safety Design Model (IHSDM) software. FHWA updated a preexisting software tool, IHSDM, to include the predictive methods in the HSM. Practitioners can now use this free software to predict crashes on rural roads and highways, suburban and urban arterials, freeways, and interchanges.

In-person opportunities and online resources have been established to facilitate information sharing between state DOTs and to help them share success stories in HSM implementation. Examples include the following:

- Lead-States Program. The intent of this effort has been to jump-start HSM implementation by providing targeted technical assistance to a select group of "lead states" in implementing the HSM. The 13 lead states and eight support states taking part in this effort have shared information on their use of the HSM through multiple peer exchange workshops. This early effort, along with

[1] Information on FHWA HSM training courses is available at http://safety.fhwa.dot.gov/hsm/courses.cfm.

the development of an HSM user guide, will provide insights to help other states apply the HSM more accurately and routinely.

• HSM website and online user forum. AASHTO established a website for HSM-specific materials that includes an online user forum where practitioners can post questions regarding the HSM and informed experts from AASHTO can post answers to their inquiries.[2]

• FHWA Crash Modification Factors Clearinghouse. In a unique forum for collaboration, FHWA established an online clearinghouse where researchers can post crash modification factors, which are then ranked on the basis of the quality of the studies that produced them. The intent of the website is to give practitioners and researchers an up-to-date library of crash modification factors that reflects the collective current knowledge base.[3]

• Supplemental HSM implementation materials. FHWA and AASHTO have collaborated to produce several supplemental publications and outreach materials regarding the HSM, all of which are available on the HSM website.

Barriers to Implementation

• Lack of financial and staff resources. There has been considerable investment in training and other implementation efforts; however, with 52 states and more than 20,000 local agencies, much more needs to be done, including determining where priority should be directed. Also, resources are needed to collect and manage additional data as the HSM methods are applied in practice.

• Communication of the benefits of using the HSM. Although nearly 5,000 copies of the first edition of the HSM have been purchased and distributed, implementation is still mixed. Although the lead states have been at the forefront of implementing the HSM, other states are just beginning to look seriously at its application. Communicating the value of the HSM analyses can be challenging, particularly in motivating decision makers and staff across multiple levels of an agency to allocate the necessary resources to learn and apply the HSM.

• Lack of data. Many of the HSM methods are data intensive, and many state and local agencies still lack the ability to implement these methods.

• Difficulty in using the HSM. In many ways, the concept of the HSM is very basic, but in practice it can be a challenge to apply. Effort needs to be made to continue to simplify the HSM methods to facilitate their use in routine projects and activities.

[2] The HSM User Discussion Forum is at http://www.highwaysafetymanual.org/Pages/forum.aspx. The HSM website is http://www.highwaysafetymanual.org/.

[3] The Crash Modification Factors Clearinghouse is at http://www.cmfclearinghouse.org/.

Lessons Learned

• Balancing technical information and easy-to-apply information. AASHTO, FHWA, and TRB collectively aimed to include the most technically robust and accurate information in the HSM, and their efforts resulted in crash prediction modeling techniques that use statistical models and analysis unfamiliar or new to many practitioners. The challenge of presenting those models and methods in a manner in which practitioners can apply them and be able to interpret the results was, and continues to be, one of the more formidable in producing future editions. As a result, there is increased focus on developing spreadsheet and software tools that automate the implementation of the methods to make the HSM easier for practitioners to use.

• Integrating the HSM into established processes and programs. The states that have had the most success in integrating the HSM are those that have used it to supplement a process or program they had already established. For example, the Utah DOT has been working on integrating the HSM into its process for design exception and design variance evaluation and approval. The Ohio DOT has implemented SafetyAnalyst as its mechanism for managing safety on the Ohio road network.

• Communication. Some of the hesitancy from states that were not early adopters of the HSM was related to whether the perceived additional effort to apply the HSM was worth the outcomes. Peer exchanges and sharing information, especially successful applications, are particularly valuable in overcoming some of the initial resistance to things that are new or different. The more that can be done at a peer-to-peer level rather than from the top down, the more successful the outcome appears to be.

• Funding and resources. Many of the barriers to implementing the HSM relate to funding and resources to collect data or to understand how to the use the HSM. Many of the combined efforts of FHWA, AASHTO, and TRB have been directed to producing training and supplemental materials that address those issues and to making them available to states and local agencies free of charge.

Flashing Yellow Arrow Left-Turn Display

This case study highlights how important research can be in providing the technical justification for change and how that can be used to successfully support the institutional decisions that follow.

Original Research Purpose and Need

Protected–permitted left-turn (PPLT) signal phasing at traffic signals has existed for many years in the United States, but prior to the completion of this research, various different displays were in use, a situation that led to driver confusion. There were also certain applications that created safety hazards as a result of the phenomenon known as yellow trap. The purpose of the research was twofold: to develop a uniform display for the PPLT that could be easily understood by motorists and also to develop a display that could overcome safety hazards presented by issues such as the yellow trap. The research was originally sought by AASHTO and was funded through NCHRP.

Research Process and Results

Figure 11 provides a summary of the major elements of the research along with a chronological overview of the research effort from project initiation through publication of the final report and beyond. The research began with a cadre of different types of PPLT displays created by innovative engineers and practitioners around the country. The research involved extensive collection of field data throughout the United States, evaluation of existing displays, and completion of extensive human factor research to assess driver understanding of various displays.

To meet the study objectives, and as shown in Figure 11, the research moved beyond traditional controlled-environment driver surveys and assessments. The project team used full-scale driving simulators to implement a pioneering effort in assessing human factors and driver understanding. The simulations were very beneficial in demonstrating to practitioners the driver understanding of the innovation. Later, the research team collaborated with FHWA and practitioners around the United States to implement the new flashing yellow arrow (FYA) display in the field. Ultimately, the research effort recommended and tested a new FYA display. The project culminated with a research report that was published in 2003.

Research Implementation

Upon publication of the final research report, *NCHRP Report 493: Evaluation of Traffic Signal Displays for Protected/Permissive Left-Turn Control*, NCHRP and the National Committee on Uniform Traffic Control Devices continued work through the summer of 2004 to advance the implementation of the project recommendations. These efforts included participation in the committee's task force meetings and review of draft language for the codes that would allow for national implementation of the FYA. Figure 12 presents the timeline and key steps associated with the implementation.

The field implementation effort required careful coordination with FHWA to secure interim approval for field testing the new FYA. It also involved considerable effort to convince practitioners to try something new and serve as early implementers of the FYA. The involvement of practitioners in the pilot evaluations was helpful in convincing the larger group of practitioners. Ultimately, the new FYA was found to uncharacteristically appeal to the public at large and generally proved to be a great success in early implementation.

Inclusion in FHWA's *Manual on Uniform Traffic Control Devices* (MUTCD) is essential for traffic control devices in the United States. The MUTCD is the U.S. national standard for traffic control devices, although each U.S. state has the ability to adopt its own standard if it has unique circumstances that justify a different standard. The first step in the process

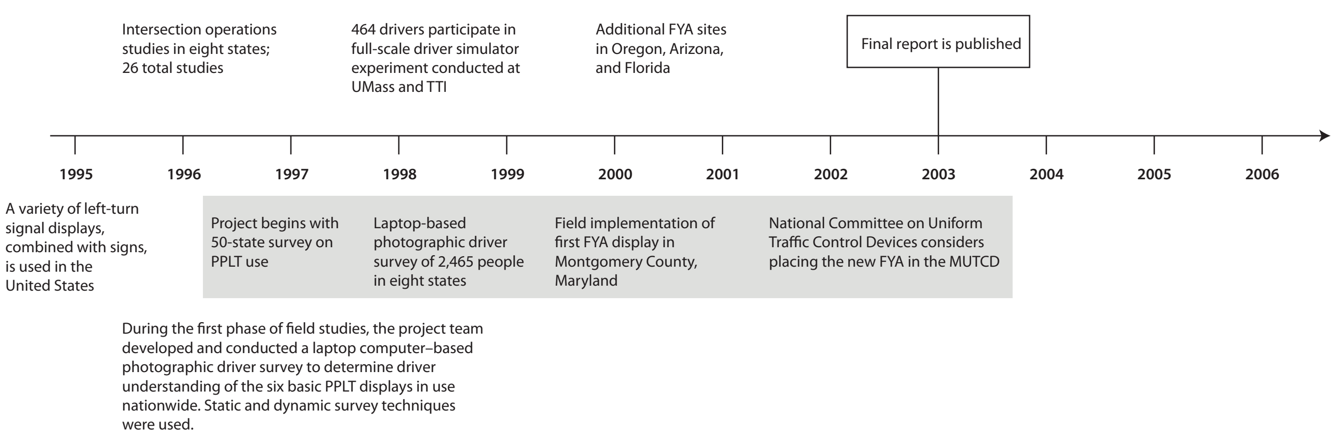


FIGURE 11 PPLT research timeline (UMass = University of Massachusetts; TTI = Texas Transportation Institute; FYA = flashing yellow arrow; MUTCD = *Manual on Uniform Traffic Control Devices*).

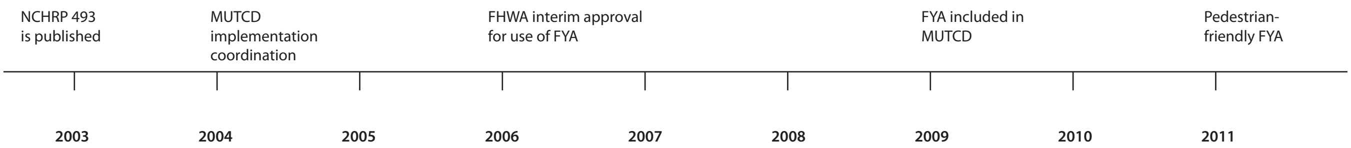


Figure 12 FYA implementation timeline.

for inclusion in the MUTCD often is being approved as an experimental device (the FYA achieved this status in 2004). Gaining interim approval is the next step (the FYA achieved this status in 2006) before achieving final approval as a standard in the MUTCD (the FYA achieved this status in 2009). After the FYA gained interim approval in 2006 and received continued positive feedback within the U.S. traffic engineering community, many more jurisdictions began implementing the device. Formal inclusion of the FYA in the MUTCD in 2009 further accelerated its application. By 2012, at least 31 of the 50 U.S. states had begun implementing FYA for PPLT treatments.

Barriers to Implementation

- Resistance to change and lack of market readiness. One of the greatest challenges to implementation has simply been overcoming the inertia of continuing to do things the way they have always been done. Traffic engineers have a tendency to be conservative and need a fair bit of motivation or convincing to try a new method. In the case of the FYA, they also needed to understand and appreciate how the risk associated with the innovation had been reduced through R&D activities and results.
- Technological barriers. For the experimental implementations, local agencies were provided a significant amount of assistance in developing signal controller logic to implement the FYA. This assistance bridged the gap between the initial research recommendation and the now-standard capabilities many controller manufacturers currently provide, but for which there initially was no market.
- Communication. A big part of the implementation was simply getting the word out to public agencies across the United States through FHWA programs, NCHRP briefs, conferences, and webinars, among other activities. Assistance was provided to agencies implementing the FYA across the country through public outreach programs and answering staff questions related to operational and safety aspects of the FYA.
- Institutional barriers. The new traffic control device could not be deployed in the field without prior FHWA–MUTCD approval. The entire FHWA approval process took approximately 6 years.

Lessons Learned

- Local connections. Local connections were a key to securing participation in the research. The initial FYA research implementation sites were often in locations with which the research team and research panel personnel were familiar. As an example, Oregon, which now has more than 500 FYA displays in use, is the home state of one of the lead researchers for the original NCHRP research project. The combination of long-standing, trust-based connections with industry practitioners and close-in location were key elements in convincing often skeptical agencies to implement the FYA.
- Federal leadership. The support and leadership of FHWA were essential to this implementation effort. While FHWA often plays an important leadership role in deploying innovation, in this case FHWA leadership was essential, given the need to gain approval for the FYA to be included in the MUTCD.
- Early adopters. The first implementers of the FYA quickly became some of its best advocates. Initial field success bred champions for the display, and they helped to spread the word through conferences and other industry venues.
- Seeing is believing. Traffic engineers and members of the law enforcement community were often the most skeptical of the FYA. In many cases, the general public and business community started requesting that the FYA be used in their locale after seeing it successfully used elsewhere. Instead of engineers installing new displays on their own initiative, public input sometimes compelled agency implementation.
- Clear explanation and management of risk. Engineers tend to be risk averse. Working with legal practitioners such as the TRB Standing Committee on Tort Liability and Risk Management can help ensure risk is managed and minimized.
- Communications. Disseminating practical lessons learned is a key. Agencies are more likely to implement the FYA if they have a good understanding of the pros and cons, of lessons learned from others, and of the technical issues and costs involved. It is the classic proverb: Tell me and I forget, show me and I remember, involve me and I understand.
- Continuing research. Continuing research helped demonstrate the success of the FYA. Following the publication of the original NCHRP research report, other

researchers at the national and state levels began to assess the operational and safety benefits of the FYA with before-and-after studies. The positive findings from these results helped keep the momentum moving forward for the FYA.

Modern Roundabouts

Although modern roundabouts are not a new concept in many European countries, their implementation in the United States has been a more recent success. This case study demonstrates how development of technical guides and tools can be a powerful accelerator for overcoming resistance to change.

Original Research Purpose and Need

Roundabouts are a form of intersection control in common use throughout the world today (Figure 13). Modern roundabouts are generally circular in shape, and their geometric features force traffic to slow down when passing through the intersection. Signs instruct motorists entering the roundabout to yield. The safety benefits of modern roundabouts are as follows:

- Fewer vehicular conflict points,
- Low absolute speeds,
- Low relative speeds, and
- Two-stage crossings for pedestrians.

The first operation of a modern roundabout occurred in the United Kingdom in 1966, when the rule that entering motorists yield was first adopted. Research in the United Kingdom showed improvements in capacity, reductions in delays, and safety benefits with the operation of these roundabouts as compared with other types of intersections.

FIGURE 13 Modern roundabout.

In the decades that followed, modern roundabouts were adopted and constructed in Europe and Australia (1970s and 1980s), but the first modern roundabout in the United States was not constructed until 1990. In the following years, roundabout construction in the United States began to rise slowly and was concentrated in states with roundabout advocates such as Maryland and Florida. However, many transportation professionals and agencies in the United States were still hesitant to recommend and install roundabouts because of a lack of objective nationwide guidelines on the planning, performance, and design of roundabouts. In 1997, FHWA commissioned the research that formed the basis of *Roundabouts: An Informational Guide* in 2000.

Research Process and Results

Although a few states published roundabout guides before 2000, the development of the FHWA roundabout guide was the first major research effort in the United States. The scope of the guide was to provide general information, planning techniques, evaluation procedures for assessing operational and safety performance, and design guidelines for roundabouts.

After the first edition of *Roundabouts: An Informational Guide* was published in 2000, additional research efforts continued. *NCHRP Report 572: Roundabouts in the United States*, published in 2007, included an inventory of existing roundabouts and data related to their safety, operations, and design; the development of safety prediction models; an operational analysis method for estimating delay and queue lengths; speed prediction tools; and a study of pedestrian and bicyclist behavior at roundabouts. NCHRP Report 572 also provided the basis for an update, *NCHRP 672: Roundabouts: An Informational Guide*, 2nd ed. Finally, in 2009–2010, guidance on roundabouts was incorporated into the MUTCD and the *Highway Capacity Manual* (HCM).

Roundabout research is ongoing, and the information and guidance available for practitioners continues to expand, including in the areas of freight movement, pedestrian and bicycle mobility, roundabout capacity models, and roundabout crash prediction models. Figure 14 provides a summary timeline of roundabout research in the United States.

Implementation Activities

After the publication of *NCHRP 572: Roundabouts: An Informational Guide* in 2000, states and local jurisdictions began to implement the research findings, publish state-specific guides, and adopt official policies

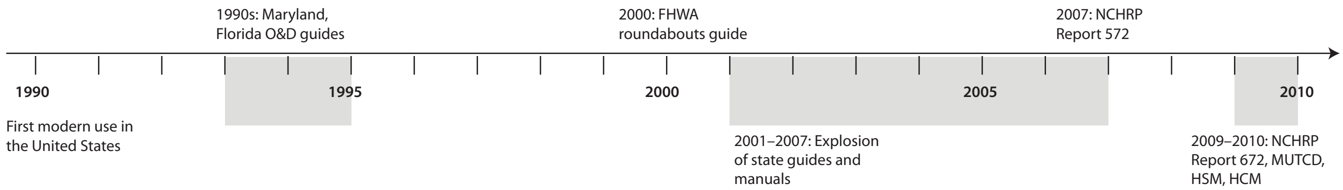


FIGURE 14 Timeline for roundabout research in the United States (O&D = origin and destination).

related to roundabouts. Figure 15 shows the rise in roundabouts in the United States.

Use of roundabouts did not grow uniformly across the United States; in 1992, only three states had roundabouts. By 1997, that number had grown by 14 states, with some states, such as Florida, Colorado, and Maryland, leading in the number of roundabouts implemented. After 2000, the number of roundabouts began to rise more quickly, as more states followed the guidance in *Roundabouts: An Informational Guide*. By the mid-2000s, only a small handful of states had not installed roundabouts, and today, all 50 states have them, although the number still varies substantially. These geographic differences in implementation are somewhat correlated with the different types of policies adopted by states and local jurisdictions. Eleven states have implemented statewide policies mandating analysis of the roundabout as an option when traffic control at an intersection is being considered, and these states have seen higher numbers of roundabouts per capita, per roadway mile, and per vehicle mile traveled than other states.

The adoption of roundabouts as a policy decision in the states has also affected the rate at which roundabouts are implemented; states with no official mention of roundabouts in their transportation policy have been the slowest to construct roundabouts. Figure 16 shows varying types of roundabout policies by state and compares the levels of roundabout implementation by state policy type.

Some states, such as Georgia, have offered educational courses in which researchers engaged state and local engineers in hands-on workshops to enable them to gain knowledge and confidence in the planning, design, and implementation of roundabouts.

In 2008, FHWA included roundabouts in its list of nine proven safety countermeasures, an action that further encouraged roundabout implementation across the United States. In 2013, roundabout design was included in FHWA's Every Day Counts initiative, which provides communications to high-level decision makers on the benefits of certain market-ready technologies and innovations and to practitioners regarding technical information.

Barriers to Implementation

• Lack of public support. In regions where roundabouts were unfamiliar to the public prior to their initial installation, public opinion has largely been negative. Research has shown that after the construction of a roundabout, public opinion generally shifts to a more positive view. However, lack of initial public

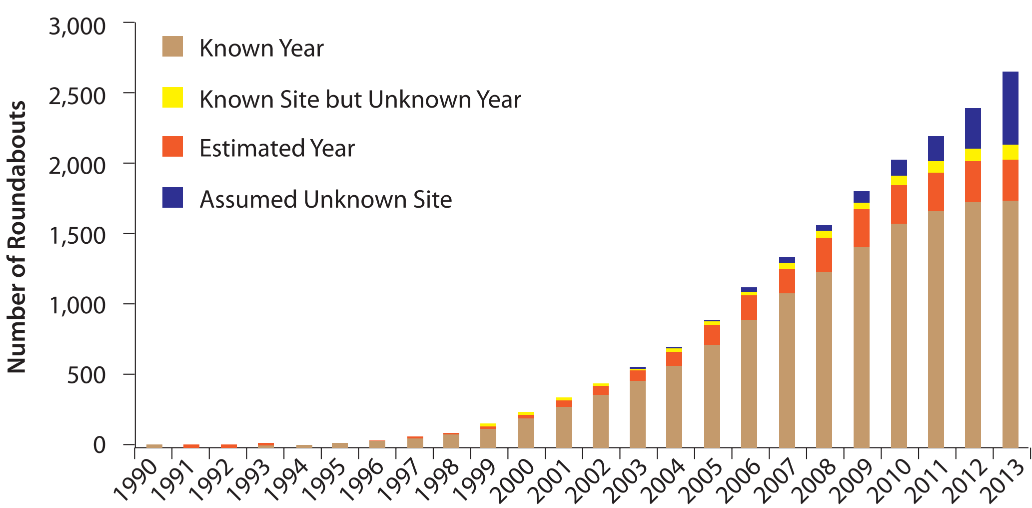
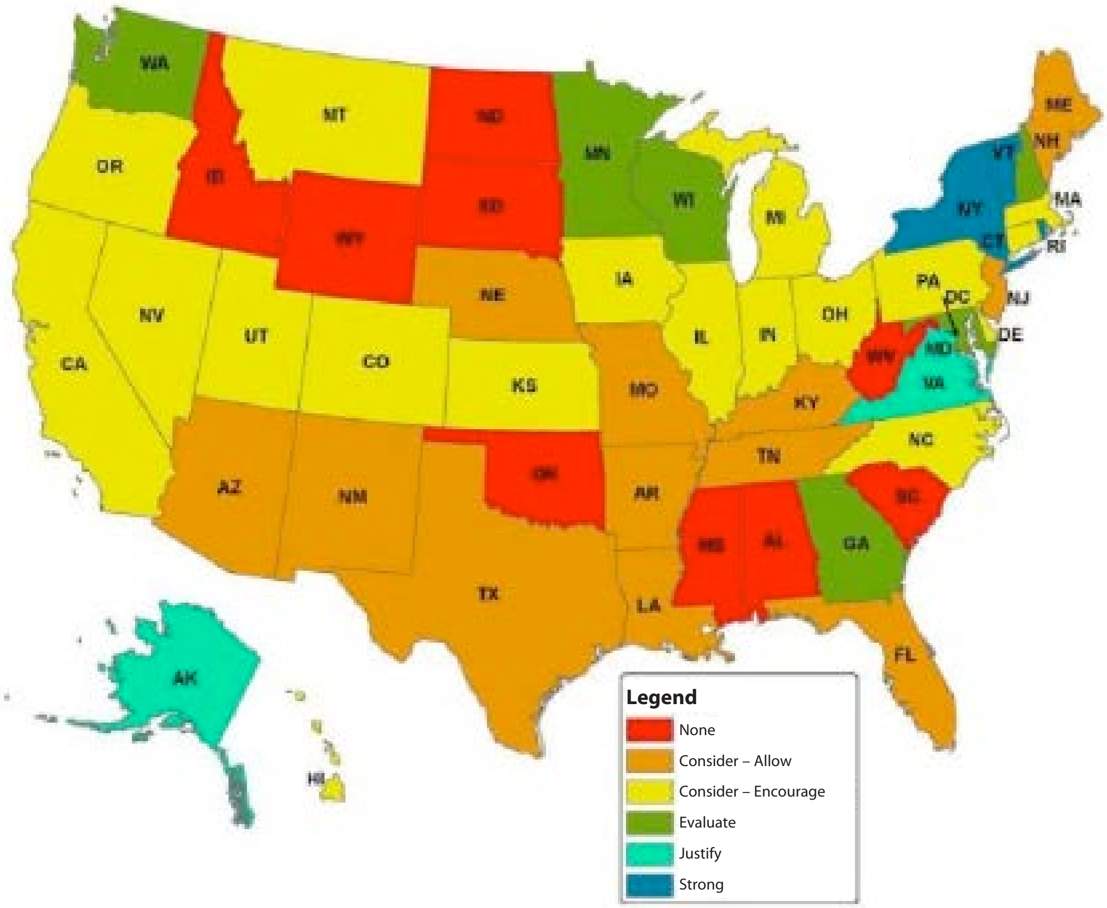


FIGURE 15 Total number of roundabouts in the United States.



Policy Type	Number of States	Number of Roundabouts	Roundabouts per Trillion VMT	Roundabouts per Million Roadway Miles[a]	Roundabouts per Million Persons
None	9	42	159.46	66.83	2.0
Consider—allow	12	280	313.62	241.25	3.2
Consider—encourage	19	1,207	979.34	812.64	9.0
Require analysis	11	747	1,277.22	1,035.01	11.6
Total	51	2,276	765.43	569.57	7.4

NOTE: VMT = vehicle miles traveled.
[a]Does not include Interstate miles.

FIGURE 16 Types of roundabout policies in the United States and comparison of the level of roundabout implementation by policy type.

understanding and experience in driving through the design has undoubtedly slowed the implementation of roundabout programs in parts of the United States. Communication and education have been key elements in improving public support.

- Governance. Implementation has also been affected by the difficulty some states have had in establishing a roundabout program within the existing organizational structure of the state's DOT. While some states have successfully implemented roundabout programs, others have lacked the internal resources and advocates to establish a roundabout program that can span internal divisions and allow for coordination and communication between agencies within their existing organizational structure, particularly with regard to design and safety.
- Risk aversion and desire to minimize liability. In some cases, state agencies and engineers were initially reluctant to implement roundabouts because of concerns about risk and liability, given that roundabouts were an unknown in the United States. Also, roundabouts were slow to be adopted into manuals—although the first edition of *Roundabouts: An Informational Guide* was published in 2000, roundabouts were not incorporated into the MUTCD and HCM until 2009 and 2010, respectively.

• Technical and safety concerns. In some states, freight industry organizations have raised concerns about affecting the movement of trucks through freight corridors. These concerns stem from perceptions that roundabout geometry will not accommodate trucks and that roundabouts would result in an overall capacity reduction and greater delays on truck routes. Additional research stemming from states, such as Minnesota and Wisconsin (*Joint Roundabout Truck Study*) and Kansas (*Accommodating Oversize/Overweight Vehicles at Roundabouts*), has provided guidance to states addressing these concerns.

• Concern regarding how to provide accessible pedestrian crossings for all pedestrians, including those who are blind or visually impaired. The Americans with Disabilities Act, comprehensive legislation unique to the United States, requires pedestrian facilities to be accessible to and usable by all pedestrians, including those who are blind or visually impaired. At double-lane roundabouts, these pedestrians are unable to safely assess gaps in vehicle flow, and a standard crosswalk is not accessible to them. NCHRP Project 3-78A investigated the effectiveness of different treatments at roundabout crossings, and the results of this research were published in *NCHRP Report 674: Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Vision Disabilities*. NCHRP Project 3-78B is developing related guidelines.

Lessons Learned

• Federal leadership. Leadership, technical support, and funding from the federal level were critical to allowing states to build roundabout programs in the United States. Initial interest in roundabouts came from early adopter states, but it was not until FHWA commissioned the research and publication of *Roundabouts: An Informational Guide* that all states had access to the guidance and technical knowledge needed to move programs forward. FHWA has continued to drive the roundabout program forward at the national level with the inclusion of roundabouts in its list of proven safety countermeasures and with its peer-to-peer program, outreach materials, support of ongoing research, and funding support of state programs.

• Advocates and champions. In the case of roundabouts, the majority of early adopter states, such as Washington State and Maryland, and local agencies had a strong roundabout champion that was willing to drive the process of installing a roundabout initially. This advocate can also guide the development of a roundabout program or policy that allows, encourages, or requires consideration of roundabouts.

• Governance and policy. Strong policy at the state level has definitely had an impact on the level of implementation. In states with stronger policies (those requiring consideration of a roundabout where feasible), roundabouts have been selected and installed more than in states with more flexible policies (those encouraging or allowing consideration of roundabouts) or no policy at all.

• Starting where there is a demonstrated need. Early adopter states and agencies have been successful in installing roundabouts and gaining public support at intersections with high historical crash rates relative to other locations.

• Sharing positive outcomes. Initially, *Roundabouts: An Informational Guide* provided evidence of the safety benefits of roundabouts. Ongoing research has continued to support the finding that roundabouts have lower levels of serious injury and fatal crashes. As more jurisdictions have experienced positive safety and traffic flow outcomes with roundabouts, the adoption of this form of intersection control has accelerated. Sharing these stories can have a snowball effect that simply feeds itself.

• Diverse stakeholders. The interest and active engagement of professionals in a variety of specializations enhanced the usefulness of the research. Because roundabouts appeal to practitioners in a variety of specializations, representatives from diverse perspectives and groups within transportation came together and learned from each other through the research process. Roundabouts provided a topic of convergence and have led to interdisciplinary work and innovative thinking.

Warm-Mix Asphalt Pavements

This case study is an excellent example of how international cooperation was the impetus for a major change in asphalt paving in the United States and how federal leadership has had a tremendous impact on both the development of the product and the acceleration of its implementation.

Original Research Purpose and Need

This case study focuses on the successful implementation of warm-mix asphalt (WMA) in asphalt pavements. WMA is a generic term for any asphalt technology that reduces the mixing and placement temperatures of asphalt mixtures for the construction of pavements. In general, WMA is produced at temperatures lower than those of typical hot-mix asphalt. WMA traces its origins to Europe in the late 1990s, and its original purpose was to respond to the need for reduced construction temperature and worker comfort in asphalt-related industries.

However, subsequent research and application of the technology soon demonstrated several other benefits. A survey conducted by the National Asphalt Pavement Association (NAPA) in 2012 revealed that every state in the United States has built at least one WMA project. The primary benefits identified in the NAPA survey are summarized in Figure 17.

Interest in the use of WMA grew at a very high rate in the United States, and the European experience indicated that with further research and development, WMA could provide many potential benefits for U.S. applications.

Research Process and Results

In 2004, the first WMA pavement was constructed in the United States. In 2005, FHWA and the industry formed a WMA Technical Working Group to further guide the implementation of WMA, collect data, conduct analysis, recommend research, and develop guidelines and specifications. The FHWA Mobil Asphalt Testing Trailer conducted the first of 14 testing and evaluation field projects in 2006. FHWA's Western Federal Lands Highway Division constructed its first WMA project in Yellowstone National Park in 2007. FHWA and AASHTO conducted a European scan of WMA technologies and their performance in 2007. The first of three editions of *Warm Mix Asphalt: Best Practices* was published in 2008.[4]

Despite the promise and potential benefits of WMA, concerns remained; as a result, several national studies needed to be conducted to address those concerns and to help better define the benefits of the technologies. One of the most common concerns was the lack of standard guidance for the mix design when WMA technologies were used. To address this concern, several national research projects were undertaken with the strong support of FHWA and equally strong participation of the member state DOTs of AASHTO. The states and FHWA were able to pool their funds to make this possible through NCHRP. These studies examined the following issues:

- Development of revisions to the Superpave® mix design process for WMA, including performance tests to assess the efficacy of WMA mix designs;
- Establishment of relationships between laboratory-measured engineering properties and the field performance of pavements constructed with WMA and HMA mixes;
- Comparison of the relative performance, costs, energy use, and emissions of WMA and conventional HMA pavements;
- Assessment of whether WMA technologies

[4] This publication is available at http://www.asphaltpavement.org/index.php?option=com_content&task=view&id=313&Itemid=1308.

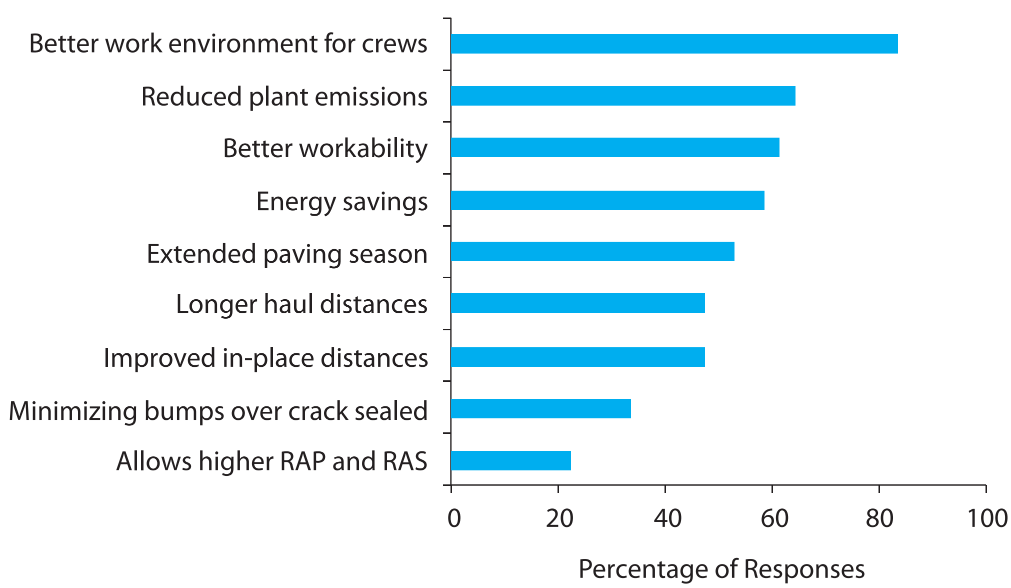


FIGURE 17 Industry responses on benefits of using WMA (RAP = recycled asphalt pavement; RAS = recycled asphalt shingles). (Source: Hansen, K. R., and A. Copeland. *Annual Asphalt Pavement Survey on Recycled Materials and Warm-Mix Asphalt Usage: 2009–2012*. IS-138. National Asphalt Pavement Association, Lanham, Md., 2013.)

adversely affect the moisture susceptibility of flexible pavements and development of guidelines for identifying and limiting moisture susceptibility in WMA pavements;

- Monitoring of the long-term field performance of selected WMA projects across the United States and evaluation of laboratory-measured mix properties to determine which characteristics can be related to field performance;
- Investigation of the key properties of foamed asphalt binders;
- Development of a procedure to simulate long-term aging of WMA and HMA asphalt; and
- Development of a design and evaluation procedure for the use of recycled asphalt shingles in WMA.

To address the need for more comprehensive guidance for the design of mixes that use WMA technologies, the Turner–Fairbank Highway Research Center recently constructed full-scale test sections that use varying levels of recycled materials (recycled asphalt pavement and recycled asphalt shingles) with alternative production technologies. These sections are being tested to failure to identify optimal pairing of WMA technology with the level of recycled materials while ensuring little or no impact on performance as compared with conventional pavement materials. Plans are to complete this testing by early 2016.

Implementation Activities

Beginning in 2010, FHWA's Every Day Counts initiative played an instrumental role in helping to spread the word about the benefits of WMA technology and research results. The fundamental purpose of Every Day Counts is to identify and deploy innovation and promising technology aimed at shortening project delivery, enhancing the safety of roadways, and protecting the environment. The program provides communications to high-level decision makers regarding the benefits of certain market-ready technologies and innovations and to practitioners regarding technical information. Every Day Counts offers extensive webinars to assist with outreach and information sharing, technical assistance (often on-site) to states and other agencies interested in the innovations, ongoing newsletters, and a limited amount of financial assistance for demonstration projects.[5]

The WMA Technology Working Group also played an important role in disseminating information to stakeholders and manufacturers. WMA was a focal point at national and international conferences related to asphalt technology.

In 2005, there were three documented technologies for WMA in the United States. By 2012, that number had increased to more than 30. NAPA surveys[6] showed that

- In 2009, WMA accounted for only 5% of all asphalt plant mix production;
- By 2010, WMA accounted for 11% of all asphalt plant mix production;
- By 2011, WMA had grown to 19% of all asphalt plant mix production;
- By 2012, with the inclusion of WMA in the Every Day Counts initiative, WMA accounted for approximately 24% of all asphalt plant mix production in the United States; and
- FHWA and its partners envisioned that WMA will constitute 75% of the market in the next 3 to 5 years.

The surveys also showed that WMA usage had grown among all segments of owners. Most new pavement technologies typically are implemented first by state agencies, but the state agency experience has led to growth in both local agencies and the private sector (i.e., real estate developers). In summary, it is clear that use of WMA is growing rapidly across all segments.

Many of the states have fully implemented WMA and allow contractors to use approved WMA technologies. However, the survey data also show that implementation of WMA is not uniform across U.S. market segments and that some state highway agencies still consider WMA an experimental technology. There is also a fairly wide disparity among the geographic regions.

The implementation of WMA can clearly be considered successful and is perhaps one of the most successful implementations of new technology in the United States in terms of how rapidly the technology has grown in such a short period of time. WMA should indeed be considered a model in many respects for rapid deployment of innovation. While research will continue to address issues of both cost and performance, it is clear that WMA technology offers many benefits from an engineering and environmental perspective.

Barriers to Implementation

- Resources. Cost is a factor. While the cost differential between WMA and high-temperature technology has decreased significantly overtime (particularly with the development of asphalt foaming systems), the initial cost of WMA is still higher than that of traditional methods.

[5] More information regarding Every Day Counts can be found at http://www.fhwa.dot.gov/everydaycounts/.

[6] Hansen, K. R., and A. Copeland. *Annual Asphalt Pavement Survey on Recycled Materials and Warm-Mix Asphalt Usage: 2009–2012.* IS-138. National Asphalt Pavement Association, Lanham, Md., 2013.

Government contracts are typically awarded to the lowest bid, which creates an inherent disadvantage for WMA.

- Governance. There is a general lack of guidance on specifications for WMA. In addition to the cost differential just noted, WMA is typically not specified as a requirement in bidding. This circumstance may very well change over time as benefits of WMA become increasingly known.
- Continuing development. There is currently a lack of long-term performance statistics for WMA. Many pavement engineers have had concerns about the long-term performance of the mixtures, especially with regard to susceptibility to rutting and moisture damage. However, significant progress is being made with continued research and development of WMA technologies. The Long-Term Pavement Performance (LTPP) program has initiated a new experiment that will collect and monitor data on the long-term performance of WMA pavements.

Lessons Learned

- Stakeholder involvement. Engaging the industry from the beginning has been, and remains, a key to success. In most states where WMA has been adopted into standard practice, the highway agencies were open to innovations through the use of permissive specifications and quickly accepted WMA technologies that have had successful demonstration projects.
- Federal leadership. FHWA's national leadership role was critical. WMA technology was a featured focus of the FHWA Every Day Counts initiative as well as the focus of the agency's WMA Technical Working Group and Mobile Asphalt Testing Trailer Program. FHWA's leadership is often an important factor in serving as a catalyst for state agencies to adopt new highway technology. In addition, the outreach program played an important role in simply educating and disseminating information.
- Development. The "D" in R&D is critical. WMA technology is another example that highlights the importance of further development and testing beyond the initial technology to address refinement of engineering properties and market concerns, including cost and performance factors.

Heavy Rail Acoustic Bearing Detector

Implementation of a new technology to a smaller community of users (e.g., the rail industry) does not necessarily make the implementation any easier. Finding support and funding for the development of the technology is critical, as is the importance of having a credible early adopter.

Original Research Purpose and Need

Preventing serious crashes on the nation's rail system is critical to protecting the lives of the public and those that work on the railroad but also has a tremendous impact on the economic viability of the industry. As in all safety issues, the greatest challenge is identifying the factors that could contribute to crashes and then taking actions to counteract those factors in a way that does not disrupt the flow of freight and passengers.

One of the factors that has been found to contribute to the potential for rail crashes is defects in the roller bearings of the wheels. From 1990 through 2005, the North American railroad system experienced an average of 40 to 60 reportable incidents per year related to bearing failure. The costs of reported derailments in 1998 exceeded $24 million. These unacceptable bearing-related derailments continued to occur despite thousands of thermal scanners placed every 10 to 20 miles along the mainline. A detection system based on earlier warnings of defects would have the advantage of allowing bearings to be removed from service proactively during routine maintenance.

Development and implementation of an improved system for wayside acoustic detection of roller bearing defects has been a railroad industry objective for at least 25 years. The work on this objective began in 1995 as an Association of American Railroads (AAR) Strategic Research Initiative with the initial step of obtaining acoustic signatures of roller bearing defects. The purpose of the research was to identify a nonintrusive approach for detecting internal bearing defects without stops in train service. The early warning would allow for removal of wheel sets before the bearings could overheat.

Research Process and Results

The research was very much a public–private partnership. The Transportation Technology Center, Inc., (TTCI) had been deeply involved in the research and development effort since 1994. The original collection of the acoustic signatures was obtained first in the laboratory and then on TTCI test tracks. The next step involved creating a developmental system for field testing and demonstration; that goal was achieved with the installation of the first functioning system on the Conrail railroad in Middlesex, New Jersey, in 1998.

After testing for some time, and with enough success to prove the feasibility of the concept, the research project was completed in 1999. Although the research work was made available to potential manufacturers, no company stepped forward to develop the system for revenue service. With no viable alternative, TTCI agreed to bring the acoustic detection concept to market.

By 2001, four production prototype acoustic bearing detection systems were operating: one in North America, two in South Africa, and one in Australia. The data these systems generated led to a production detection system for tapered roller bearings that was available for implementation on any heavy haul freight railway.

Implementation Activities

Early implementation proved somewhat challenging, but AAR has a robust system for communicating new technology through research briefs, publications, and conferences. Further, the international rail community is relatively small as compared with the highway community, which makes it easier to share and disseminate new technology and research results. However, as with others of these case studies, finding early adopters of the technology was critical to achieving widespread implementation.

The first North American acoustic detection systems were installed in 2002. The Trackside Acoustic Detection System (TADS) was originally designed to detect internal defects that met AAR standards for condemnable roller bearing defects. After some use of the system, however, it became apparent that larger defects representing higher risk needed to be correctly detected and characterized in order to prioritize bearing removals. This issue became one focus of further development of the detection algorithm, which was first installed in the field in 2005.

In North America 18 TADS are now in use, including three portable systems. It is estimated that approximately 75% of the Class I rail network is covered by acoustic bearing detectors. With the wider implementation of acoustic bearing detection systems and with improvements in the use of the existing thermal systems, reportable incidents related to bearings, which ranged from 40 to 60 per year between 1990 and 2005, have fallen to an average of 10 to 15 per year since 2010.

In December 2003, the first TADS was installed in China. After its initial evaluation of TADS, the Chinese Ministry of Railways made plans to install acoustic detection systems across its national rail network. Today approximately 80 TADS are in operation in China. Examples of TADS are shown in Figure 18.

Barriers to Implementation

- Resources. Funding for further development and refinement of the technology beyond the initial research project was needed. For this particular technology, there was a need to develop a product that could overcome several issues, including working in extreme weather conditions and limiting false positive detections.
- Lack of early adopters. There was a lack of railroad operators willing to deploy the early versions of the technology for testing and further development. Railroad operators needed to see success before implementation on a wider scale.

Lessons Learned

- Early adopters. Finding a willing test partner was again an important part of the success. In North America,

(a) (b)

FIGURE 18 Typical TADS installations: (*a*) North America and (*b*) China.

Conrail and BNSF Railway were early partners, and they saw potential for the technology. As discussed previously, the railroad community is fairly small, and word of the early results and sharing of results led to wider implementation.

- Development. Once again, the "D" in R&D was critical. With most new technology (particularly for new products), the initial research is often just the beginning (and often the least expensive). Further development and testing is required to make a product market ready. Fortunately, in this case, TTCI was willing to invest its financial resources to further develop the product and bring it to market. Without that investment, the results of this research easily could never have been implemented.
- Resources. This case study can clearly be considered a successful implementation, but it was one that required patience, perseverance, and financial resources to bring the product to market. One of the more important lessons learned is perhaps the need to devote money in research programs to further development of promising technology to get it closer to being market ready and to help overcome some of the inherent risk and uncertainty of product development.

Bus Rapid Transit

This case study is centered on a fairly mature practice, bus rapid transit (BRT), that had already been implemented in several other countries. Although BRT was in practice elsewhere, research was still needed to refine the concept to meet needs of the U.S. market and to address that market's unique concerns. Once this goal was achieved, BRT became widely accepted.

Original Research Purpose and Need

Like modern roundabouts, BRT had been used successfully in many places outside the United States, but research was required to determine how to best support its implementation inside the United States. The timeline for BRT development in the United States (Figure 19) can generally be divided into three phases:

1. **Phase 1. Pioneering implementations.** Between 1977 and 2002, BRT service was initiated in 14 North American cities; in eight of these cities, the service was initiated even before the earliest U.S. BRT guidelines had been developed. However, it became clear that information needed to be shared between those who had implemented BRT and those who were considering such systems. In 2003, the Transit Cooperative Research Program (TCRP) published *TCRP Report 90: Bus Rapid Transit* in two volumes. *Volume 1: Case Studies in Bus Rapid Transit* studied international BRT systems and several of the pioneering U.S. systems. *Volume 2: Implementation Guidelines* provided broad implementation guidelines based on international and domestic experience. A year later, the Federal Transit Administration (FTA) published *Characteristics of Bus Rapid Transit for Decision-Making*, which provided information about characteristics of the first wave of BRT in the United States, discussed the benefits of BRT, and offered implementation guidelines.
2. **Phase 2. Early lessons learned and guidelines.** By around 2003, BRT was moving from a pioneering phase to one that was built on the experience and les-

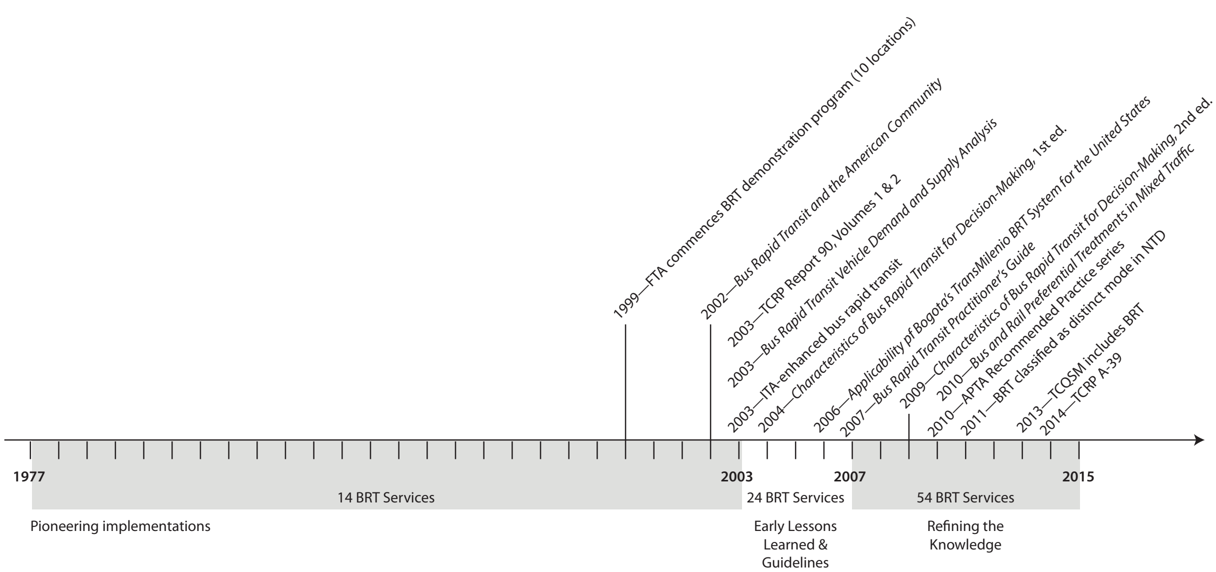


FIGURE 19 Timeline of North American BRT development (ITS = intelligent transportation systems; NTD = National Transit Database; TCQSM = *Transit Capacity and Quality of Service Manual;* TCRP A-39 = Improving Transportation Network Efficiency Through Implementation of Transit-Supportive Roadway Strategies).

sons learned by the early adopters. As guidelines were developed that incorporated those lessons and experiences, BRT made the transition from an experimental application to an accepted (and highly regarded) solution to multiple urban transportation issues. By 2005, 24 new BRT systems were being implemented in 11 North American cities. Several of these services were expansions of existing BRT systems. As an example, in Los Angeles, the success of Metro Rapid (BRT in mixed traffic operation) led to the development of the Orange Line (BRT in busway operation).

3. **Phase 3. Refining the knowledge.** In more recent years, implementation efforts have focused on developing and sharing information on particular issues that affect BRT installations. In many ways, this activity could be considered development, as it recognizes that BRT is an evolving concept that needs to continue to mature, even this far into deployment. By 2007, North American experience with BRT and growing interest from communities led to research that explored specific emerging issues and concerns and offered U.S. transit agencies stronger guidance for BRT implementation. Research conducted during this period including studies focused on

- At-grade crossings of busways,
- The costs and impacts of specific BRT components,
- Development of a method for forecasting BRT ridership,
- Recommended practice for BRT running ways and stations and other BRT service components, and
- Approaches to implementing transit preferential treatments in conjunction with BRT and other types of bus services.

Between 2007 and 2013, 54 new BRT services were implemented in North America. As in the previous wave of implementations, several were expansions of existing BRT networks. Some of the new services included more high-end features than the original services in the same community (e.g., in the York Region of Ontario, Canada, and in Las Vegas, Nevada). Two more BRT services were implemented in the United States in January 2014. This means that, as of January 2014, at least 94 BRT services had begun operations in North America. Implementations by year through 2013 are depicted in Figure 20. At least 70, and possibly up to 90, new BRT services are currently proposed or under development in North America.

One indicator of the extent to which BRT has become a state of the practice modality is treatment of BRT as a distinct mode in the National Transit Database (NTD) as of 2011 and in the *Transit Capacity and Quality of Service Manual* (TCQSM) as of 2013. These changes to the NTD and the TCQSM are promising developments for the future availability of BRT data and analysis tools.

Barriers to Implementation

- Product definition. The development of BRT in the United States has faced several challenges. A fundamental challenge has been defining what is and what is not BRT. This definition is an ongoing impediment for practitioners who are trying to describe BRT to stakeholders, decide between alternative transit modes and services, and make effective decisions for transportation investment. FTA says

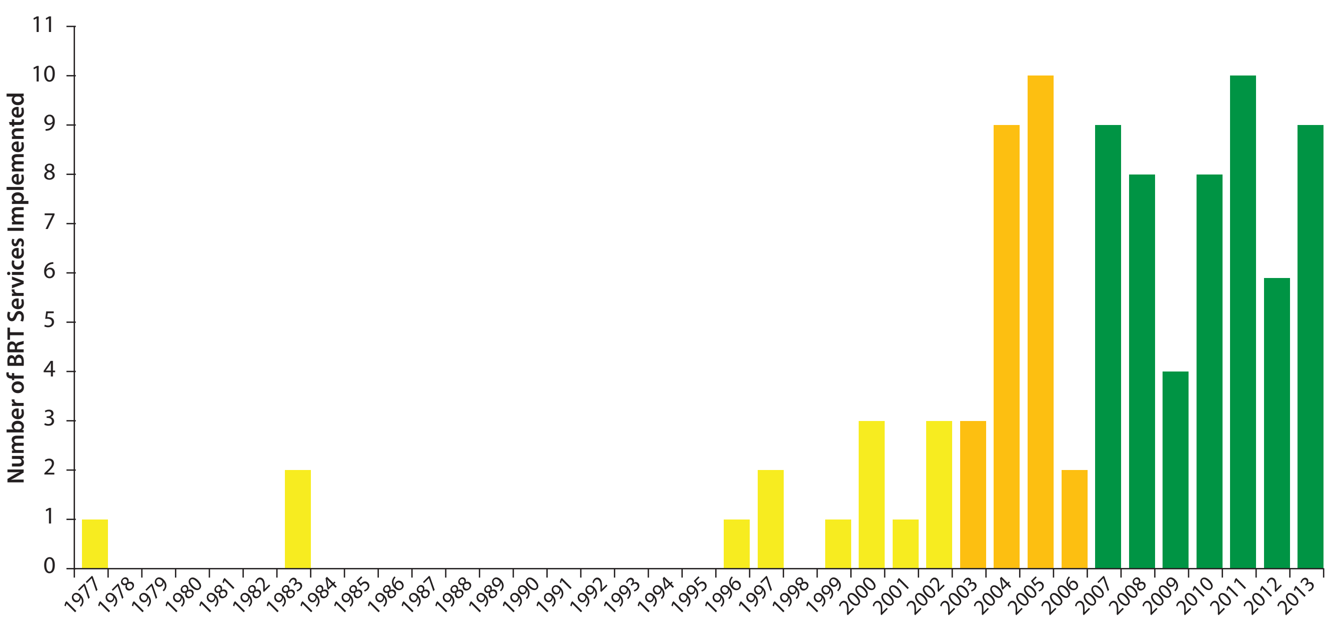


FIGURE 20 North American BRT services implemented, by year.

that BRT is "a rapid mode of transportation that can provide the quality of rail transit and the flexibility of buses." TCRP Report 90 says that BRT is "a flexible, rubber-tired form of rapid transit that combines stations, vehicles, services, running ways, and ITS [intelligent transportation systems] elements into an integrated system with a strong identity." BRT has been implemented as the bus equivalent of streetcar or light rail transit service, but BRT has also been implemented as a branded express bus service.

- Product flexibility. Although the flexibility with which BRT can be designed, implemented, and operated is one of its strongest advantages, this flexibility is also one of its greatest challenges. Given that BRT systems can include an extensively varying combination of features (e.g., different types of vehicles, running ways, stations, and service plans), it is all the more imperative that planners carefully consider options for each feature of the service, how those features will be packaged, and how they will be phased into implementation. There is no simple, one-size-fits-all approach to implementing BRT; what works in Cleveland may not work in Los Angeles. Fortunately, as more cities implement BRT and variations thereof, there is an increasingly larger body of knowledge and experience for researchers to study and for agencies to benefit from. Looking at other agencies' experiences with BRT should be part of any analysis of alternatives that considers BRT. Finally, while BRT can provide similar service at a lower cost than light rail transit and streetcar service, recent studies do show that BRT can still be an expensive capital project.
- Communication of purpose. A related challenge is that rail modes are typically seen as better and more desirable than bus modes and that BRT might be perceived as just another bus service. Accordingly, it is important to consider how well informed stakeholders are with respect to BRT and BRT features. These stakeholders include the public, landowners, and developers as well as public agencies and local governments with an interest in the project. Some stakeholders, such as developers, may initially see BRT as just another bus service and not realize that BRT has been shown to have positive impacts on land development when it is appropriately designed (e.g., Boston, Massachusetts; Pittsburgh, Pennsylvania; and Ottawa, Canada). The specific features of the BRT service will have an influence on whether or not developers will continue to see it as just another bus service.

Lessons Learned

- Evolution. The development of BRT in North America has been cyclical. Initial implementations provide a body of experience that can be analyzed and can serve as the basis of planning, operations, and design guidelines. Continued implementation supports more robust analysis and the development of more robust guidelines. This cycle is anticipated to continue, given the number of BRT services proposed for future implementation.
- Supporting data. Successful BRT implementations lead to (*a*) expanded BRT systems, (*b*) higher-level BRT services, and (*c*) increased interest in BRT within communities that have not implemented it. In addition, BRT has been implemented in communities of varying size, from Aspen, Colorado, to New York, New York. These facts demonstrate one of BRT's strengths: its flexibility with respect to features and configurations. Continued implementation of BRT services tailored to the needs of individual communities and individual corridors means that data will become available for more features and more configurations. Such new data will support future BRT research efforts.
- Educating officials. The public and elected officials must be educated as to what BRT is, what it can be, and what benefits it can provide. For example, BRT can be implemented incrementally or in a single phase. Incremental implementation can be used as a means of seeing investments pay off sooner, but because BRT as a complete service will not make as big a splash in the minds of riders and nonriders, the strength of its identity and branding may be diluted. In this regard, case studies can demonstrate that BRT can be successful.
- Early adopters. A successful first implementation of BRT in a community leads to support for additional implementations in the community. The first project should be chosen carefully.

Lessons Learned from the Case Studies

This section illustrates the lessons learned from the case studies about the implementation of transportation research. In the fairly broad cross section of cases that have been examined, it is apparent that there are many common lessons that provide instruction about what works and what challenges to plan for. These are neither success factors nor barriers, but rather are topic areas in which there is a fairly rich range of experiences that can be used to improve the practice of research implementation.

When the different phases in the research value chain are considered, the main lesson is probably that there is a considerable gap between research and implementation. Many of the case studies show excellent research results, successful pilots or tests, and extensive reporting of results, including recommendations for follow-up. However, the implementation often stops at conducting a demonstration project, delivering a final report, or holding a conference, even with research projects that pay extensive attention to the follow-up of their findings. Market uptake is very slow and often cannot directly be related to the preceding research. The good news, however, is that market uptake does seem to take place eventually, although in a different shape than the outcome of the research would have it. In European programs, especially, the specific technical, legal, financial, political, national, or even local conditions tend to determine the rate and form of the uptake.

Although each case was selected to highlight a particular aspect of the implementation process, as a group the case studies present several reoccurring themes that apply to both the U.S. and EU programs:

1. Stakeholder involvement,
2. Resources for implementation,
3. Development,
4. Early adopters and champions,
5. Overcoming institutional barriers,
6. Government leadership,
7. Communication, and
8. Market readiness.

It is always difficult to make generalizations about such broad issues; however, the hope is that focusing on a finite set of themes may enable the group to more easily and effectively discuss these points and provide a framework for future actions. Although there are clearly issues where there is some overlap, each of these areas does attempt to bring forward one major theme emerging from the case studies.

Stakeholder Involvement

Perhaps the most common factor noted in the case studies as a criterion for successful implementation efforts is early and continuous stakeholder involvement. The stakeholders for each project clearly were different, but they generally included representation of those who had experienced the problem to be addressed and therefore would be the end users of the research. They also included those who would be responsible for moving the research products into and through implementation. When such stakeholders are involved in the definition of the research and remain involved in ensuring that the research does produce a solution that meets their needs, implementation tends to move far faster and more smoothly. Some examples of such stakeholders in the case studies include the following:

- *Highway Safety Manual*. A broad range of academics and practitioners not only were involved in setting the research agenda but are continuing to stay engaged in its implementation.
- Modern Roundabouts. Engaging a diverse group of stakeholders early in the process led to broader support and acceptance for the outcomes.
- INNOTRACK. Participants representing all stakeholders were already involved in defining the problem, but the group was small enough to be able to work efficiently.
- Climate Change. The national road authorities were part of the project.

Resources for Implementation

Even in cases in which there had been a substantial investment in research, the funds programmed or available for implementation activities were often very limited. Part of this appears to be a result of the manner in which funds were allocated to different programs and sponsors and a lack of clarity regarding who was responsible for the implementation costs (e.g., the end user, the research sponsor). However, some of the cases also showed that even a small amount of funding can be a very strong incentive for implementation. Such funding helps to underwrite the risk, whether real or perceived, in using the new technology and often demonstrates an official endorsement of the products and practices. Staffing resources are equally important, particularly in ensuring that there is continuity throughout the process. Examples include the following:

- Warm-Mix Asphalt Pavements. Through the federal contributions from the FHWA Every Day Counts program, implementation of this practice has reached every state faster than nearly any other technology.
- SAMARIS. The absence of resources for implementation in former East European countries was one of the main factors in why research outcomes were not implemented.
- Silent and Durable Road Expansion Joints. The resources for implementation were ensured through regular road construction and maintenance budgets.

Development

Several of the cases point to the challenges in trying to deploy research products that had not been fully developed or field tested. In addition to ensuring that the technology is, in fact, ready for user applications, the development phase can also be the time in which additional data and evidence can be collected to substantiate the value and need for the product. There were also cases that illustrated the success of building public–private partnerships during this time; these partnerships ensured that the research products would be commercially available for implementation. Examples include the following:

- Heavy Rail Acoustic Bearing Detector. Although the concept for this kind of detection approach existed, it was not until TTCI stepped forward to develop and field test a prototype that interest really accelerated.
- River Information Services. The role of PIANC in bringing together experts in a neutral platform helped to develop the sense of urgency and applicable solutions.

Early Adopters and Champions

Successful cases often highlighted the importance of having a champion that was an advocate for the innovation from research through implementation, a period that in some cases spanned more than a decade. Champions that represent the end user community were particularly effective and often recruited early adopters of the technology or served as one of them. Their involvement was critical because it provided a credible peer-to-peer basis for sharing knowledge with other end users. Examples include the following:

- Bus Rapid Transit. The early adopters of this approach in the United States provided a hands-on opportunity for other cities to see what BRT really offered as well as a basis for refining the concept as more was learned from actual applications.
- Climate Change. With their specific climate conditions, some northern European countries were clearly front runners in developing and implementing solutions. Interest was low in countries where these conditions did not prevail.

Overcoming Institutional Barriers

Many of the cases illustrate the multiple approvals and institutional actions that are often required to move a product from research into practice. These actions include everything from changes in standards or specifications, approvals of governing bodies or councils, and the resolution of intellectual property issues. In particular, procurement rules and regulations can prove to be a major obstacle to quickly advancing implementation efforts. Some of the cases illustrate the value of planning for such barriers and ensuring that the key stakeholders that control those processes are included in the research from the beginning. Further, it is apparent that some organizations have made a concerted effort to streamline these institutional processes to accelerate the implementation process.

- Asset Management in the Netherlands. Involvement of the management of the implementing organization was essential to overcome institutional barriers and to adapt administrative procedures.
- INNOTRACK. The relatively slow implementation of many research results in spite of widespread support was due to lack of incentives (e.g., procurement incentives) for market parties.

Governmental Leadership

Although the governmental structures of the United States and the European Union and its member nations differ greatly, several of the cases illustrate how leadership at that level can be a powerful catalyst and engine for change. As noted before, the government is often the source of funding for both research and implementation activities, and governmental leadership at the federal level or through the European Commission can also help overcome institutional barriers. Ultimately, government leadership can also seek to use regulatory and standard-setting authorities to accelerate implementation of a product from state of the art to state of the practice. This kind of governmental support appears to be more prevalent when the subject of the research reflects a clearly felt societal issue, such as safety or congestion. Larger research programs that address broad technical issues may not attract the same support or sense of urgency for implementation by the public or politicians. An example of governmental leadership is ALJOIN, in which the translation of research results into new standards for the construction of rail vehicles was key to Europe-wide implementation.

Communication

Effective technology transfer is based largely on the sharing of knowledge, and consistent internal and external communication is a key to making that happen. Beginning in the research phase, communication can build a pull for research results as well as establish realistic expectations about what may be coming from the research. There are a number of excellent examples in the case studies showing how continuous communication helped educate potential end users, inform decision makers, and, where appropriate, gain public support. The specifics of how the message is communicated are equally important. For example, in the European context, language can be an issue. Although those conducting the research are usually fairly proficient with English as a working language, the decision makers responsible for implementation may not be. Examples of the importance of communication are as follows:

- SAMARIS and ARCHES. The SAMARIS and ARCHES case studies show that translation of the results into the local language of the responsible implementing agency is essential, though not enough.

- INNOTRACK. Communication was an essential condition for the financing of this program, as for many EU-funded programs. Many deliverables were directed at transfer of knowledge.

Market Readiness

In the analogy of planting seeds, seeds are more likely to sprout when the soil they are scattered on has already been tilled. Likewise, when the market is well informed and prepared, new ideas are likely to find an easier place to grow and mature. Many of the cases indicated that such efforts could greatly accelerate the implementation process and provide highway users with benefits faster. One question that surfaced was how to change today's college curricula to ensure that the next generation of transportation professionals will also be prepared to use these new technologies and practices? The approach in the Silent and Durable Road Expansion Joints program showed how innovation-driven research was directed at solving a very practical problem on short notice. The market took up that challenge.

Comparison with Lessons Learned from Other Projects

The lessons learned from the case studies in this paper were compared with lessons learned from the ERRAC WP06 evaluation project. This comparison showed that the findings from ERRAC projects that proved to have a strong market uptake were consistent with the findings in this paper, as shown in extracts from a presentation for ERRAC members. Below are key extracts from the ERRAC WP06 PowerPoint presentation regarding the market readiness evaluation from 2012:

- The projects were aimed at solving issues of general acknowledged interest (e.g., technical, safety, harmonization, and business cases).
- The projects had strong interaction between partners and relevant stakeholders.
- The projects had a clearly defined scope and objectives from the beginning.
- Project results were applied and implemented for products or for regulatory application and were made available for future revision.
- The project had the capability of building on results of previous projects (systematic view).
- The project pilot cases or business cases were developed to provide viable solutions and not just as an exercise.

The lessons learned in the Strategic Highway Research Program (SHRP) regarding research implementation also share many common themes with the U.S. experience highlighted in the case studies presented in this paper. Following is a summary of key lessons learned in SHRP presented by Neil Pedersen, a SHRP 2 deputy director, at the 2013 TRB annual meeting:

- A research program should be established by leaders of the organizations who will implement the results.
- Oversight should be provided by end users throughout the research and development phase.
- Additional development work will often be needed to convert research results into usable products.
- Planning for implementation needs to begin even before the research phase starts and should continue throughout the research phase.
- Research results that necessitate a business process or organizational change require a different approach than deployment of new technology.
- Pilot testing of research products is critical for identifying refinements and for demonstrating benefits and value.
- The evaluation phase is a critical part of implementation planning and should be done early in the research phase.
- Personal communication with and education of potential users is critical to successful implementation.
- Communications materials about research products need to be meaningful for the target audience, namely, the user community.
- Users react very differently if they think a product is being pushed on them than they do if they themselves reach the conclusion that the product will be useful in meeting a need they have.
- Potential users want to know technical assistance is available.
- It is important to listen to feedback from potential users.
- Not all research results will be of equal value or importance to users.
- Leadership is key to successful implementation of research results.
- A research program should be prepared to answer the question, How will this research make a difference in addressing priority needs and goals of the agency and the transportation system?

Acknowledgments

EU Case Studies

Author Joris Al thanks his many Dutch and international colleagues for helping find cases and the necessary documentation and for giving their time for interviews and in reviewing drafts of this paper. The illustrations in this paper are all taken from public reports.

The following people were interviewed for the EU case studies:

• Asset Management: Bert de Wit, Senior Project Manager, Project Asset Management, and Jenne van der Velde, Senior Research Advisor on Asset Management, Rijkswaterstaat, the Netherlands.
• ALJOIN: Dan Otteborn, who suggested this case and provided very relevant material.
• INNOTRACK: Rolf Dollevoet, Professor of Rail Construction, Delft University of Technology, and System Expert, Prorail.
• River Information Services: Cas Willems, Senior Advisor on Navigation, and Yvo Ten Broeke, Senior Advisor on Navigation and Rhine Commissioner, Rijkswaterstaat.
• SAMARIS, ARCHES, CERTAIN: Tomas Wierzbicki, Road and Bridge Research Institute, Poland; and Ales Znidaric and Aljosa Sanja, National Building and Civil Engineering Institute ZAG, Slovenia.
• Silent and Durable Expansion Joints: Willem Jan van Vliet, Senior Advisor Noise Policy, and Bert Elbersen, Senior Advisor Innovation, Rijkswaterstaat.
• Climate Change: Kees van Muiswinkel, Senior Researcher, Rijkswaterstaat; Gordana Petkovic, Norwegian Public Roads Administration; and colleagues at CEDR who provided the latest information on implementation, notably in Germany, Ireland, and Norway.

U.S. Case Studies

Author Mark Vandehey thanks the following individuals from Kittelson & Associates, Inc., for their invaluable contributions to the overall content of this paper: Joe Toole, for his time, energy, and thoughtful editorial efforts and his help in organizing a great series of interviews in Washington, D.C.; Karla Kingsley, for her work in developing the Roundabout case study, help coordinating the graphics and reference list, and general support in other areas; and Ralph Bentley for excellent graphics work and document formatting. He also thanks the following individuals who provided extremely valuable input on the topic of research implementation in the United States and, in particular, the roles of FHWA, AASHTO, and TRB:

• From AASHTO: King Gee, Director of Engineering and Technical Services;
• From FHWA: Gregory G. Nadeau, Acting Administrator; Michael Trentacoste, Associate Administrator for Research, Development, and Technology and Director, Turner–Fairbank Highway Research Center; Debra Elston, Director, Program Management; Hari Kalla, Director, Center for Accelerating Innovation; and Jack Jernigan, Director, Research and Technology Program Development and Partnership Team; and
• From TRB: Christopher Hedges, Manager, National Cooperative Highway Research Program; and Neil Pedersen, Deputy Director, Implementation and Communications.

Finally, the author sincerely thanks the following individuals for their valuable contributions to the development of the case studies:

• *Highway Safety Manual*: Erin Ferguson of Kittelson & Associates, Inc.
• Flashing Yellow Arrow Left-Turn Display: Michael Trentacoste and others at FHWA.
• Modern Roundabouts: Randy C. West, Director, National Center for Asphalt Technology, Auburn University, Alabama, who provided much of the background material and research developed in this case study; Karla Kingsley and Lee Rodegerdts of Kittelson & Associates, Inc.; and Michael Trentacoste and others at FHWA.
• Warm-Mix Asphalt Pavements: Randy C. West, Director, National Center for Asphalt Technology, Auburn University, Alabama, who provided much of the background material and research developed in this case study; and Michael Trentacoste, Hari Kalla, and Jack Jernigan of FHWA.
• Heavy Rail Acoustic Bearing Detector: Gerald Anderson, Senior Principal Investigator, Transportation Technology Center, Pueblo, Colorado, for providing the background material, technical content, and research developed in this case study and for excellent comments on the draft of the case study; and Bill Millar for help in identifying the case study and making the initial contact with Gerald.
• Bus Rapid Transit: Kelly Blume of Kittelson & Associates, Inc.

Resources

Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
CEDR	Conference of European Directors of Roads
ERA-NET ROAD	Coordination and Implementation of Road Research in Europe
ERRAC	European Rail Research Advisory Council
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
TRB	Transportation Research Board

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Bus Rapid Transit

NOTE: The lists of bus rapid transit (BRT) services and research documents used in this case study are not comprehensive. With regard to the former, it is possible that there are proposed services that have not yet been identified; with regard to the latter, the documents are key documents and illustrative documents. An initial list of BRT projects (updated May 2012) was obtained from the National Bus Rapid Transit Institute, http://www.nbrti.org. The following sources provide information about specific BRT services:

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APPENDIX C

Final Program

TRANSPORT RESEARCH IMPLEMENTATION: APPLICATION OF RESEARCH OUTCOMES

EU-U.S. Transportation Research Symposium 2

Organized by
European Commission
Office of the Assistant Secretary for Research and Technology, U.S. Department of Transportation
Transportation Research Board

April 10–11, 2014
Ministère de l'Écologie, du Développement Durable et de l'Énergie (MEDDE)
Parvis de la Défense
Paris, France

THURSDAY, APRIL 10, 2014

9:00 a.m. **Welcome and Introductory Remarks**
Jean-Bernard Kovarik, French Ministry of Ecology, Sustainable Development and Energy
Alessandro Damiani, Directorate-General for Research and Innovation, European Commission
Kevin Womack, Office of the Assistant Secretary for Research and Technology, U.S. Department of Transportation
Robert E. Skinner, Jr., Transportation Research Board

9:10 a.m. **Session 1: Setting the Scene**
Jesús Rodríguez and John Mason, *Cochairs*

Transportation Research Implementation in the European Union and the United States: Observations and Working Hypotheses
John F. Munro, University of Maryland
Ángel Aparicio, Universidad Politécnica de Madrid

Lessons Learned from Case Studies of Successful Research Implementation in Europe and the United States
Joris Al, Forum of European National Highway Research Laboratories (FEHRL) (past president)
Mark Vandehey, Kittelson and Associates

Keynote Speech
Transport Research Implementation: What Society Really Needs
Terry Hill, Arup Group Trusts and International Organization for Standardization

Discussion

10:30 a.m. Morning Break

11:00 a.m. Breakout Session 1: Stakeholder Perspectives on Implementation
Alessandro Damiani, Directorate-General for Research and Innovation, European Commission
Francesca La Torre, University of Florence
Harold (Skip) Paul, Louisiana Department of Transportation and Development

12:30 p.m. Lunch

2:00 p.m. Session 2: Institutional Incentives and Disincentives to Successful Implementation
Astrid Linder and John Mason, *Cochairs*

Institutional Program Experiences Addressing Research Implementation
Ann Brach, Second Strategic Highway Research Program, Transportation Research Board

Building Research Programs for Deployment: Road Authorities Working Together
Steve Phillips, Conference of European Directors of Roads (CEDR)

Discussant 1: Michael Trentacoste, Turner–Fairbank Highway Research Center

Discussant 2: Liam Breslin, Surface Transport Unit, European Commission

Full Group Discussion

3:30 p.m. Afternoon Break

4:00 p.m. Session 3: Framing and Conducting Research to Ensure Implementation
Francesca La Torre and Anne Ellis, *Cochairs*

Policy, Data, and Research: Getting Value from International Collaboration in Research and Policy Analysis
José Viegas, International Transport Forum, Organisation for Economic Co-operation and Development

Transportation Research Board's Cooperative Research Programs: Considering Implementation from the Start
Stephen Andrle, Second Strategic Highway Research Program, Transportation Research Board

Designing Road Safety Research Aimed at Increasing Implementation Possibilities and Assuring Actual Safety Improvements
Horst Schulze, German Federal Highway Research Institute (BASt)

Discussion

6:00 p.m. Welcome Reception

Friday, April 11, 2014

8:30 a.m. Session 4: Using Research Results in Effective Ways
Jesús Rodríguez and Raj Rajkumar, *Cochairs*

Implementation of R&D Results in Railway Infrastructure
Luis Fernando López Ruiz, Administrator of Railway Infrastructures (ADIF)

Implementation of R&D Results in Operating Roads and Motorways
Allen Biehler, Carnegie Mellon University

User–Procurer's Approach to the Vehicle–Infrastructure Interaction
Chris Martin, Robert Bosch Corporate Research

Implementation of R&D Results in a Multimodal Urban Environment, Including Public Transport
Natalia de Estevan-Ubeda, Transport for London

Discussion

10:30 a.m. Morning Break

11:00 a.m. Breakout Session 2: Identifying the Success Factors

12:30 p.m. Lunch

2:00 p.m. Session 5: From Principles to Practice
Marit Brandtsegg and William Millar, *Cochairs*

Final Discussion

Concluding Keynote Address
Kirk Steudle, Michigan Department of Transportation and Chair, Transportation Research Board Executive Committee

Final Remarks by the Organizers

APPENDIX D

Symposium Attendees

Joris Al
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Self-employed
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Marit Brandtsegg
Norwegian Public Road Administration
Oslo, Norway

Liam Breslin
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Paris, France

Philippe Citroën
Association of the European Rail Industry
(UNIFE)
Brussels, Belgium

Alessandro Damiani
European Commission
Brussels, Belgium

Natalia de Estevan-Ubeda
Road Space Management Directorate
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London, United Kingdom

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Boulogne-Billancourt, France

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Genoa, Italy

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University of Minnesota
Ann Arbor, Michigan, USA

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European Investment Bank
Luxembourg

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Phoenix, Arizona, USA

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Vinci Autoroutes
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Terry Hill
Arup Group Trusts
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and
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Geneva, Switzerland

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American Association of State Highway and Transportation Officials (AASHTO)
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South Salt Lake, Utah, USA

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Transportation Research Board
Washington, D.C., USA

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Forum for Innovation in the Transport Sector
Sweden

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European Commission
Brussels, Belgium

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ISBN 978-0-309-29559-8
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