TR NEWS

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ENVIRONMENTAL SUSTAINABILITY IN TRANSPORTATION

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COVER: Parks and other natural settings grapple with transportation noise mitigation. Government agencies and state departments of transportation deploy sustainability initiatives suited to specific community and environmental needs. (Photo: Volpe Center)

TR NEWS

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

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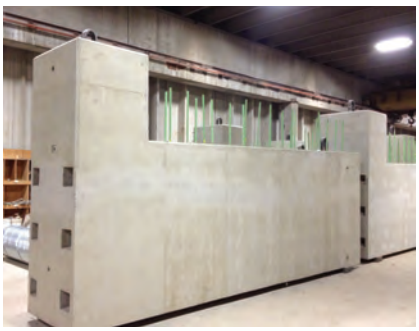
ALSO IN THIS ISSUE:

SPECIAL INSERT: ***Critical Issues in Transportation: 2013*** appears between pages 28 and 29.

COMING NEXT ISSUE

The impacts and implementation of products, tools, and research results and findings of the Second Strategic Highway Research Program (SHRP 2) are presented in the November–December issue of *TR News*. Articles spotlight each SHRP 2 focus area—renewal, capacity, reliability, and safety—from the perspectives of the research contractors and the users of the research products, including instructive case studies. Also described are the systematic implementation vision and goals of the Federal Highway Administration, the American Association of State Highway and Transportation Officials, and the National Highway Traffic Safety Administration, as SHRP 2 innovations gain widespread adoption and upgrade the U.S. highway system, "saving lives, reducing congestion, and improving the quality of life."



Precast integral abutments produced for the Vermont Agency of Transportation (VTrans), which piloted the SHRP 2 accelerated bridge construction (ABC) toolkit. VTrans faced many emergency bridge replacement projects after tropical storm Irene in August 2011; these abutments were for the agency's first ABC project, Hancock Bridge on Route 125, constructed in May and June 2013.

INTRODUCTION

Environmental Sustainability in Transportation

Improving the Quality of Life

ROBERT M. O'LOUGHLIN

The author is Air Quality Technical Service Team Leader, Resource Center, Federal Highway Administration, San Francisco, California, and Chair of the TRB Environment and Energy Section.

Environmental sustainability is the theme of this issue of *TR News*. Going back to the 1987 Brundtland Commission Report, which defined sustainability as meeting present needs without compromising the ability of future generations to meet the same needs, transportation agencies have refined their organizational goals to foster sustainable strategies and approaches to problems. More specifically, the transportation community is addressing present and future problems from the perspective of the "triple bottom line"—environment, economy, and social equity.

Achieving the triple bottom line involves, for example, preserving and restoring environmental and ecological systems, ensuring community health and values, advancing economic development and prosperity, and fostering social equity among populations. As the Brundtland Commission's definition indicates, these tasks continue over generations.

Addressing environmental issues in transportation project development dates back to the National Environmental Policy Act (NEPA), signed into law in January 1970. The NEPA sought to balance environmental concerns with the social, economic, and other requirements of present and future generations of Americans. In practice, before making decisions, federal agencies must consider the effects of their actions on the quality of the human environment.

The consideration of environmental impacts during the transportation project development process has evolved, as more sophisticated technical approaches—some highlighted in this theme issue—have emerged, as well as practices that involve citizens and stakeholders to ensure that decisions reflect community values and quality of life. Context-sensitive solutions, for example, offer a collaborative, interdisciplinary, holistic approach to the development of transportation projects. This approach leads to effective transportation solutions yet preserves and enhances the community and natural environments.

In this issue of *TR News*, articles and sidebars contributed by the TRB Transportation and Sustainability Committee focus on advances that transportation agencies have made in environmental sustainability across the transportation modes. Specific examples of how environmental sustainability is contributing to the quality of life for citizens can be found in the articles and sidebars developed through the following TRB committees: Transportation and Air Quality, Ecology and Transportation, Transportation-Related Noise and Vibration, Historic and Archeological Preservation in Transportation, Waste Management and Resource Efficiency in Transportation, and Environmental Impacts of Aviation.

Appreciation is expressed to TRB Senior Program Officer Christine L. Gerencher for her work in developing this issue of *TR News*.

Evaluating Sustainable Development

A Quality-of-Life Focus for Transportation Decision Making

ADJO A. AMEKUDZI

The author is Professor, School of Civil and Environmental Engineering, Georgia Institute of Technology, Atlanta.

Sustainable development and environmental sustainability—although not new concepts—have been elevated in recent decades into the laws, policies, and regulations that shape decision making about transportation and land use. Sustainable development requires a stewardship approach to assuring the quality of life for individuals and society and to preserving natural and human-made capital. Communities and transportation networks that are developing sustainably are more likely to continue to develop and innovate and to demonstrate resilience in response to setbacks.

PHOTO: JASON REEDY

In 2010, the city of Greenville, South Carolina, received a grant through the Partnership for Sustainable Communities to support planning and revitalization of the downtown area. The 20-acre Falls Park on the Reedy River, part of the city's redevelopment, now is a regional attraction.

The 2012 surface transportation reauthorization act, Moving Ahead for Progress in the 21st Century (MAP-21), not only articulates a performance-based planning paradigm for national transportation investment but also explicitly cites environmental sustainability as one of seven national transportation goals. The legislation is potentially transformative.

Along similar lines, the Department of Housing and Urban Development, the U.S. Department of Transportation (DOT), and the Environmental Protection Agency formed the Partnership for Sustainable Communities in 2009 to improve access to affordable housing and transportation while protecting the environment. This effort draws attention to quality-of-life goals, such as livability and public health, which may be pursued more effectively through interagency collaboration. Transportation, land use, and environmental decisions should be made collaboratively, not just concurrently.

Effective data and analysis tools are important for a decision-making framework that has a quality-of-life focus, helping communities and agencies implement their visions for positive impacts on individual and societal quality of life. The goal is to encourage economic competitiveness without sacrificing environmental quality.

Evaluating Outcomes

Quality of life is multidimensional—it depends on internal conditions, such as well-being and personal satisfaction, and on external conditions, such as the built and natural environments and social and economic conditions, which include air quality, access to health care, educational attainment, and income (*1–3*).

To demonstrate that communities are preserving or advancing quality of life, as well as the ability to deliver quality of life, the impacts of decisions—policies, plans, programs, and projects—should be evaluated. Models are being developed and applied to evaluate the quality of life and other outcomes of sustainable development.

The literature reveals that effective methods for

modeling and evaluating sustainable development share the following characteristics:

- An unambiguous definition of sustainable development and a clearly defined terminology;
- The potential for interdisciplinary approaches;
- The ability to address long-term intergenerational concerns;
- The capacity for managing uncertainty;
- The ability to address local–global interactions—including, for example, urban–rural issues;
- The ability to accommodate stakeholder participation; and
- The ability to accommodate process-based and outcome-based measures for sustainable development.

Several modeling approaches have been applied to evaluate sustainability in development, including macroeconometric models, computable general equilibrium models, optimization models, system dynamics models, multiagent simulation models, Bayesian network models, integrated dynamic models, multiobjective models, and resource footprints (*4–6*). Three model applications to address quality-of-life issues in transportation decision making are presented here:

- The sustainability footprint,
- Multiple-attribute decision making (MADM), and
- Strengths–weaknesses–opportunities–threats (SWOT) analysis.

PHOTO: METRO TRANSIT

The Central Corridor, a light rail line in Minneapolis–St. Paul, Minnesota, is a case study of the Partnership for Sustainable Communities.

Sustainability Footprint

The sustainability footprint model evaluates the effects of civil infrastructure on the quality of life and on other measures of sustainable development. The model was developed in the late 2000s (*7*) and builds on earlier research (*5, 8, 9*) to measure the impact of infrastructure system performance on social quality of life, the use of natural resources, and the generation of waste (see Figure 1, below).

The model indicates that infrastructure systems—that is, services and products—that have the highest positive impacts on the quality of life for users and affected populations have the highest value from the viewpoint of a community that is developing sustainably. The model can include an economic component that captures the life-cycle net benefits of the system (*10*).

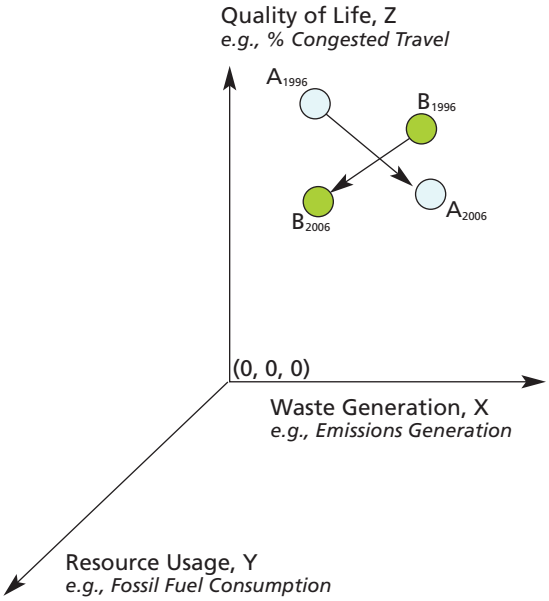


FIGURE 1 Sustainable footprint model for calculating the impact of infrastructure system performance on social quality of life, natural resource use, and waste generation.
[A, B = stakeholder entities: city A, city B. $A_{1996} = (X_{A\,1996}, Y_{A\,1996}, Z_{A\,1996})$, or the location of city A in the XYZ space of quality of life, resource usage, and waste generation in 1996. $SF_{A,\,1996\text{-}2006} = (dZ_A/dt, dY_A/dt, dX_A/dt)_{1996\text{-}2006}$—that is, the sustainability footprint of city A between 1996 and 2006 is the system-related quality-of-life change in city A as a function of resource usage and waste generation between 1996 and 2006. The SF of an entity—for example, a municipality, metropolitan area, or nation—between two definite points in time, $t = i$ and $t = i + 1$, can be formulated as a vector of quantities showing baseline conditions (Z_c, Y_c, X_c); the marginal rates of change with respect to time (dZ_c/dt, dY_c/dt, dX_c/dt); and resource efficiency measures (dZ_c/dY_c, dZ_c/dX_c) that capture the rate of change of one type of capital with respect to another.]

TABLE 1 Sustainability Assessment for Atlanta and Chicago Metropolitan Area Highway Networks: Quality-of-Life and Natural Environment Data

Sustainability Element	Selected Measures	Year	Atlanta	Chicago
Quality of life	Congested travel (percent of peak vehicle miles traveled)	1990	43	69
		2000	80	80
Resource consumption	Annual excess fuel consumed (gallons per person)	1990	7	9
		2000	21	14
Waste generation	Annual delay per person (person-hours)*	1990	55	17
		2000	52	25

**Annual delay used as a surrogate for vehicle emissions.*

Footprinting Chicago and Atlanta

The sustainability footprint was used to evaluate the metropolitan highway networks of the Chicago, Illinois, and Atlanta, Georgia, regions in the decade of the 1990s, with data from the Texas A&M Transportation Institute's *Urban Mobility Report*. Table 1 (above) shows the quality-of-life and natural environment data that were used in evaluating the highway networks; the assessment did not include economic data.

The example in Table 1 depicts the status and evolution of the Atlanta and Chicago metropolitan area highway networks from 1990 to 2000 with respect to congested travel, a quality-of-life measure; excess fuel consumption, a measure of resource consumption; and delay, a surrogate measure of vehicle emissions and waste. The model evaluated both baseline and marginal measures; the baseline measures showed that Atlanta was better off than Chicago at the beginning of the analysis period in terms of the percentage of congested travel per system user and in terms of annual excess fuel consumed per person; highway users in Atlanta, however, were experiencing more delays, on average, than those in Chicago.

Marginal rate-of-change measures show that both Atlanta and Chicago moved away from sustainability during this period; in Atlanta, the per person peak vehicle miles traveled increased by 37 percent, compared with an 11 percent increase in Chicago. The Atlanta metropolitan area also showed a greater increase in annual excess fuel consumed—14 gallons per person compared with 5 in the Chicago area. Atlanta experienced a moderate reduction of 3 person-hours in delays, however, compared with Chicago's increase of 8 person-hours of delay.

The analysis results from the sustainable footprint model indicate higher growth in congestion in Atlanta than in Chicago, with a corresponding increase in fuel consumption, but a slight reduction in delays per person. Chicago, in contrast, showed a relatively moderate increase in congested travel in comparison with Atlanta, with a correspondingly moderate increase in fuel consumption; nonetheless, Chicago's increases in delay per person were higher than Atlanta's.

Analyses with the sustainable footprint model can be retrospective, to evaluate the quality of life related to developing sustainably, as well as prospective, to forecast the impacts of alternative plans, policies, and programs. A broader scope of measures can capture the key quality-of-life issues of concern or interest to communities in the area under study.

The Tom Moreland Interchange northeast of Atlanta, Georgia, also known as Spaghetti Junction, was included in a sustainability footprint evaluation of the region's highway networks.

Photo: U.S. Geological Survey

Evaluating Alternatives

MADM methods, created to address issues related to sustainable development, were used to evaluate alternatives for transportation and land use plans in the Atlanta metropolitan region (*11–14*). First, critical sustainability issues or goals were identified in Mobility 2030, the long-range regional transportation plan for metropolitan Atlanta. Transportation system effectiveness was evaluated based on the regional goals of

- Improving accessibility and mobility,
- Maintaining and improving system performance and preservation,
- Protecting and improving the environment and quality of life, and
- Increasing safety and security.

The second step was to define performance measures for each goal and analyze and quantify the impacts of each plan. The measures were normalized to construct a composite sustainability index from the criteria, weighted to reflect the relative importance to the decision maker. The results were plotted on a four-dimensional (4-D) graph, generating a sustainability diamond, a visualization tool that can help in identifying the dominant alternatives and in evaluating the trade-offs between alternatives (see Figure 2, right).

Using MADM methods to evaluate quality of life and the impacts of other policy, plan, and program alternatives for sustainable development can highlight the relative importance of the decision criteria—for example, safety or congestion reduction—and can facilitate analysis of the many influences on the ways that communities protect their quality of life and sustainable development. The method focuses on the relative effectiveness of the alternatives, helping decision makers identify the dominant alternatives when considering all the decision criteria; this was done for the Mobility 2030 Plan (Figure 2). The method also helps in evaluating the trade-offs—such as the economic impacts or the effects on the natural environment—when no alternatives are dominant.

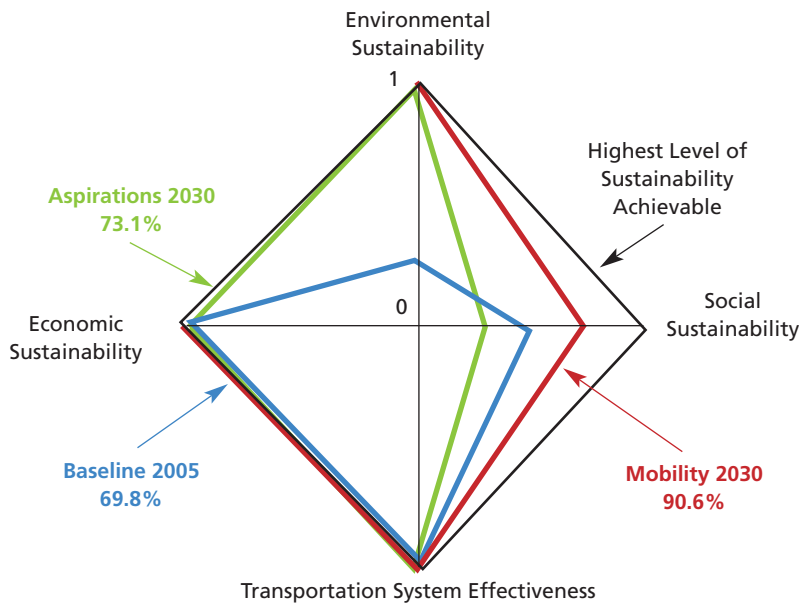


FIGURE 2 The sustainability diamond visualization tool showing the relative effectiveness of transportation and land use alternatives for metropolitan Atlanta.

Seven States Assessment

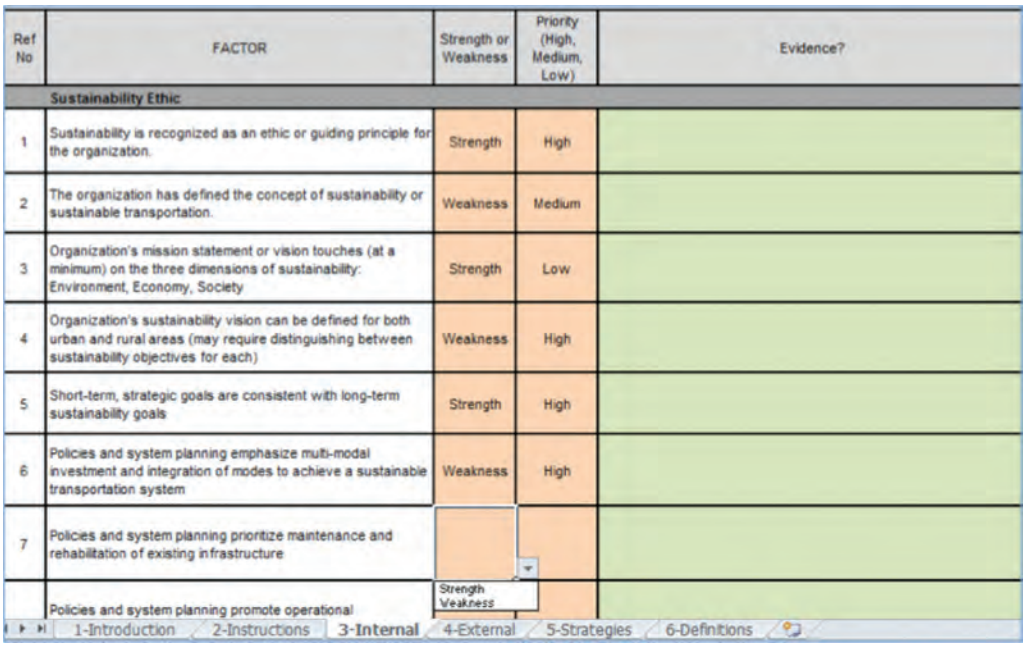
Transportation and other agencies can use SWOT analysis as a strategic planning tool to support and advance a variety of quality-of-life standards for communities. A SWOT-based assessment framework tool was applied to seven state DOT programs pursuing sustainable performance outcomes in transportation decision making (*15*). The evaluation considered the agencies' systems and programs in terms of functional performance, as well as of the triple bottom line of financial, social, and environmental performance.

Although other tools are available, the SWOT self-assessment framework is appropriate for evaluations at the strategic and organizational levels, guiding agencies through an examination of the strengths, weaknesses, opportunities, and threats to achieving sustainability and performance outcomes through transportation decision making (Figure 3, right). A panel of executive-level practitioners assisted in developing 32 factors for internal self-assessment, applicable to four major areas:

- Frameworks that assign priority to sustainability considerations in strategic planning,
- Organizational culture and structure,
- Collaboration and communications, and
- Institutionalizing sustainability.

Also identified were 16 external factors, covering the economic, environmental, social, and technological pressures that state DOTs face in working toward their goals. The factors related to the various phases of the planning and design process.

FIGURE 3 SWOT self-assessment framework.



Ref No	FACTOR	Strength or Weakness	Priority (High, Medium, Low)	Evidence?
	Sustainability Ethic			
1	Sustainability is recognized as an ethic or guiding principle for the organization.	Strength	High	
2	The organization has defined the concept of sustainability or sustainable transportation.	Weakness	Medium	
3	Organization's mission statement or vision touches (at a minimum) on the three dimensions of sustainability: Environment, Economy, Society	Strength	Low	
4	Organization's sustainability vision can be defined for both urban and rural areas (may require distinguishing between sustainability objectives for each)	Weakness	High	
5	Short-term, strategic goals are consistent with long-term sustainability goals	Strength	High	
6	Policies and system planning emphasize multi-modal investment and integration of modes to achieve a sustainable transportation system	Weakness	High	
7	Policies and system planning prioritize maintenance and rehabilitation of existing infrastructure			
	Policies and system planning promote operational	Strength Weakness		

1-Introduction 2-Instructions 3-Internal 4-External 5-Strategies 6-Definitions

Pavement restoration and rehabilitation on Route 501 in Virginia, an example of sustainability efforts commonly under the purview of state departments of transportation.

Photo: Al Covey, Virginia DOT

States' Findings

The results of the SWOT evaluation showed that the participating state DOTs identified two internal factors as their strongest:

- Communicating and collaborating with external stakeholders, and
- Demonstrating a sustainability ethic.

The DOTs judged internal promotion of a sustainability culture, however, as the weakest factor.

Respondents identified a range of high priorities; common to all were multimodal investment and maintenance and rehabilitation. Although admitting a disconnect between policies or plans and the allocation of resources, the agencies had positive views of the external conditions influencing the pursuit of sustainability. The agencies cited opportunities arising from public opinion favorable to sustainability, the deployment of new technologies, and increased employment. Issues and impacts related to climate change were viewed as a threat to achieving sustainability goals.

The study recommended that state DOT analyses of sustainability initiatives include the following factors: land use, routine education programming, procurement processes, and implementation. The study also recommended the linking of strategic planning to actions and performance measures.

The SWOT tool can guide strategic planning by business units within an agency; can support strategic planning at an organizational level through consensus building, and can facilitate executive-level discussions with other state agencies. The SWOT tool also can be used to assess an agency's readiness to address sustainability issues strategically and systematically in a performance context.

Light rail in historic Southend, Charlotte, North Carolina, was studied in the Federal Highway Administration's *Livability in Transportation Guidebook* for integrating land use and transit plans.

Photo: James Williamor

Additional Resources

Several additional analytical and data resources are available for decision making to improve societal quality of life and to pursue other elements of sustainability in development. Key examples include the following:

- The Federal Highway Administration's (FHWA's) *Livability in Transportation Guidebook* presents planning approaches that promote livability.[1]
- FHWA's *Transportation Planning for Sustainability Guidebook* offers an extensive catalogue of

[1]www.fhwa.dot.gov/livability/case_studies/guidebook/livabilitygb10.pdf.

analytical and data resources for addressing quality of life and other sustainable development considerations in transportation decision making.[2]

◆ NCHRP Report 708, *Guidebook for Sustainability Performance Measurement in Transportation Agencies,* describes performance measures and data to address quality of life and other elements of sustainable development.[3]

In addition, several initiatives in research and practice can serve as resources for addressing quality-of-life issues in decision making, including findings and applications on adapting to climate change (*16–18*); on infrastructure resiliency (*19*); on life-cycle assessment (*20*); and on scenario planning and backcasting, strategic environmental assessments, health impact assessments, context-sensitive solutions, equity analysis, and asset management.

The growing national and international focus on quality-of-life outcomes reflects a deepened understanding that economic, technological, and other advances can be made without sacrificing the quality of life in societies or the quality of the natural environments, in the short term or the long term. Pursuing a stewardship approach to the physical, human, and natural environments can improve the quality of decision making through appropriate applications of sustainability and performance evaluation tools that make values and trade-offs explicit.

These decision-making processes can help in actualizing the vision for economic competitiveness in livable and resilient communities and in achieving a higher level of stewardship for quality of life in this and future generations.

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[2]www.fhwa.dot.gov/environment/climate_change/sustainability/resources_and_publications/guidebook/sustain00.cfm.
[3]www.trb.org/Publications/Blurbs/166313.aspx.

Transit and other sustainable development initiatives are examined in National Cooperative Highway Research Program Report 708.

Online Tool Invests Highway Projects with Sustainability

BENJAMIN COTTON

In October 2012, the Federal Highway Administration (FHWA) launched a voluntary online tool to help agencies identify opportunities for incorporating sustainability into transportation projects and programs. INVEST 1.0 consists of a collection of sustainability best practices, called criteria, in three modules—system planning, project development, and operations and maintenance—that address the full life cycle of a highway.

With this web-based tool, an agency can evaluate each module independently and receive a score based on the points achieved for each criterion. Beyond the score, however, INVEST 1.0 meets an identified need for a collaborative virtual workspace that promotes communication and encourages participation by a range of sustainability-minded practitioners, including transportation planners, engineers, construction specialists, asset managers, ecologists, economists, maintenance technicians, and executive leaders.

Photo: Justine Belson/U.S. Fish and Wildlife Service

Central Federal Lands Highway is using the online tool INVEST to evaluate the sustainability of transportation projects in the Don Edwards San Francisco Bay National Wildlife Refuge in California.

Incorporating Feedback

INVEST 1.0 underwent an extensive review process during development. When the beta version was released in 2010, FHWA sought feedback from all potential users and stakeholder organizations, including the American Association of State Highway and Transportation Officials, the Association of Metropolitan Planning Organizations, federal partners—such as the Federal Transit Administration and the Environmental Protection Agency—and many state departments of transportation.

A pilot test version was released in 2011 and 2012, and 17 transportation agencies around the country tested the tool and provided feedback to FHWA. The development team received more than 2,000 comments from the beta and pilot testing, addressed all, and incorporated many into INVEST 1.0.

Photo: Walsh/HNTB Innerbelt Bridge Team

The Innerbelt 90 project in Cleveland, Ohio, received a gold score from the INVEST pilot. The bridge replacement project aimed for sustainability in several categories, such as energy efficiency, waste reduction, and project administration.

Flexibility and Functionality

The pilot tests led to a significant change in the project development module of INVEST 1.0. Users suggested that the module, designed to evaluate specific highway projects, should be more flexible and customizable, so that all types of highway projects could have the opportunity to score points. FHWA created multiple scorecards for the module, acknowledging differences in project setting and scope. The revision allows for an urban pavement rehabilitation project, for example, to have a unique set of criteria tailored to its sustainability needs, and a large, rural highway project to have its own set of criteria. The module offers an option to create a custom scorecard around certain base criteria.

The pilot test also yielded valuable input for the tool's functionality. FHWA requested that each agency participating in the pilot test send its evaluation team to a scoring workshop covering each criterion and its scoring. A representative from FHWA attended the workshops to observe the process, answer questions, and record feedback. The workshops offered insights into the user-friendliness of INVEST and into ways for improving the online working environment.

Version 1.0 incorporates several new features as a result. Every user now has access to a project work space, which can store multiple project scorecards. In addition, supporting documents can be uploaded into the system, along with notes that reflect the scoring rationales.

To learn more about INVEST 1.0 or to try out the tool, visit www.sustainablehighways.org.

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Fitting Livability into a Sustainability Framework

Making the Case

MICHAEL J. SAVONIS

The movement toward sustainability, a critical advance for the transportation community, has inspired a generation of professionals to think broadly about transportation's societal benefits and costs. Although new approaches have promoted sustainability in the transportation sector, the lack of an organizing framework has allowed some sponsors to promote projects as sustainable on the basis of a few selective criteria and without full consideration of the triple bottom line of economy, environment, and equity.

How can an objective case be made that livability projects, which focus on improving quality of life, fit into sustainability? Merriam–Webster's defines a sustainable approach as using "a resource so that [it] is not depleted or permanently damaged."[1] This definition suggests that sustainability can be determined by a project's impact on resources. What are the underlying criteria for assessing a livability project? Viewed in the full context of all affected resources, the sustainable benefits of livability projects become clear.

Under this notion, a project's sustainability depends on the availability, quality, and usage rate of resources over the project's life cycle. Some resources, like energy, are obvious and are frequently employed in sustainability frameworks. Many livability projects, especially bicycle- and pedestrian-related improvements, need fewer materials and construction resources and require only the renewable resource of human locomotion. Other resources sometimes are ignored, and comprehensive approaches are rare.

Consider the basic resources for a comprehensive sustainability framework:

[1]www.merriam-webster.com/dictionary/sustainable.

PHOTO: DAN BURDEN, PEDESTRIAN AND BICYCLE INFORMATION CENTER

A mixed-use development in Lake Oswego, Oregon. Livability projects often are economical as well as environmentally friendly.

PHOTO: WALTER PARENTEAU

Increasing traffic congestion highlights the need to consider the environmental, equity, and economic effects of new projects.

◆ **Environmental resources,** such as energy, air, water, land, and ecosystems. Sustainability frameworks frequently include air and water resources; pollution degrades these resources, and projects are assessed accordingly. Nevertheless, land is rarely recognized as a resource in sustainability, yet land is finite and can serve as a limiting factor in already dense development. Ecosystems also play a crucial role in modern society. Livability projects are likely to have less harmful effects on these environmental resources.

◆ **Human and financial resources.** Other resources are less obvious but no less important to sustainability. Human capital is an essential resource that can not only be maintained but optimized. Research shows that walking and biking promotes better health; healthier people have lower medical costs, are more alert, and live longer, which also makes them more productive. Time is a critical resource to most Americans; livability projects can optimize personal time budgets by providing a quick and efficient means to exercise and travel at the same time. In an era of tight budgets, financial resources must be considered; livability projects typically cost less than highway or transit capital improvements and maintenance.

Although alternative approaches can be taken, a focus on resources allows for baseline and performance metrics for assessing sustainability objectively. Each project must be analyzed individually, but livability projects can score well when examined on a comprehensive basis—they can help conserve resources. An explicit framework for objective decision making can advance the goals and practice of sustainability.

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Paths, Roads, and Rails to Better and More Sustainable Living

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Sustainability has become such a buzzword that its root meaning often seems to have been lost. In its most basic sense, sustainability means being able to continue, either indefinitely or for a defined period. The sustainability of human civilization requires that all people achieve an acceptable quality of life, without degrading the natural environment (*1, 2*). The environment provides natural resources; without these, the economic and social resources that support quality of life could not exist. Economic resources include money and financial markets, as well as the physical assets that make up the built environment. Social resources include the intellect, skills, knowledge, work, culture, and interactions of human beings.

The sustainable development process can be visualized as a bicycle ride.[1] The riders represent human civilization, and their continued experience of the bicycle ride represents human quality of life. The journey is supported by the quality of the path, which represents the built and natural environment. The front wheel of the bicycle, which steers the ride, represents social processes. The back wheel, which powers the ride, represents economic processes. Like the two wheels of a bicycle, social and economic processes are linked inextricably, and defects in either can slow progress.

[1]The bicycle analogy was developed in the author's doctoral research and was previously unpublished.

Photo: North Carolina DOT

An effective transportation system offers a variety of travel options to commuters and travelers.

Transportation's Role

As the adage maintains, "transportation is a derived good." The primary purpose of transportation systems is to expand the choices available to people, connecting them with goods, services, and opportunities that promote quality of life. Moreover, transportation is a sociotechnical system (*3*). Some human and social inputs into the transportation system include people's attitudes, such as modal preferences; choices and behaviors, such as driving speed or helmet use; and the skills of system users and designers. Technical inputs include infrastructure, such as roads, rails, and signals; other mechanical components, such as vehicles; and software components, for operational management.

Nevertheless, transportation also may create risks and barriers to quality of life. A transportation system may constrain or enhance people's life choices, depending on the mix of modes, configurations, and land use. For example, life choices that affect quality of life include what to eat, how much to exercise, and whether or not to breathe clean air. According to the *CDC Recommendations for Improving Health Through Transportation Policy,* the choice of what to eat often depends on whether or not grocery stores are accessible from a person's regular travel modes and routes (*4*); the choice of how much to exercise may be enhanced by the availability of safe and pleasant walking and bicycling paths, or it can be limited by time spent in a car; and the choice of whether or not to breathe clean air may become irrelevant to someone who must walk along a busy roadway corridor at rush hour.

The U.S. Department of Transportation (DOT) publication, *Livability 101: Six Principles of Livability,* emphasizes the benefits of "more transportation choices," "transit-oriented development," and "safe and walkable neighborhoods" (*5*). Greater variety in mode choice accommodates the preferences and abilities of a greater number of people. At the same time, public transit options with connecting bicycle and pedestrian infrastructure can allow more opportunity for physical activity, with motorized transportation—automobile and transit—providing time savings for long-distance travel.

Promoting Quality of Life

To promote quality of life effectively, transportation agencies need decision-support tools, performance metrics, and context-sensitive policies to inform investment decisions. Some agencies are making headway in these areas. For example,

◆ Several state DOTs—among them California, Florida, Maryland, and Louisiana—report performance information related to multimodal accessibility (*6*):

– Percent of total commute trips by each mode, including single- and high-occupancy vehicles and transit;

– Monthly percentage changes in vehicle miles traveled and intercity rail boardings;

– Percentage of roadways with sidewalks and percentage of sidewalks that meet the standards of the Americans with Disabilities Act; and

– Crash rates, serious injuries, and fatalities, separated by mode.

◆ Some transportation agencies, including metropolitan planning organizations and state DOTs, are incorporating public health and safety concerns into their planning and performance management processes:

– The Louisiana Department of Transportation and Development is addressing bicycle and pedestrian safety through a complete streets policy (*7*);

– The San Diego Association of Governments has drafted a health and wellness policy framework that includes performance measures for safe and walkable streets, equity in mobility, and access to resources such as healthy foods, medical care, recreation, jobs, and schools (*8*); and

– The Nashville Metropolitan Planning Organization scores transportation projects with a points system based on outcomes in air quality and physical activity, among other health concerns (*9*).

Continuing the Journey

Moving Ahead for Progress in the 21st Century (MAP-21), the 2012 federal legislation authorizing transportation programs, mandates new performance reporting and management strategies from state DOTs, metropolitan planning organizations, and others that receive federal funds. MAP-21 also provides several grant programs supporting the new federal emphasis on livability.[2] This and future federal policies are intended to motivate state, regional, and local transportation agencies to develop their own metrics, policies, and tools to support decisions related to quality of life. As these processes gain momentum, they can help the transportation system evolve to enhance, preserve, and provide access systematically—and long into the future—to the social, economic, and environmental resources that support quality of life.

[2]www.dot.gov/livability/grants-programs.

Photo: Dan Burden, PBIC

Departments of transportation in California and several other states report performance information such as the percentage of sidewalks that meet the standards of the Americans with Disabilities Act.

Acknowledgment

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[3]www.irg.ce.gatech.edu.

Infrastructure elements, such as a bicycle rack at a bus stop, can allow travelers to combine modes of travel in a single trip.

Photo: Dan Burden, PBIC

Integrating Vegetation and Green Infrastructure into Sustainable Transportation Planning

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An international consensus has emerged that people living, working, and going to school near roads with high volumes of traffic face increased risks for adverse health effects (*1*), most likely from acute and chronic exposures to elevated levels of air pollution, including particulate matter (PM), gaseous criteria pollutants, and air toxics.

Field measurements conducted in the United States and throughout the world have shown that air pollution levels are highly elevated near high-volume roadways (*2*). Pollutant concentrations are often highest within the first 100 to 150 meters of the road, and some pollutants are found in concentrations that have increased by an order of magnitude. Pollutant concentrations from traffic emissions can remain elevated as far as 300 to 500 meters or more from the road (*1, 2*).

Urban Form and Air Quality

With increased urbanization worldwide, the number of people exposed to traffic emissions near high-volume roadways continues to increase. Moreover, urban form indirectly affects air quality and global climate conditions (*3*).

Public transportation and land use policies and practices increasingly support sustainable development patterns by promoting compact growth in infill locations along major transportation corridors. An example is transit-oriented development, a mix of housing and supportive land uses near transit, with access to jobs and services, intended to capture the benefits of location efficiency (*4*).

The U.S. Environmental Protection Agency (EPA) is implementing policies to address the impacts of major roads on nearby air quality. Recent revisions to

Example of a vegetation barrier along a highway; roadside vegetation barriers have been shown to improve near-road air quality. Questions remain on the optimal design features for effectiveness.

PHOTO: ARLINGTON COUNTY

The Clarendon neighborhood of Arlington, Virginia, just outside of Washington, D.C., features a mix of housing and business land uses within walking distance of Metro rail and bus stops.

the monitoring rules for the National Ambient Air Quality Standards (NAAQS) require monitors for PM, carbon monoxide (CO), and nitrogen dioxide (NO_2) near high-traffic roads in large metropolitan areas.

EPA's transportation conformity rule requires the modeling of hot-spot concentrations of PM in the immediate vicinity of large federal highway or transit projects in nonattainment and maintenance areas that have high levels of heavy-duty diesel vehicle traffic. Projects are required to model concentrations at or below the NAAQS or to model the concentrations to be at lower levels after the project is built than they were before the project.

In California, three recent state laws have given impetus to sustainable development patterns.[1–3] Under California Senate Bill 375, regional transportation plans of metropolitan planning organizations must include "sustainable community strategies."[2] These strategies forecast development patterns integrated with the transportation network and other transportation measures and policies to reduce regional greenhouse gas (GHG) emissions from automobiles and light trucks; the goal is to achieve regional GHG emission reduction targets by 2020 and 2035 (*5, 6*).

Reducing Exposures

Although development patterns that limit urban sprawl and vehicle miles traveled can have a major impact on reducing GHG emissions, these plans, as well as similar proposals in other localities, concentrate development along major transit corridors. The result is to increase the local population's exposure to emissions generated from the high-volume freeways.

Transit-oriented development and similar policies increase the population's access to services and transportation options and lead to regional reductions in vehicle miles traveled and air pollution. Nonetheless, these practices often bring people closer to the sources of air pollutant emissions, such as traffic activity. As a result, ways to reduce the exposure of people residing and working near high-volume roadways are needed.

A workshop in Sacramento, California, on June 5–6, 2012, gathered a multidisciplinary group of researchers and policy makers to discuss roadside vegetation as an option for mitigating the health impacts of air quality near roads. The following is a summary of the workshop discussions, including an overview of the role that roadside vegetation may play in reducing population exposures to air pollutants emitted by traffic. Roadside vegetation also is examined as a sustainable mitigation option in the context of other potential benefits and disbenefits.

Vegetation Barriers

Research studies measuring and modeling the impacts of vegetation barriers on near-road air quality suggest that a barrier can lead to reductions in pollutant concentrations. Field measurements comparing pollutant concentrations behind roadside vegetation with the concentrations in a clearing at the same distance and along the same stretch of limited-access highway generally show lower pollutant concentrations downwind of the vegetative barrier, as illustrated in the example in Figure 1 (below).

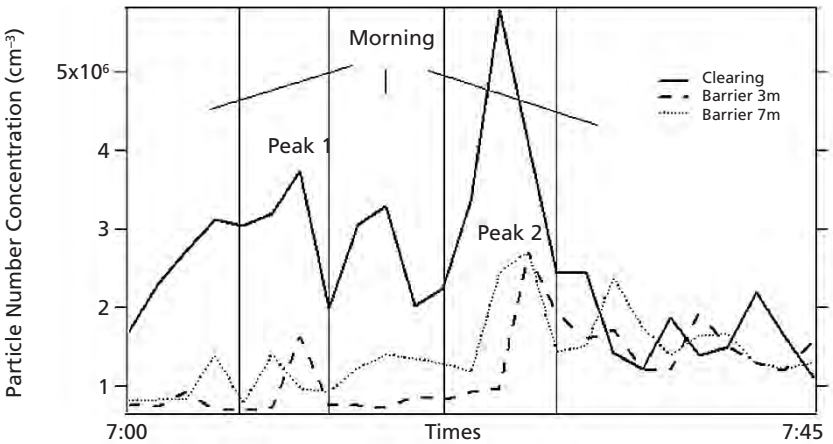

FIGURE 1 A study in North Carolina measured PM concentrations at a clearing and behind a vegetation stand along the same stretch of highway and the same distance from the nearest pavement edge. Substantial reductions in PM concentrations occurred during morning time periods with light winds from the road; however, as winds became variable, the vegetation did not effectively reduce PM concentrations, with some instances of higher concentrations behind the vegetation than at the clearing (*7, 8*).

[1]California Assembly Bill 32, Global Warming Solutions Act (2006), and Climate Change Scoping Plan (2008).
[2]California Senate Bill 375, Sustainable Communities and Climate Protection, Ch. 728 (2008).
[3]California Assembly Bill 1358, Complete Streets Act, Ch. 657 (2008).

Photo: North Carolina DOT

Wildflowers at I-40 and US-421 in Forsyth County, North Carolina. Besides aesthetic benefits, native vegetation along highways improve ecosystems, air quality, and stormwater regulation.

The measurements suggest that the barrier led to an increase in air mixing, resulting in lower behind-barrier concentrations at ground level. Field and wind tunnel studies also suggest an enhanced capture of PM by the vegetation; generally, the concentrations of ultrafine and coarse-mode PM decrease, with limited reductions in fine-particle $PM_{2.5}$ mass.

The field measurements, however, also indicated that under certain meteorological and design conditions, the PM concentrations could be higher behind a vegetative barrier than in a clearing. These results suggest that higher pollutant concentrations could occur behind a vegetation stand when wind speeds are low and the winds are parallel to or toward the road. In addition, gaps in the barrier from dead trees or natural openings could cause wind stagnation, leading to higher downwind concentrations behind the vegetation (*9*).

Computational Models

Researchers have incorporated the representations of the aerodynamic and deposition effects of vegetation barriers on transportation air quality into a computational model based on fluid dynamics. To explore the effects of vegetation barriers on near-road air quality, the simulation results were compared with the data collected from field studies (*7, 8*).

The models consistently reproduced the spatial variations of pollutants behind barriers under different atmospheric stability conditions. With the accuracy of the three-dimensional, detailed modeling verified, researchers are examining the effects of different barrier designs, wind speeds, and turbulence environments (*10*).

Too-heavy tree canopy can obstruct roadway visibility and trap source particles.

Photo: Virginia Travis, Flickr

Cobenefits and Disbenefits

Urban forestry and landscape ecology offer insights on potential additional advantages and disadvantages of implementing vegetation to mitigate near-road air quality impacts. Vegetation in urban settings can provide benefits beyond improvements in air quality—these include carbon sequestration, temperature and storm water regulation, noise reduction, aesthetic improvements, and opportunities for physical exercise and the experience of nature. These cobenefits, known as ecosystem services, have been associated with improved physical and mental health and community vitality.

Positive associations between personal health and physical or visual access to green space have been observed in children, the elderly, persons with limited mobility, and families in military and low-income housing. Trees also have been shown to have direct health benefits (*11*). In addition, the services provided by urban vegetation can yield significant economic returns, such as averted energy and medical costs, increased worker productivity, and increased property values (*9*).

Near-road vegetation, however, has some potential disbenefits, such as pollen production, water demand, introduction of invasive or nonnative species, channeling of invasive pests and fire into the urban environment, and expanding the urban footprint by distancing buildings and other land use activities from roadways. Trees also may obstruct roadway visibility, cause damage or injury by falling, and create slippery conditions from dropped debris.

Barrier Design Considerations

Meeting participants agreed that further exploration of vegetative barriers to mitigate adverse air quality is worth pursuing; the design process should maximize the potential benefits and avoid the disbenefits to the extent feasible. Successful designs would match plant species with each site and with the site's purpose, to achieve optimal performance for the service life of the project. Many sites and designs are unique, with no single recipe for effectiveness.

Roadside vegetation barriers designed to reduce harmful PM concentrations, for example, should be tall and wide enough to enhance particle deposition and dispersion—a minimum width of 5 meters has been suggested (*12*). A closed canopy over roadways, however, can trap source particles and increase concentrations below the canopy unless prevailing

winds continuously flush out the pollutants (*13*).

Vegetation barriers with a porosity of 20 to 40 percent have been suggested, because higher or lower porosities are likely to reduce efficiency in capturing pollutants (*12*). A porosity of less than 20 percent can increase turbulence, so that the vegetation acts more like a solid structure.

A multirow barrier combines shrubs along the edge to protect young trees from exposure and reduce subcanopy air flow for deciduous and coniferous trees. Plants can be staggered to eliminate gaps horizontally and from the ground level to the canopy top.

In terms of performance, conifers are superior to deciduous trees because of their year-round foliage and greater amounts of leaf and stem surface area per unit of land. Their demand for water, however, may be greater for the same reasons (*14*). A diverse mix of well-adapted species increases the barrier's long-term resilience to drought, pests, storm damage, and other urban stressors (*15*).

Barriers also may be designed to accomplish other environmental objectives, such as carbon storage, rainfall interception, and reduction of contaminated storm water runoff. Desired characteristics for trees include high wood density values, large crown projection areas, long life spans, and tolerance to inundation.

Addressing Negative Effects

An important design goal is to minimize the potential negative impacts of roadside plantings through the judicious selection and placement of species. Single-vehicle collisions with trees account for nearly 25 percent of all fixed-object fatal accidents each year (*16*). Improving driver visibility and providing a safe distance between travel lanes and trees through clear zones can alleviate this threat.

Avoiding plant species that have invasive qualities and shallow roots can reduce long-term maintenance costs. Tree species with small leaves and open crowns are less likely to clog drains during rain storms or to slow the ice melt from paved surfaces in winter.

Clustering trees within shrub borders can reduce damage from mowing. Understory plantings, however, may limit access and may conceal encampments in certain areas. When the flammability of plantings is a concern, designs should avoid continuous planting strips and "ladder fuel" plantings that allow fires to climb from the ground to the tree canopy via branches touching the ground or via high grasses and underbrush that extend into the trees.

Nut and fruit production from trees near paved surfaces also can be a nuisance. Emissions of pollen and biogenic volatile organic compounds, which are highly species-specific, can adversely affect human health and air quality (*17*). Most of these effects can be avoided.

Site Characteristics

Understanding how a site's microenvironments will change over time and influence plant growth is fundamental to good barrier design. Grading for optimal surface drainage before planting will promote the survival and growth of the vegetation. Soil sampling is an important first step, followed by subsoiling, or ripping, to reduce compaction and address the nutrient deficiencies in the soil. Chloride content, soil pH, and concentrations of metals may change with the use of deicing salts and other road- or vehicle-generated contaminants.

Designing the barrier to create and protect healthy soil over the long term often reduces maintenance while promoting survival and growth. Traffic volumes influence the dispersion of pollutants, as well as the drying effects on roadside vegetation from local turbulence. Slope and direction also influence plant stress from heat and wind and should be considered in planning and designing the barrier.

Planting Trees

Trees generally are planted into augured holes from containers or bare root stock (caliper of 2.5 centimeters or more), liners (1.2-centimeters caliper), or as seedlings (30 to 45 centimeters tall). The tree size at the time of the planting appears to be related to survival—smaller stock, although less expensive than larger stock, is more vulnerable to physical damage from mowers and animals and to competition from weeds. Larger-stock trees will provide a more immediate barrier for mitigating the impacts of pollutants soon after construction.

Photo: Washington State DOT

Newly planted trees along SR-542 in Washington State. A mix of tree varieties can balance disease and pest resistance, water use, foliage sizes, and root depths.

PHOTO: MASSACHUSETTS DOT

Massachusetts DOT replanted 20 linden trees as part of a 2010 bridge rehabilitation project. Mature trees are less likely to experience transplant shock and begin to mitigate pollution effects more quickly than young trees.

Mulch helps to conserve soil moisture around the tree. Too much mulch, however, can become a seedbed for weeds and fungus. Most trees require staking for support and protection at planting. Removing stakes after trees have become established and self-supporting is an important maintenance task because of the damage that vestigial stakes can cause to trees, through girdling and wounds.

Watering trees during the establishment period is key to long-term success, as is controlling weeds by mechanical or chemical means. In some cases, a cover crop can control weeds effectively while the woody plants become established. Care must be taken to avoid plants that are invasive or that attract deer and other animals that pose a threat to motorists. Monitoring the barriers is also critical to their performance and survival.

Pilot Studies Needed

Roadside vegetation barriers can improve near-road air quality and can affect the public health positively for populations near high-volume roadways. Although questions remain about the optimal design features for vegetation barriers, the current scientific understanding warrants pilot studies to investigate this potential strategy for mitigating air quality. Three-dimensional modeling of PM transport and deposition in roadside barriers, combined with field monitoring and verification studies, are contributing valuable new knowledge to the design and management of effective barriers.

Tree species such as oaks can produce gutter-clogging leaf drops in the fall.

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Impacts of Storm Water Pipe Lining on Water Quality

Virginia Research Leads to Improved Construction Specifications

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Many storm water pipes and culverts have reached the end of their service life, and their repair or replacement is a significant maintenance concern. Trenchless technologies that repair pipes in place have become a frequent alternative to pipe replacement. Many U.S. transportation agencies routinely repair storm water culverts with cured-in-place pipe (CIPP), a trenchless technology favored by the underground pipe industry.

In conventional CIPP installations, a flexible liner saturated with a thermosetting styrene-based resin is pulled or inverted through the host culvert and cured by recirculating steam or hot water for up to several hours. The result is a rigid liner within the damaged or deteriorated host pipe.

The waste by-products of CIPP include styrene-contaminated cure water or steam condensate. According to several reports in the past decade, styrene contamination from conventional CIPP installation has caused fish kills and has affected downstream wastewater treatment processes. No previous field investigations, however, had examined the potential effects of CIPP on water quality.

Alternative CIPP technologies include vinyl ester-based resin systems, which are typically steam-cured, and a styrene-based resin system cured with ultraviolet (UV) light. In addition, spraying coating material to line the culvert interior is gaining acceptance for the repair of storm water culverts. The spray-on coatings have rapid setup times and become fully cured within 24 hours.

PHOTO: BRIDGET DONALDSON, VCTIR

Conventional CIPP liner inserted into host pipe.

Photo: Bridget Donaldson, VCTIR

Conventional CIPP steaming process.

Testing the Technologies

From 2006 through 2012, the Virginia Center for Transportation Innovation and Research, a division of the Virginia Department of Transportation (DOT), evaluated three CIPP technologies: conventional styrene-based, vinyl ester-based, and styrene-based UV; and two spray-on technologies: cementitous and polyurea. The goal was to determine the potential impacts on water quality. Field evaluations were conducted for each technology during and up to 120 days after the installation of the storm water culvert lining. In addition, laboratory leaching tests were conducted for the spray-on liners.

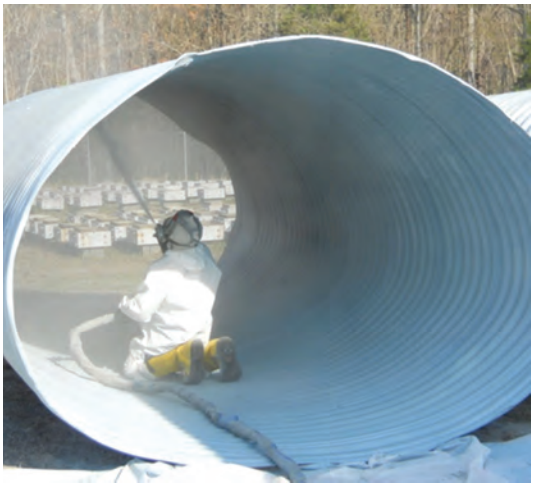

Photo: Bridget Donaldson, VCTIR

Polyurea spray-on installation.

Water quality analyses of conventional thermosetting, styrene-based CIPP installations revealed styrene concentrations at levels that exceeded the toxicity thresholds for certain aquatic species. Tests of the vinyl ester-based CIPP showed that concentrations of the chemical diallyl phthalate also exceeded the toxicity thresholds. Styrene concentrations after UV-CIPP installations were significantly lower than those from the thermosetting styrene-based resin systems; however, at one site, the concentration immediately after installation was above the toxicity thresholds.

Although minimal effects on water quality were detected in field tests of the spray-on liners, the laboratory leaching tests suggested potential impacts from elevated pH and alkalinity from the cementitious spray, and elevated chemical oxygen demand, total organic carbon, and total nitrogen from the polyurea spray. These results strongly supported the need to develop additional control specifications to ensure environmental protection.

New Specifications

Applying the findings from this research, Virginia DOT developed contractor construction specifications for all CIPP and spray-on lining technologies. Key requirements include the following:

- Submittal of design calculations and job-specific installation specifications before construction;
- Deployment of spill prevention measures at the inlet and outlet ends of the pipe to capture any release of raw resin with CIPP or of overspray with spray-on products;
- Continuous time and temperature monitoring of the liner with multiple thermocouples and a data logger for CIPP installations;
- Rinsing the finished liner and properly capturing and disposing of any cure water and rinse water; and
- Testing soil and water before and after the CIPP and polyuria spray-on installations.

These measures not only ensure protection of the environment but also increase the performance of the finished products by requiring tighter quality controls. The specifications are available on the web at www.virginiadot.org/business/resources/const/07RevDiv_III.pdf (pages 3-146 to 3-150).

Historic Preservation and Sustainability in Taneytown, Maryland

ANNE E. BRUDER

In 2010, the Maryland State Highway Administration (SHA) undertook a community safety and enhancement project on two state highways, MD-140 and MD-194, in Taneytown, Carroll County. Popularly known as a "streetscape," the project was located within the Taneytown Historic District, listed in the National Register of Historic Places since 1986. Maryland SHA's improvements to the intersection and the historic district included parking, new sidewalks, and landscaping—features that often encourage business owners to make improvements to their historic buildings.

The Taneytown Historic District is at a significant crossroads formed around the two state highways, with buildings from the 18th, 19th, and 20th centuries. During the 18th century, inns and taverns stood at the crossroads, and railroad construction produced growth and prosperity on the east side of Taneytown after the Civil War. By the 1930s, local manufacturing companies were shipping canned fruits and vegetables, as well as clothing, throughout the United States. As in many small towns in the late 20th century, the buildings occasionally were altered to accommodate new businesses, sometimes without regard for maintaining historic integrity. Taneytown's downtown area, however, largely preserved its historic core.

The proposed streetscape project had the potential of affecting archeological resources under the sidewalks. Maryland SHA normally would monitor the construction, but after consultation with the Maryland State Historic Preservation Officer, the agency decided that the funds could be spent more usefully on a project to benefit Taneytown's historic downtown core.

In concert with Taneytown's Economic Development Director and its Heritage Committee, Maryland SHA developed interpretive panels and revised the walking tour brochure for the historic district. The revised tour pamphlet features 21 buildings near the town's main crossroads.

Owners of historic buildings have responded positively to the improvements. One owner has restored the ground-floor façade of a building to its original 19th century appearance, as shown in the before-and-after photographs at right. The project improvements have helped to sustain the historic features of Taneytown's crossroads.

The author is Senior Architectural Historian, Cultural Resources Section, Office of Planning and Preliminary Engineering, Maryland State Highway Administration, Baltimore.

Photo: Ed Zepp, courtesy of the Historical Society of Carroll County

Baltimore Street in Taneytown, looking east, 1903.

Photos: Anne E. Bruder, Maryland SHA

Eckenrode Building (*above*) in August 2010, before restoration, and (*below*) in February 2013, after restoration.

Eco-Logical in Practice

Implementing an Ecosystem-Based Approach, Streamlining Environmental Processes for Transportation Projects

JULIANNE SCHWARZER AND HALEY PECKETT

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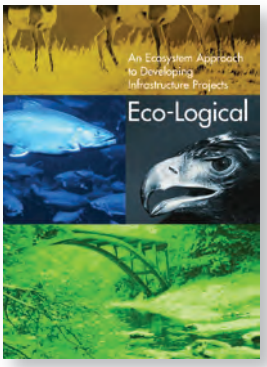
Developing and maintaining transportation infrastructure can have a negative impact on ecological resources. State departments of transportation (DOTs) historically have employed a variety of techniques to avoid, minimize, and mitigate these impacts on a project-by-project basis. The techniques may have satisfied regulatory requirements but did not always provide the greatest environmental benefits.

At the same time, the environmental review and permitting processes often raised issues that were perceived as major causes of project delay. Concern for ecosystem protection, along with legislative and policy initiatives to foster an ecosystem-based approach while streamlining environmental processes, led an interagency steering team to collaborate to write *Eco-Logical: An Ecosystem Approach to Developing Infrastructure Projects*.[1]



Eco-Logical: An Ecosystem Approach to Developing Infrastructure Projects was developed to facilitate collaboration between agencies in the environmental review process.

The interagency team shared a vision that collaborative infrastructure development and delivery processes that are more sensitive to ecological resources could reduce the time frames for environmental review and permitting. Eco-Logical encourages all partners involved in infrastructure planning, design, review, and construction to use the flexibility in regulatory processes to achieve this vision. The Eco-Logical publication puts forth a framework for integrating plans across agency and political boundaries and endorses ecosystem-based mitigation—an innovative method of addressing infrastructure impacts.

Several current initiatives are institutionalizing or adapting the Eco-Logical approach, as states and regions seek technical assistance to streamline the transportation process and to achieve better environmental outcomes. The evolution of the Eco-Logical approach and examples of its early successes provide background and insights.

[1]www.environment.fhwa.dot.gov/ecological/ecological.pdf.

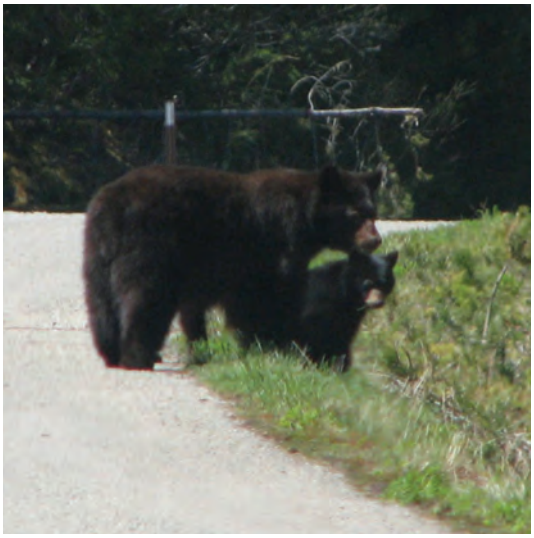


Photo: Washington State DOT

A bear and her cubs cross North Cascades Highway in Washington State. In 2002, an interagency team comprising state and federal representatives created a framework for infrastructure development that is sensitive to animal and other habitats.

How It Began

In the late 1990s, Montana DOT and the Montana Division Office of the Federal Highway Administration (FHWA), along with resource and regulatory agency partners, anticipated an increase in development throughout the state and were concerned about the vanishing opportunities to conserve natural resources.

Like many other states at that time, Montana primarily performed environmental mitigation for transportation projects on an individual project basis, generally at the permitting stage. This approach did not always yield the greatest environmental benefit and did not promote long-term ecosystem sustainability. To address these issues, agencies in Montana formed a partnership known as the Integrated Transportation and Ecological Enhancements for Montana (ITEEM), which sought to develop an ecosystem-scale approach to infrastructure development.

In 2002, in response to the work in Montana and to the release of Executive Order 13274, Environmental Stewardship and Transportation Infrastruc-

ture Project Reviews,[2] an interagency steering team from eight federal agencies and several state DOTs convened to create a framework for ecosystem-scale infrastructure development.[3] The group sought "an enhanced and sustainable natural environment," and maintained that "necessary infrastructure can be developed in ways that are more sensitive to terrestrial and aquatic habitats."[4]

The team also believed that the transportation project development and delivery processes could be streamlined, saving time and resources. As a result, the team developed an approach that promoted early coordination to establish environmental commitments and to apply the flexibilities allowed under the regulations.

In April 2006, leadership from the federal steering team agencies signed the resulting document,

[2]http://ceq.hss.doe.gov/nepa/regs/eos/eo13274.pdf.

[3]The team consisted of representatives from the U.S. Army Corps of Engineers, the Bureau of Land Management, the Environmental Protection Agency, FHWA, the Fish and Wildlife Service, the Forest Service, the National Oceanic and Atmospheric Administration, the National Park Service, Volpe National Transportation Systems Center, Knik Arm Bridge and Toll Authority, North Carolina DOT, Vermont Agency of Transportation, and Washington State DOT.

[4]From *Eco-Logical: An Ecosystem Approach to Developing Infrastructure Projects*, 2006.

Success in Montana

ITEEM yielded new and important positive relationships among agencies in Montana. Participants have contacted each other to discuss environmental issues and mitigation opportunities for ITEEM and non-ITEEM projects. These personal relationships have helped to erase historical biases or misconceptions that some agency staff held about other agencies.

Staff in participating ITEEM agencies have begun to appreciate each other's missions and core responsibilities. According to one participant, "ITEEM helped build more trust and credibility; it erased misconceptions." Another participant noted, "Relationships are built between people, not between agencies. ITEEM opened our eyes to what was possible and took away assumptions about agencies." Some participants anticipated the relationships would make future interagency collaboration "more effective and efficient."[a]

[a]www.environment.fhwa.dot.gov/ecological/ITEEM/study.asp.

Mitigation projects along the Jordan River in Utah were based on Eco-Logical.

Photo: Cory Maylett

Eco-Logical: An Ecosystem Approach to Developing Infrastructure Projects. The recognition by agency leaders signified a joint commitment to promote and support Eco-Logical.

What Is Eco-Logical?

The Eco-Logical approach calls for early collaboration among transportation, resource, and regulatory agencies to establish joint environmental priorities and identify critical resources. After establishing priorities, federal, state, tribal, and local partners can work to sustain or restore ecological resources on an ecosystem scale in developing infrastructure projects, using the flexibility within regulatory processes.

To help agencies tap this flexibility, Eco-Logical sets forth a framework for integrating plans and data across agency and political boundaries and for identifying a region's ecological priorities. The framework proposes that infrastructure and resource agencies collaborate before transportation planning to incorporate data at the ecosystem scale, identify critical ecological resources, and establish joint environmental priorities.

Transportation agencies then can use jointly established priorities in planning and decision making to avoid negative environmental impacts and to undertake mitigation when impacts are unavoidable. During the transportation design and permitting phases, early decisions and commitments should ensure faster permitting times and better environmental outcomes.

Signatory Agency Programs

Since 2006, representatives from each of the federal steering team, or signatory, agencies have held meetings to identify opportunities to support each other, as well as state and local entities, in implementing the Eco-Logical approach.

In 2011, the signatory agencies undertook an effort to identify the programs within each agency that closely related to Eco-Logical. Each agency noted that although its leadership supported the concept of Eco-Logical, in many cases the approach had been modified to meet agency needs. Each agency was able to identify at least one program that shared the same founding principles as Eco-Logical.

The initial outcome of this effort was a document titled *Eco-Logical Successes*.[5] After its publication, the signatory agencies decided to assemble more in-depth descriptions of key agency programs, including on-the-ground applications. Since 2011, FHWA, in collaboration with the signatory agencies, has developed three additional volumes of *Eco-Logical Successes*, all available on the FHWA Eco-Logical website.[6]

Eco-Logical Grants and Resources

The FHWA Office of Planning, Environment, and Realty established the Eco-Logical grant program in 2007, providing approximately $1.4 million to 15 projects selected to test an ecosystem-scale approach to infrastructure development.[7] Project activities included transportation and environmental planning, data collection and analysis, environmental mitigation, public education, and prioritization of natural and cultural resources.

[5]www.environment.fhwa.dot.gov/ecological/successes/index.asp.

[6]www.environment.fhwa.dot.gov/ecological/eco_entry.asp.

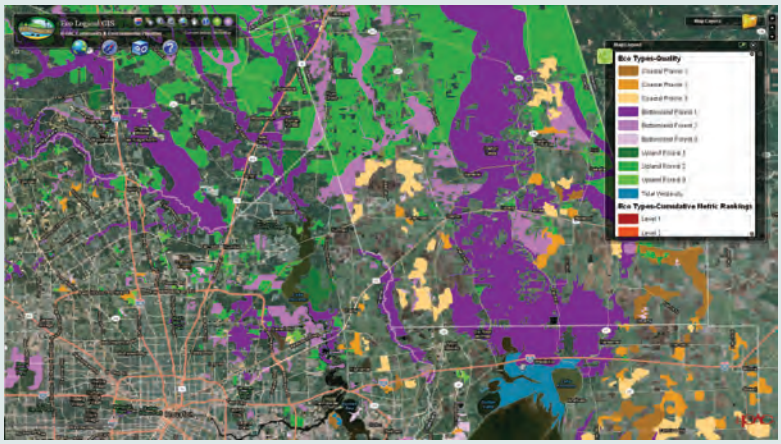
[7]The grant program was funded by the Surface Transportation Environment and Planning Cooperative Research Program, FHWA Office of Planning, Environment, and Realty.

Applying Eco-Logical

Through an FHWA Eco-Logical grant project, the Houston–Galveston Area Council (H-GAC) created a geographic information system (GIS) tool to identify areas for environmental resource priority. H-GAC is a regionwide voluntary association of local governments in the 13-county Gulf Coast Planning region of Texas.

Since the completion of the tool, which comprises more than 12,000 mapped features covering six ecotypes, staffers have been drafting recommendations for inclusion in the 2040 Regional Transportation Plan. The recommendations are developed in coordination with the Transportation Policy Council, which provides policy guidance and coordination of transportation planning within the region.

The Conservation Fund, a not-for-profit organization active in land conservation across United States, is applying a similar methodology to expand the tool's functions in five counties outside of H-GAC's regional boundaries. Local and regional foundations are funding the project. H-GAC plans to integrate the Conservation Fund's work into the online tool, including a methodology that will show the monetary benefits of ecological services.



Environmental resource priority areas can be identified with the Houston–Galveston GIS tool.

Photo: USACE

A 2012 U.S. Army Corps of Engineers (USACE) Nashville District project diverted water from entering Greenbelt Lake to remove sediment. USACE's Aquatic Ecosystem Restoration Program uses Eco-Logical.

Since 2007, FHWA has tracked the progress of the grants, developed annual reports summarizing findings, and provided recommendations.[8] This year, FHWA worked with the grant recipients to identify the key requirements to achieve success in implementing Eco-Logical. The grant recipients agreed that the following four characteristics were most important:

- Access to tools to advance Eco-Logical,
- Adaptable organizational structure and flexible staff capacity,
- Strong interagency partnerships, and
- Technical and financial support for Eco-Logical projects.

To provide additional resources for stakeholders implementing Eco-Logical, FHWA initiated several additional communications, outreach, and research projects. Past projects have included research on the origins of the Eco-Logical approach in Montana and a peer exchange for the early implementers.

Other ongoing activities that demonstrate FHWA's commitment to assisting its stakeholders in putting Eco-Logical into practice include producing a monthly webinar series, developing and implementing a training strategy, and creating a benefit assessment framework to assist FHWA in determining the economic benefit of applying the Eco-Logical approach.

Eco-Logical and SHRP 2

The Transportation Research Board's second Strategic Highway Research Program (SHRP 2)[9] has included two projects to develop the institutional and technical processes needed to put the Eco-Logical approach into practice. The projects address a charge from Congress to develop methods that systematically integrate environmental requirements into the planning and design of new highway capacity.

The SHRP 2 efforts produced a nine-step integrated Eco-Logical framework, along with the supporting scientific and technical processes and tools. The tools and processes are being introduced to the transportation and environmental communities as

[8]Eco-Logical grant program annual reports are available at www.environment.fhwa.dot.gov/ecological/eco_grant_program.asp.

[9]SHRP 2 was authorized by Congress to address some of the most pressing needs related to the nation's highway system. The Transportation Research Board administers the program under a memorandum of understanding with FHWA and the American Association of State Highway and Transportation Officials. For more information, visit www.trb.org/StrategicHighwayResearchProgram2SHRP2/Blank2.aspx.

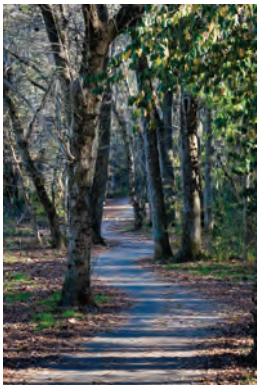


Photo: Bob Travis, Flickr

The Rivanna Trail in Charlottesville, Virginia. Existing and planned trails are among the cornerstones of the Thomas Jefferson Planning District Commission's green infrastructure plan.

Eco-Logical in Action

Through an FHWA Eco-Logical grant project, the Thomas Jefferson Planning District Commission (TJPDC) in Charlottesville, Virginia, developed a green infrastructure plan for the central Virginia metropolitan planning organization and local governments. The TJPDC staff finalized a set of GIS maps ranking mitigation sites around the region on a detailed scale appropriate for project-level planning. Staff also created a "least environmental cost analysis" framework for developing alternatives in construction projects. The input assisted in prioritizing transportation projects on the basis of potential environmental impacts during the long-range transportation planning process.

TJPDC has integrated the methodologies and maps from its Eco-Logical product into the region's long-range transportation plan, which is expected to be adopted in 2014. TJPDC continues to promote its Eco-Logical project among stakeholders, such as the Virginia Departments of Environmental Quality, Forestry, and Transportation, and hopes to work with these agencies to use an ecosystem-scale approach in selecting mitigation sites.

Implementing Eco-Logical and will become a part of the ongoing activities, initiatives, and research associated with FHWA's ongoing Eco-Logical program.

In September 2012, FHWA and the American Association of State Highway and Transportation Officials (AASHTO) met with a panel of stakeholders and experts and developed a plan to implement the Eco-Logical approach and the new SHRP 2 research through an implementation planning workshop. The final version of the implementation plan recommends six strategies to promote the adoption of the Eco-Logical approach as part of routine business practices at state DOTs, metropolitan planning organizations, and federal and state resource and regulatory agencies:

◆ Educate agency leadership about the value and benefits of the ecosystem-scale approach;

◆ Develop incentives or support for state and regional transportation agencies to adopt the Eco-Logical approach;

◆ Provide technical assistance and peer learning opportunities to educate staff-level practitioners about Eco-Logical;

◆ Develop a business case highlighting the time and cost savings associated with Implementing Eco-Logical;

◆ Develop new tools and technologies that increase or enhance access to available data and support interagency collaboration; and

◆ Develop communications and outreach materials to increase awareness about Implementing Eco-Logical and to facilitate information sharing among potential users.

These strategies form the basis for the implementation activities to be overseen and managed by FHWA and AASHTO. As a first step, FHWA and AASHTO initiated a selection process for funding through the first round of the SHRP 2 Implementation Assistance Program. In May 2013, FHWA offered six lead adopter incentives of $200,000 to $250,000, for applicants already working to adopt Eco-Logical principles, and seven user incentives of approximately $25,000 each, for applicants to begin adopting Eco-Logical or to address a challenge in adopting the approach.

After selecting the projects to be funded through the Implementation Assistance Program, FHWA and AASHTO began to pursue the other actions in the plan. FHWA will fold the implementation procedures into the Eco-Logical program as one of a suite of tools and efforts to ensure the nationwide adoption of the approach.

National Initiatives

The Eco-Logical approach has gained traction through major national policy and agency initiatives, including the Moving Ahead for Progress in the 21st Century Act (MAP-21) and Executive Order 13604: Improving Performance of Federal Permitting and Review of Infrastructure Projects. The inclusion of Eco-Logical in these initiatives is critical to mainstreaming the approach nationwide.

MAP-21

President Barack Obama signed MAP-21 into law on July 6, 2012. Many sections of the bill aim to streamline elements of the surface transportation program consistent with the Eco-Logical approach. By applying Eco-Logical, agencies will establish joint conservation priorities and mitigation opportunities well before project development, streamlining the environmental review and permitting processes.

MAP-21 emphasizes early interagency coordination and collaboration in the planning and environmental processes. Developing agency agreements for early coordination, as outlined in Section 1320, will

provide a framework for partner agencies to set joint priorities and understandings for the expedient delivery of transportation and mitigation projects. The emphasis in MAP-21 on integrating information developed in planning into the environmental review process will ensure that these joint priorities are reflected in transportation project decisions.

Eco-Logical supported the concept of "out of kind mitigation" or "mitigation–conservation banking," so that impacts to a wetland, stream, or habitat can be mitigated through the creation, restoration, or enhancement of similar wetlands, streams, or habitat within the same ecosystem. MAP-21 reemphasizes a preference for this type of mitigation, as established under the 2008 Mitigation Rule. MAP-21 also encourages programmatic mitigation plans; when agencies establish these plans at an ecosystem or watershed scale, they achieve the Eco-Logical principles of early coordination and out-of-kind mitigation.

In the past, Eco-Logical was presented as a best practice that acted on flexibilities within regulations. The formal establishment of this approach through MAP-21 provides additional leverage and opportunities for state, regional, and local governments to adopt Eco-Logical.

Executive Order 13604

Issued on March 22, 2012, Executive Order 13604 stated that federal permitting and review processes must be transparent, consistent, and predictable. The order aimed to hold agencies to performance goals by measuring the timelines for permitting and emphasized the use of cost-effective review methods. The executive order advocated early interagency collaboration, early consultation, and establishing shared agency priorities—concepts closely aligned with Eco-Logical.

To ensure implementation of Executive Order 13604, federal agencies were required to develop a federal plan and agency plans that committed to specific actions to improve the infrastructure permitting and review process. Recognizing the similarities between the executive order and the Eco-Logical approach, FHWA and the other signatory agency partners sought to incorporate Eco-Logical into the federal plan and the agency plans. As a result, the federal plan directly references Eco-Logical, and the U.S. DOT plan includes many FHWA initiatives related to Eco-Logical, including Every Day Counts, an initiative to expedite project delivery.

Next Steps

Eco-Logical began as a concept developed by a state, was cultivated at the federal level, and is now being packaged and delivered to all states, with financial incentives and technical support. The Eco-Logical approach stretches beyond a best practice and proposes a new way of doing business that will streamline the transportation process and improve environmental outcomes.

As the Eco-Logical approach matures, FHWA and its partners are working to provide support for states and regions that have adopted or are interested in adopting Eco-Logical. These opportunities are available through the implementation of SHRP 2 and through the FHWA Office of Planning, Environment, and Realty. For more information, visit FHWA's Eco-Logical website, www.environment.fhwa.dot.gov/ecological/eco_entry.asp/.

Photo: Washington State DOT

Children install native plants as part of a Washington State DOT mitigation banking project in Renton.

Creating a Multiagency Sustainability Framework for Colorado Agencies

JESSICA S. MYKLEBUST

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Conversations between agencies about sustainability can be riddled with mismatched terminology that does not translate. For example, one agency may be referring to the social, economic, and environment categories of sustainability, but another agency may be focusing on efforts involving art or wellness. Establishing a common terminology promotes the seamless integration of sustainability into projects without the barrier of variant definitions.

To facilitate positive, productive planning and the integration of sustainability into projects in Colorado, the Transportation Environmental Resource Council (TERC)[1]—a forum sponsored by the Colorado Department of Transportation (DOT)—established the Sustainability Subcommittee (TSSC). TSSC was charged with developing a common language and framework for sustainability that TERC members could use in their projects.

[1]For a complete listing of TERC members, see www.coloradodot.info/programs/environmental/transportation-environmental-resources-council-terc/terc-members.html.

PHOTO: USACE

Civil engineers from the U.S. Army Corps of Engineers Albuquerque District perform a flood risk assessment after Waldo Canyon Fire in Colorado Springs, Colorado. The district is one of the many agencies participating in the Transportation Environmental Resource Council.

Topics and Tools

A consultant team from Felsburg Holt & Ullevig, Good Company, and CH2M Hill assisted by facilitating five half-day workshops between September 2010 and April 2011. TSSC agency members from 15 state and federal agencies attended the structured, sequential series of workshops, which focused on refining and advancing internal agency principles into a meaningful sustainability framework. The topics of the workshops were as follows:

Workshop 1. Moving from Principles to Guiding Framework;

Workshop 2. Developing Performance Measures for Sustainability;

Workshop 3. Evaluating and Planning for Sustainability in Projects;

Workshop 4. Resolving Conflicts and Constructing Partnerships; and

Workshop 5. Building the Centralized Resource.

During the workshops, TSSC agreed to a common language and framework for sustainability that included three key topic areas:

- Community well-being,
- Environmental stewardship, and
- Economic vitality and quality.

Participants also agreed to a hierarchy of terms for the key topic areas, as illustrated in Figure 1 (page 29).

The five workshops included discussions on the development and dissemination of eight tools to assist agencies with integrating sustainability into their policies and projects. How and when an agency uses each tool will depend on the sustainability objectives, the regulatory context, and the extent of the current sustainability program. The tools are described in Table 1 (page 29) and are available on the web.[2]

[2]www.coloradodot.info/programs/environmental/transportation-environmental-resources-council-terc/sustainability-workshop-tools.html.

Centralized Resource

The workshop series culminated with the decision to develop a centralized resource for TSSC participants to use in maintaining progress toward sustainability. The centralized resource would provide the following:

- **Tools**, static and active, such as the eight tools developed in the workshops;
- **Experts forum**, to share files on sustainability and to receive input from other agency sustainability experts;
- **Sustainability announcements**, posting events, seminars, and workshops related to sustainability;
- **Research and development**, to keep agencies up-to-date on ongoing research and on initiatives within other agencies, to reduce redundant efforts;
- **Peer agency contacts**, an address book of sustainability contact staff;
- **Opportunities**, a list of projects with opportunities for sustainability efforts;
- **Project examples**, showing how sustainability elements have been implemented and sharing lessons learned from the projects; and
- **Funding sources**, including grant opportunities and other funding for sustainability efforts.

Foundation for Success

The TSSC considered the workshop series a success for several reasons:

1. The series produced a common language and framework for agencies in streamlining and enhancing sustainability projects, providing an effective mechanism for interagency collaboration and for success in achieving sustainability goals and objectives.

2. The series advanced individual agencies' efforts to become more effective, efficient, and elegant in their sustainability programs, benefitting agency sustainability functions internally and externally.

3. The series established a foundation for TERC to pursue sustainability efforts successfully, with tools for developing achievable goals and priorities, for determining strategic agency partners, for measuring and monitoring progress, and for prioritizing initiatives for the best use of limited funds.

FIGURE 1 Hierarchy of terms for the key topic areas of community well-being, environmental stewardship, and economic vitality and quality.

Photo: Susan Haig, U.S. Geological Survey

The Colorado Parks and Wildlife Wetlands Program funded efforts to protect the piping plover and other at-risk species.

TABLE 1 Tools Developed for TSSC Workshops to Assist Agencies with Integrating Sustainability into Policies and Projects

Tool	Value of Tool
Program Inventory and Planning Worksheet	Inventory of an agency's programs, assets, and activities under way; a baseline for comparing future sustainability activities.
Handbook to Develop Sustainability Measures	A 30-page guide for measuring sustainability and managing sustainability performance; includes practice tables to measure efforts.
Sustainability Evaluation Tool Worksheet	Spreadsheets to evaluate projects and initiatives at a high level or at a detailed, quantitative level; includes information on life-cycle analysis.
Tool to Determine Topics, Categories, and Aspects	A spreadsheet to establish short- and long-term internal and external goals, as well as to identify responsible parties, performance measures, and data sources.
Decision Flow Chart	A flow chart that provides a path for decision making when conflict arises within a project or program between sustainability measures or strategies and between agencies.
Mitigation Screening Tool	If conflict is encountered within a project or program, this matrix allows for screening the sustainability strategies to determine which is preferable.
Identifying Key Partners	A worksheet for determining the key partners to invite into the project.
Strategy Plan	An approach for breaking down identified sustainability strategies into smaller components (e.g., contracting, technologies, risk).

Recycling Materials and Techniques to Improve Sustainability

Delaware Department of Transportation's Model

JIM PAPPAS

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From project development through delivery, the Delaware Department of Transportation (DOT) works to maintain and develop an infrastructure that is a sustainable asset for current and future use. One of the goals advanced in Delaware DOT's Mission Statement of Excellence in Transportation is to "minimize the environmental impact of the state's transportation system." The agency is committed to protecting the environment and to planning, constructing, and maintaining a transportation network with increased sustainability.

For Delaware DOT, sustainability is defined as economic development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs (*1*). Most people may not associate highway construction with sustainable practices. Sustainability typically conjures up images of recycling household items such as newspapers, plastic and glass bottles, cardboard, batteries, and the like. Yet the road and bridge building industry is a beneficiary of recycled materials and industrial byproducts. Incorporating these materials into construction projects provides economic, environmental, and engineering benefits for the projects and ultimately for the users of the infrastructure by providing long-lasting roadways.

Materials and Technology

For example, for the past 20 years, Delaware DOT projects have made use of recycled asphalt pavement and more recently have incorporated other recycled materials, including asphalt shingles, concrete aggregate, tire-derived aggregate, crumb rubber, cellulose fibers, and plastic from bottles. The agency also has used industrial byproducts, such as ground, granulated blast furnace slag, silica fume, and fly ash in the portland cement concrete placed on projects.

In addition, in the past decade, Delaware DOT has specified in-place roadway reclamation and recycling operations for maintaining roadways. The process keeps pavements in place for pulverizing, stabilizing, and reshaping. The reclaimed and recycled pavement provides a base course as a stable construction platform for the overlay of pavement materials designed for the roadway. The overlay could be a surface treatment for a low-volume road or a major structural overlay for a higher-volume facility.

Delaware DOT has used two in-place reclamation and recycling techniques: full-depth reclamation and cold in-place recycling. Both techniques pulverize the pavement section to a specified depth and add a stabilizer—such as portland cement or emulsified asphalt—to produce a stabilized base for overlays appropriate to the traffic needs.

PHOTO: BLOG.UDOT.UTAH.GOV

Emulsion being added to crushed asphalt in full-depth, in-place asphalt reclamation. Delaware DOT has used this and other materials recycling techniques to "minimize the environmental impacts of the state's transportation system."

Partners and Benefits

The success of these recycled materials, industrial byproducts, and in-place reclamation and recycling technologies was achieved with support from industry partners, contractors, and the Federal Highway Administration (FHWA), which not only has provided funding but technical support. FHWA is committed to recycling; in February 2002, FHWA formalized a policy that "recycled materials should get first consideration in overall materials selection" (2).

Although not a regulation or requirement, the FHWA policy encourages states to use recycled materials or at least to review and consider the possibility of use on projects. Like many other states, Delaware DOT has determined that the use of recycled materials, industrial by-products, and in-place reclamation and recycling techniques is beneficial and has incorporated these materials and methods into projects whenever feasible.

These environmentally supportable options, however, also are key as Delaware DOT manages limited funding. The department has a fiscal responsibility to the taxpayers of the state to use funds in the most fiscally responsible way. Over the years, Delaware DOT, like many other agencies, has realized the economic benefits of an extensive recycling program—for example, significant savings have resulted from using recycled materials and industrial byproducts instead of virgin mixes with no recycled content.

Three-E Framework

The "triple bottom line" of sustainability balances economic progress, social responsibility, and environmental protection. Within the transportation industry, the phrase also refers to the three benefits of a recycling program: environment, economics, and engineering—or the three E's. The success of a recycling program is to integrate the three E's into the planning, design, construction, operation, and maintenance of a transportation network to meet the goals of an agency and the needs of the traveling public.

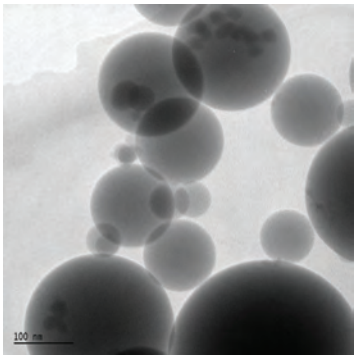
Delaware DOT's recycling program follows the three-E framework:

◆ **Environment**—By using in-place materials or reusing materials, Delaware DOT reduces aggregate mining and saves precious natural resources, reduces asphalt refining and cement production, and reduces trucking costs and emissions. Reuse saves the costs of extracting, processing, and transporting virgin materials.

◆ **Economics**—Using materials that have already been paid for reduces the costs of exporting or importing and handling. The time savings translates to additional monetary savings; moreover, the reduced exposure of workers in a construction zone increases safety.

◆ **Engineering**—Through in-place reclamation and recycling, Delaware DOT can address deteriorated pavements by stabilizing and strengthening the underlying base pavements; the stable base for overlays increases long-term pavement performance. Recycled materials and industrial byproducts, moreover, have demonstrated engineering benefits—for example, slag cement reduces the permeability of portland cement concrete.

Combining environmental, economic, and engineering benefits into the project delivery process can have a significant benefit for the transportation infrastructure. Delaware DOT understands the benefits of reusing materials in highway construction and looks for every opportunity to meet the needs of the traveling public and to apply sustainable materials and construction practices. This not only benefits users today but users in the future—a primary goal of a sustainable program.



Photos: Left, Zeiss Microscopy; right, Silcaaa/Wikimedia Commons

Delaware DOT incorporates industrial byproducts such as fly ash (*left*) and silica fume (*right*)—both shown under the microscope—into portland cement concrete used in road projects.

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Photo: Missouri DOT

Recycled materials such as asphalt shingles can be used in asphalt pavement projects.

Soundscapes

A Sustainability Approach to Transportation Noise Management

KENNETH D. POLCAK AND NICHOLAS P. MILLER

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The goal of environmental sustainability presents new challenges to traditional notions of how transportation systems and their components affect the quality of life. For transportation noise control, the shift to planning for sustainability advances the concept of the soundscape or sound environment. In this context, the quality of life is improved to the extent that the soundscape is deemed desirable—that is, appropriate for the location and the associated activity.

Traditional noise control strategies focus on one sound source at a time and target the intensity or loudness of that source. In contrast, the evaluation of a soundscape considers a multitude of sources and the desirability of their combinations.

Transportation design requires standards or guidelines, but few metrics are associated with soundscape desirability. To pursue desirable soundscapes as part of the transportation planning process, policy makers, engineers, and design professionals will need to understand subjective judgments about the sonic environment. Soundscape considerations are likely to alter the analysis and design processes, particularly in relation to noise barriers, quieter pavement, and source reduction.

PHOTO: MARYLAND SHA

Noise walls are a traditional option for noise control, but incorporating sustainability into planning requires evaluating an area's soundscape.

Role of Soundscapes

The "triple bottom line" for sustainability requires a transportation project that is economical, environmentally friendly, and improves the quality of life. All transportation modes create some level of noise for those living in the vicinity. Improvements to the soundscape must address not only the undesirable aspects of noise produced by transportation but also the preservation or restoration of the desirable sounds that are covered up or masked by transportation noise. For transportation improvements or expansions to achieve the triple bottom line, the full panoply of sounds must be considered, with the goal of preserving or restoring desirable soundscapes.

The soundscape is the total sound environment "with emphasis on the way it is perceived and understood by the individual or by a society" (*1*). In other words, a proper analysis must understand a soundscape's subjective meaning for the individuals who experience it.

Judgments of a soundscape may depend on its location and visual appearance (*2*), the type of activity or activities that occur (*3*), and the observer's personal history, expectations, emotional reaction, culture (*4*), and age (*5*). Evaluating this multiplicity of factors so that decisions can be made about soundscape improvement or preservation is a formidable challenge.

Noise Control

A three-pronged approach has guided environmental noise control and management and the noise reduction strategies for highway traffic (*6*):

- Quieting the source,
- Reducing noise along the path of transmission between the source and the receiver, and
- Land use planning.

The first two are direct abatement strategies that for a long time have been the foundation for effec-

Photo: Kenneth Spencer, Flickr

As it crosses over the campus of the Illinois Institute of Technology in Chicago, a train on the Green Line travels through a noise barrier.

tively reducing the impacts of noise in communities near transportation facilities. Whether the facility is a commuter rail line, an airport, or a major highway, the overarching efforts since the landmark environmental regulations of the early 1970s have focused on these two components in the approach to noise control. Which of the two yields the most benefits will depend on the particular mode of transportation involved and on the particular situation.

Land use planning, the third prong in the approach to transportation noise control, may be viewed as a strategy of avoidance, as opposed to abatement. For example, prohibiting new residential development along a major Interstate highway will avoid a noise impact scenario; the goal is to promote or allow only development or activity that is compatible with the level of noise in an area. Noise abatement, in contrast, would require a noise barrier for the new residential development along the Interstate.

In applying the concept of soundscape to the abatement of highway traffic noise, the focus is less on the physical reduction in the level of noise and more on how the traffic noise is perceived as a component of the sonic environment. With the trend to sustainable development and sustainability, new developments tend to be more compact, urban-oriented environs, and the spaces that are created will have soundscapes that differ from those in the more traditional living spaces that characterize many suburban or rural environments. In either case, the totality of the sonic environment and the context of the various sounds indigenous to the area may be viewed in terms of their contribution to the quality of the environment.

Quieting the Source

Automobile and truck industry efforts have made steady progress in quieting the source. The primary subsources of noise from highway vehicles—the engine, the exhaust, and the drive train—have undergone technological advances and design improvements in the past 20 to 30 years that have resulted in some noise reductions. With these advances and increasingly stringent vehicle noise standards, a clear trend to quieter vehicles—particularly in heavy trucks—is emerging in the fleet.

In addition, the development of alternative-fuel vehicles—for example, hybrid and electric—has achieved a new level of quieting at the source. Design modifications to truck engine enclosures, improved muffler systems, and other redesigned vehicle components also have yielded noise reductions.

Tire–pavement interaction is another major subsource of noise from highway vehicles—it is the primary source of traffic noise for most roads and for most vehicles at speeds above 30 mph (7). Although the physical quieting of many vehicle components has been accomplished gradually and through attrition—with older, noisier vehicles being replaced—quieter pavement technology has developed only recently.

A quieter pavement surface can result in immediate reductions or alterations of source noise. Quieter pavements perhaps are not an alternative to traditional noise barriers but offer an additional option in the noise control arsenal, despite issues with the longevity and durability of their quieting aspects.

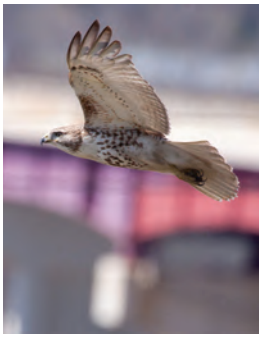

Photo: Chris Capell, Flickr

A soundscape approach masks transportation noise while allowing desirable sounds, like those of the natural environment, to be heard.

Influencing Perception

These efforts at quieting or altering the character of particular sources or subsources of noise are important to the soundscape approach. Traditional noise abatement seeks to reduce offending or unwanted sounds according to established numerical criteria or limits; in contrast, the soundscape approach focuses on the human perception of the acoustic environment and on "sounds of preference" (*8*) that contribute to human enjoyment or well-being—that is, to quality of life.

Because the soundscape concept focuses on the identification, perception, and characterization of sounds in the total aural environment, the ability to alter the character of the contributing sounds presents an opportunity to influence the perception of the sound or noise in a positive way. In an environment in which multiple sources may contribute to the overall sound energy, the perception of dominant sounds, which are judged as negative or undesirable, and of sounds that are masked or overwhelmed complicates assessments of an individual's annoyance or satisfaction.

For example, human-made sounds—such as traffic noise—that mask the natural or desirable sounds indigenous to an area or community would typically be viewed as degrading the environment. Sounds are processed differently according to an individual's culture or experience, so that the same acoustical event can yield different meanings and interpretations, depending on the situation (*9*).

Path Control

Noise reduction at the source or subsource level can be effective, depending on the transportation mode. Reductions in the overall noise effects of aircraft, for example, have resulted principally from design improvements to the engine and airframe to quiet noise, as well as from operational modifications during take-offs and landings. In contrast, highway traffic noise abatement has relied on noise barriers as the primary and most effective approach.

As noted earlier, the concept of sustainability and sustainable development fosters a design philosophy and characteristics, conditions, and practices different from more traditional development scenarios. Suburban sprawl—that is, suburban development that is centered on the single-lot, single-family dwelling—comes with a closer-to-nature atmosphere of open space, wooded areas, and backyards.

Noise barriers target the single primary noise source—for example, an adjacent highway—and provide a means of restoring or improving the soundscape by reducing the intrusive and typically dominant traffic noise and by simultaneously unmasking other desirable natural sounds in the community, such as birdsong or rustling leaves. Although not eliminated, the traffic noise can be relegated to a background component.

In a sustainable development scenario, however, a more urbanized, compact approach to housing, along with a more pedestrian and public transit orientation, fosters greater use of public spaces, producing a more complex soundscape. Multiple sound sources affect audibility and may vary in time and duration, making the assessment of the soundscapes' contribution to the quality of life challenging and complex. An assessment must include not only the A-weighted sound pressure level but also the link with psychoacoustic parameters to accommodate the multidimensional nature of perception (*10*).

Acceptable Noise

For soundscapes, the context or prevailing environment can have a substantial effect on how a particular sound is perceived. For example, a study of a major urban district in Kyoto, Japan, found that traffic noise was generally considered a positive sign of commercial activity, and rarely was characterized as an annoyance (*11*). Would traditional noise abatement strategies yield substantial benefits? In a suburban or rural context, that same traffic noise more likely would be viewed negatively, and abatement measures would be highly valued.

As the example suggests, inhabitants of more urbanized places may perceive transportation noise as less of an annoyance and perhaps more acceptable within the soundscape. As a result, the desire for transportation noise abatement in urban settings may be expected to be reduced or at least altered, depending on the characteristics of the area.

In addition, the physical parameters of the development—for example, the presence of multistory, high-rise residences—may preclude the effective use

Design modifications such as turbine chevrons can decrease aircraft noise.

Photo: MilbrneOne, Wikimedia Commons

of such traditional abatement measures as noise barriers, although absorptive or quieter pavements may be effective in reducing the prominence or at least in altering the character of the traffic noise.

Assessing Community Impact

In the suburban setting, the traditional approach to traffic noise abatement is focused on substantially reducing the noise level from the highway source. In the majority of circumstances, this approach will yield meaningful and beneficial results for the community. But when the soundscape is more complex and varied, with both positive and negative contributory sources, additional attention may be needed to preserve or enhance the soundscape according to the community's preferences. An assessment of the total soundscape, beyond the numerical noise levels, would be informative.

This more integrated approach would require more effort in assessing community impacts. Studies on soundscapes often involve surveys and questionnaires that probe the attitudes, expectations, and preferences of the community residents. The studies have found that the context of the various sounds, including both visual and sonic cues, has a major effect on the judgment of sound quality. Soundscape studies also can involve laboratory-based experiments with recorded data and statistical analysis of feedback from study participants.

Researching Soundscapes

Research comparing field measurements of quieter pavements has revealed that shifts away from the higher frequencies, to which the human ear is more sensitive, could translate into a more positive rating or perception of traffic noise as a component of the soundscape. Similarly, changes in the frequency characteristics of the traffic noise that reflects or echoes off of a building facade or other structure also could affect the perception. These shifts in frequency often are perceived as a change in the character of the noise source.

In 2004, a laboratory-based soundscape experiment explored perceptions of the effects of a roadside traffic noise barrier (*12*). Participants listened to recordings of conditions before and after a roadside noise barrier was built and were asked to determine if the randomly selected sounds were with or without the noise barrier. In addition, participants were asked to describe the cues they used to discriminate between the with-barrier and without-barrier samples.

The results indicated that the noise barrier caused perceivable changes in the soundscape and that the changes could be interpreted as positive (*13*). The primary finding was that the noise barrier made the traffic noise in the soundscape more homogeneous, or less variable, which in general is perceived as more desirable. The noise barrier reduced higher frequency sound but made difficult the identification of single vehicle pass-bys and of changes in directionality—that is, the perceived relative position of single vehicles and their direction of movement.

Photo: Ville Misaki, Flickr

In Kyoto, Japan, and other areas, traffic noise is perceived as a sign of a healthy economy and rarely is considered an annoyance.

Land Use and Soundscapes

The consideration of prevailing environmental noise conditions in land use planning—the third prong in noise reduction strategy—seeks to design or direct development compatible with the prevailing noise environment. The strategy is an exercise in avoidance—that is, avoiding the introduction of noise-sensitive activities into an already noisy environment. The approach also tends to focus on the negative aspects of the sonic environment and does not seek to change it but to adapt to it.

In applying the concept of the soundscape, the goal is to improve the relationship between the aural space and the people in the living environment (*13*). The soundscape approach includes management of the elements of the acoustic environment that are of high quality and value to people, either through acoustic design or by management of the outdoor space, much in the same way that landscape design is applied to improve visual perception of the environment (*8*).

Crafting Soundscapes

In summary, sustainable development practices require the consideration and assessment of how the

A 2004 study showed that noise walls reduce higher-frequency sounds and cause traffic noise to be perceived as more homogeneous.

PHOTO: MARYLAND SHA

physical effects of traditional traffic noise control measures affect the soundscape as a whole. The consideration of soundscape as a gauge of environmental quality, however, has an inherent complication—multiple variables, contextual and subjective, influence individuals' perceptions of the sonic environment (*9*). The context therefore includes cultural and personal preferences, sensitivities, and attitudes.

An improvement in the soundscape does not involve noise level reduction only (*9*). The challenge is to craft meaningful and effective links between the tangible—sound levels and decibel values—and the intangible, multidimensional nature of human perception.

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Judging Soundscapes

NICHOLAS P. MILLER

Soundscapes are complex. A soundscape is the all-encompassing, audible environment experienced in a specific location. In considering a soundscape's effect on quality of life, the question to answer is "How can the soundscape be judged in a way that will facilitate improvement?"

Improving Soundscapes

For decades, efforts to improve soundscapes have focused on noise control, treating a single source at a time, seeking improvement by minimizing annoyance, limiting noise as quantified by a single noise metric, such as the day–night sound level or the community noise equivalent level. This approach has been successful, so that fewer numbers of residents are exposed to higher noise levels and presumably experience less annoyance.

But consideration of the entire soundscape needs to address multiple sources, some undesirable, some desirable. The noise control approach focuses on one undesirable source at a time and does not consider desirable sounds or judge which undesirable sound most needs quieting. Improving soundscapes means reducing the noise from undesirable sources and permitting the desirable ones to be heard.

Judging Soundscapes

Just as the concept of annoyance has been used to summarize the multiple adverse effects of transportation noise on people, a simplifying subjective judgment may emerge to summarize the human factors, experiences, and emotions that influence a person's reaction to a soundscape. For instance, a soundscape's contribution to quality of life could be summarized by rating the components of the soundscape on a scale of desirability.

An example of a video for use in laboratory sound tests can be found on You Tube—see footnote on page 37.

One method of collecting this information is to survey residents to identify the sounds they hear and to rate each sound. Desirability could serve as the rating scale, ranging from –4 or extremely undesirable to +4 or extremely desirable. Figure 1 (page 37) shows hypothetical results from a survey of residents that readily distinguishes the sounds people like and those they do not. The values are cumulative, moving from undesirable at the left to desirable at the right. The more rapidly the cumulative value increases, the less desirable is the sound. Birdsong is desirable for most people, but most rate road traffic noise as undesirable.

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Guidance for Action

Two additional questions need to be asked about the ratings in Figure 1:

◆ What are the objective sound levels from each source that each respondent is rating?

◆ For each source, what is the threshold sound level separating an undesirable rating from a desirable rating?

The answers can provide noise control design goals for each source.

The type of data shown in the figure could be acquired through a mail survey, but important questions would remain unanswered:

◆ Are all respondents hearing the same sounds?
◆ What are the levels of the sounds that respondents hear?
◆ What time of day, week, or year do the ratings represent?

Proper identification of the respondent's location—and careful survey wording—could resolve some of these questions, but determining objective sound levels for each source for each person is an expensive and complicated, if not impossible, proposition.

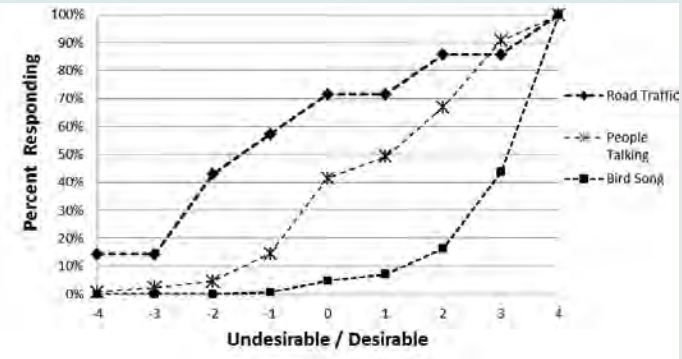

FIGURE 1 Respondent ratings of three sounds in a selected location or neighborhood: extremely undesirable to extremely desirable.

Laboratory Trials

Although collecting desirability ratings and sound levels in situ would be the gold standard for soundscape analysis, laboratory studies could associate human reactions to soundscapes with metrics of sound. Researchers have had success bringing an outdoor experience into a laboratory setting to judge outdoor sounds. The technique of using various combinations of audio and visual reproductions in the laboratory has yielded subjective evaluations that correlate closely with evaluations made in the field.

Laboratory tests could employ high-definition videos and high-quality sound to learn how people rate the components of different soundscapes, and to test the correlation of various sound metrics with the ratings.[1] The soundscapes would be constructed in the laboratory setting, from separate recordings of individual sources and of different ambient backgrounds. Patching the soundscapes together would permit accurate determination of the sound metrics of each contributing source—a disaggregation not always possible with in situ measurements.

Laboratory results, especially acquired from subjects who are not familiar with a specific soundscape, may differ from the results that derive from people who live within that soundscape. But work in the laboratory could help develop a general understanding of how people subjectively evaluate different soundscapes and the component sound sources and could test the utility of different noise metrics.

[1]An example has been uploaded to http://youtu.be/NjOIfUrFcR8. Listen with high-quality headphones for full effect.

Noise and Natural Sounds in America's National Parks

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Photo: Volpe Center

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(*Photo above*:) Aircraft overflight, Zion National Park.

In comparison with the built environment, parks and other natural settings offer a measurable difference in air quality, sounds, and open spaces. Research has shown that time spent in natural settings can improve a person's mood and sense of well-being, can increase cognitive performance and sleep quality, and can attenuate stress or response to pain. Park visitors and wildlife, however, can suffer from the adverse effects of noise from on- and off-road vehicles, as well as from military and commercial aircraft, including air tours over parks.

The National Park Service, the Federal Aviation Administration, and other organizations have been working to understand and reduce these transportation noise sources to protect the sound environments in parks. Recent work includes the following:

- Conducting research to help parks assess, predict, and minimize road noise;
- Evaluating the impact of aviation noise on a park visitor's experience; and
- Outlining a comprehensive program to evaluate the potential health benefits of the natural sounds potentially masked by road noise and aviation noise.

More information on each topic is available through the Natural Sounds and Night Skies Division of the National Park Service[1] and the U.S. Department of Transportation's Volpe Center.[2]

[1]www.nature.nps.gov/sound_night/.
[2]www.volpe.dot.gov/coi/ees/index.html.

Motorcycles and Pavements

To help parks assess, predict, and minimize road noise in the park environment, research has focused on motorcycle noise and on quieter pavements. Motorcycle noise was measured on the side of the road and in noise-sensitive locations at Blue Ridge Parkway National Park. Motorcycles were classified into five categories for inclusion in a special research version of the Federal Highway Administration's Traffic Noise Model (TNM). The model has helped in examining and understanding motorcycle noise and its effects and has contributed to informed decision making about ways to reduce motorcycle noise in a park setting.

Two documents were written to guide the use of quieter pavement types and quieter, bicycle-friendly

Photo: Volpe Center

Motorcycle traffic was studied as a potential source of controllable noise in national parks.

Photo: Volpe Center

Vehicle equipped for research on tire–pavement noise on a roadway in Death Valley National Park.

rumble strips. Another research version of TNM was generated for quieter pavements and included the noise effects of various pavement types. Tire–pavement and sensitive receiver–location noise measurements were conducted at Death Valley National Park; the measured sound levels were used with the model to demonstrate the potential effectiveness of quieter pavement in a park environment. This type of analysis can be applied to any park to determine potential noise reductions and to help in making roadway paving decisions that benefit the acoustic environment.

Judging Aviation Noise

The potential impact of aviation noise on a park visitor's experience will likely be assessed with both quantitative and qualitative criteria. Qualitative visitor responses can be related to quantitative noise exposure through mathematical expressions developed to describe the relationship between the noise exposure during a park visit and the visitor's judgment about the impact of the exposure on the quality of the experience, as stated in an on-site survey.

To develop these criteria, experts in the social sciences, natural resource management, and acoustics collaborated on the research strategies, data collection methods, and survey instruments. During the summer of 2011, more than 4,500 visitor surveys and corresponding measurements of the soundscape and aircraft noise were collected at seven backcountry locations in four national parks. In conjunction with similar data collected in the 1990s, the results were used to examine the correlation between noise exposure and subjective visitor responses.

Dose–response relationships were developed that showed the following:

◆ Noise exposure, described in terms of the equivalent sound level from aircraft during the visit, correlated well with visitor response.

◆ The visit context strongly influenced the response—visitor activity, opinion on the importance of natural quiet, time spent at the site, familiarity with the site, and the presence of children in the group were important factors.

◆ The types of aircraft generating the noise exposure dose were important—visitors reacted more negatively to helicopters than to fixed-wing aircraft, propeller planes, and high-altitude jets.

Benefits of Natural Sounds

To determine the potential benefit of natural sounds, a research approach must characterize the underlying value of the acoustical environment. This can be done through a comprehensive program based on investigation of objective, physiological outcomes, such as cognitive performance, attention, anxiety, fatigue, heart rate, blood pressure, increased productivity, and more. The aim of the program would be to

◆ Identify the physiological and behavioral responses associated with exposure to natural sounds, such as sounds of the ocean, the forest, and the desert;

◆ Evaluate the therapeutic potential of exposure to natural sounds for vulnerable populations such as veterans with posttraumatic stress or children with attention-deficit hyperactivity disorder; and

◆ Build a comprehensive base of evidence to support public policy decisions directly related to the management of soundscapes in national parks and indirectly related to health care services, air traffic management, and urban planning, among other things.

The target research population would be those who could benefit, including children, backpackers, veterans, and workers exposed to natural sounds.

Photo: Volpe Center

National park visitors complete a survey on the impact of aviation noise on their park experience.

Quieter Pavements for Roads

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As its name implies, quieter pavement is a relative term. Tire noise produced by pavements has a large range; the noise from some pavements is perceived as much louder than that from others. At highway speeds, the noise from tire–pavement interaction often determines the intensity of the traffic noise; therefore reducing this component can have a dramatic effect.

Highway agencies and the public in general have been interested in quieter pavement for more than a decade. Quieter pavement controls noise at the source—the most preferred approach—and can have lower initial costs than traditional noise barriers; moreover, quieter pavements can offer a solution when barriers may not be viable because of physical or performance limitations or a lack of cost-effectiveness.

Nevertheless, the quietness of a pavement remains relative, and if the original or proposed pavement is not considered loud, the noise reduction may be limited. The noise performance of pavements tends to degrade over time, and the quieter pavements typically degrade more quickly. Because the "acoustic longevity" is uncertain, federal policy does not consider quieter pavements as options for noise abatement.

In response to these issues, several state agencies have been conducting research and demonstration projects on the initial effectiveness, the acoustic longevity, and other properties of quieter pavements, including safety, durability, and response to climate and weathering and to other special conditions, such as exposure to studded snow tires. Applying the research results, several agencies have adopted policies on when to consider quieter pavement and on what design specifications to follow.

Photo: Bruce Rymer, Caltrans

Pavement noise measuring equipment in use by Caltrans, which also participates in the Transportation Pooled Fund Tire–Pavement Noise Research Consortium.

California and Arizona have the longest-running research programs on quieter pavements. California has documented the initial performance and acoustic longevity of both asphalt and concrete pavement surface textures for more than 10 years. Grinding concrete surfaces to reduce tire–pavement noise has become a common practice in the state. In Arizona, a pilot program with the Federal Highway Administration has monitored the performance of a rubber asphalt pavement overlay applied extensively for noise reduction in the greater Phoenix area since 2003. This quieter pavement offers the additional benefit of recycling tire rubber as an ingredient.

Although quieter pavements are gaining application in some states, more knowledge is needed. Pavements age, and their noise performance deteriorates, but the mechanisms of the effects on tire noise are not understood, nor are the means to improve a pavement's acoustic longevity. Recent projects under the National Cooperative Highway Research Program have developed a method for evaluating the life-cycle cost of quieter pavement and noise barriers[1] and for maintaining performance; the adoption and integration of these methods into practice is yet to come. Similarly, noise performance is only starting to be considered in pavement performance specifications and in pavement performance monitoring systems.

[1]www.trb.org/main/blurbs/169200.aspx.

A quiet pavement project on Route 199 near Williamsburg, Virginia.

Photo: Trevor Wrayton, Virginia DOT

Effective Noise Barriers

Case Study from North Carolina

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When the North Carolina Department of Transportation (DOT) widened a 6.2-mile corridor of I-40 west and southwest of Raleigh in 2009 to 2011, the design–build team[1] recognized several design changes that could improve the acoustical performance, aesthetic appeal, and context sensitivity of the noise wall near Jones Franklin Road. Although the wall's initial design complied with the state's 2004 traffic noise abatement policy, North Carolina DOT was amenable to the proposed changes.

I-40–Jones Franklin Road noise wall: elevation view at maintenance gap.

The western section of the initial noise wall design was approximately 40 feet beyond the top of the slope of the roadway section cut. The design–build team saw an opportunity to reduce noise levels further without increasing the wall area, by shifting the horizontal alignment of the noise wall toward the highway; North Carolina DOT approved the request.

The initially recommended design for the noise wall was based on a Federal Highway Administration Traffic Noise Model (TNM) that set the barrier segments to nominal heights; in this case, however, the irregular elevations of the horizontal alignment ground line would have created a jagged, acoustically inefficient top-of-wall profile, as depicted in Figure 1 (above right). The reevaluation revised the heights of the modeled barrier segment to set the tops of the panels to whole-foot elevations, as depicted in Figure 2 (above right). The new design not only met the requirements for acoustical performance but also achieved a more aesthetically appealing profile.

The plans for the initial project called for the full clearing of vegetation between the edge of the pavement and the right-of-way in the vicinity of the noise wall. This would have fully exposed shaded residential backyards to the sun. The revised design required clearing only the areas necessary for access by construction personnel and equipment for the construction of the noise wall; as a result, the shade cover was preserved to the greatest degree, as seen in the photograph below.

FIGURE 1 I-40–Jones Franklin Road noise wall with an initial jagged, acoustically inefficient top-of-wall profile.

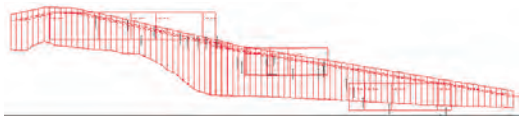

FIGURE 2 Revised Traffic Noise Model profile of I-40–Jones Franklin Road noise wall with whole-foot top-of-wall elevations.

The initial traffic noise analysis did not investigate whether the maintenance gap was technically warranted. North Carolina DOT Division 5 Maintenance and the Traffic Noise and Air Quality Group, along with the design–build team, conducted a thorough field inspection. Although the findings showed that a maintenance gap was warranted for the I-40–Jones Franklin Road noise wall, the field investigation influenced North Carolina DOT to change its practice—the agency no longer includes maintenance gaps in all lateral shifts of noise wall horizontal alignments unless the gaps are functionally necessary.

The improvements to the I-40–Jones Franklin Road noise wall, depicted in the photograph at left, confirmed the viability of many technical aspects of the 2011 North Carolina DOT traffic noise abatement policy and of the *Traffic Noise Analysis and Abatement Manual*. The 2011 policy revisions have improved confidence in noise impact determinations and abatement performance, and the public is better served with the implementation of noise abatement measures that are more effective and aesthetically appealing.

[1]S. T. Wooten Corporation,Wilson, North Carolina, and RK&K Engineers.

Bird's-eye view of I-40–Jones Franklin Road noise wall.

Sustainability in Airspace System Planning

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Much of the recent focus on sustainability for aviation has been on airports, through the development of sustainability planning documents for achieving airport-specific goals. These documents identify initiatives for improving environmental performance, such as energy-efficiency programs and Leadership in Energy and Environmental Design certification, as well as for attaining economic benefits while fostering collaborative relationships with local communities.

The scope of aviation sustainability goals and efforts, however, can expand beyond airports to the national airspace system as a whole. With evolving air transportation needs, revised traffic growth forecasts, and tighter government budgets, sustainability principles can provide insights for assessing priorities and making investment decisions. The Federal Aviation Administration's (FAA's) Next-Generation Air Traffic Management System (NextGen) offers opportunities to improve systemwide environmental performance yet balance economic and social objectives.

Systemwide Goals

FAA's most recent strategic plan, Destination 2025, recognizes the need for systemwide sustainability goals and emphasizes the agency's commitment to "ensuring America has the safest, most advanced and efficient, and sustainable aviation system in the world" (*1*). Although the previous strategic plan included environmental goals embedded within capacity goals (*2*), Destination 2025 advances a specific goal "to develop and operate an aviation system that reduces aviation's environmental and energy impacts to a level that does not constrain growth and is a model for sustainability." This represents a move toward a system-level approach to sustainability.

Destination 2025 characterizes sustainability in terms of environmental and energy goals. Sustainability often is treated as synonymous with the environmental goals of the triple bottom line, because the social and economic components typically are addressed by other means, and the motivation for a more balanced, sustainable approach was driven by a heightened awareness of environmental outcomes.

Photo: San Diego County Regional Airport Authority

Six new gates in Terminal 2 West, part of The Green Build project at San Diego International Airport in California, opened in the spring. Aviation sustainability encompasses airspace as well as airport initiatives.

In addition to the goal of environmentally oriented sustainability, Destination 2025 addresses safety, a workplace of the future, access, and global collaboration. These goals represent a complementary blend of social and economic considerations.

Although comprehensive economic guidelines call for trade-off analysis (*3*), the triple-bottom-line approach prompts a clear dialog about diverse, explicit priorities for informing decisions. This elevates social and environmental considerations that historically were difficult to quantify and offers an opportunity to reassess priorities in an evolving system. Economic and social considerations can change with the system, opening up opportunities to improve environmental performance.

Changing Priority on Delay

For instance, the emphasis on managing delay is changing, as expectations of traffic growth in the national airspace system decreased with the recent economic recession and the accompanying changes in air carriers' business models. Current aircraft operations levels are approximately 74 percent of the 2000 level (*4*) at airports with FAA and contract traffic control service. FAA's 2013 aerospace forecast estimated the number of aircraft operations in 2030 at 86 percent of the level observed in 2000 (*4*). This contrasts starkly with the high-demand growth envisioned years earlier. In 2005, 2016 was forecast at 115 percent of the 2000 levels (*5*), and the 2011 forecast predicted operations at 99 percent of the 2000 level in 2030 (*6*).

Although congestion in the national airspace system is as much a function of traffic distribution as of overall volume—some airports and airways are more capacity-constrained than others—the long-term delay problem may not be as dire as predicted. Within a framework of sustainable system planning, reductions in future anticipated delay may present an opportunity to reevaluate priorities in the context of reductions in future traffic volumes.

This scenario represents a potential shift in the relative importance of each component in the triple bottom line and could result in specific outcome goals that could lead to even greater improvements in the environmental performance of the national airspace system than those described in Destination 2025. In a future characterized by less delay, a reevaluation of priorities may elevate initiatives that were not as highly valued when the expectations of greater delay governed decision making.

Delay in the national airspace system is an economic, social, and environmental driver, raising costs and limiting system access by operators and passengers and creating negative environmental impacts through excess fuel burn. Consequently, reductions in delay typically translate into improvements in all three aspects of the triple bottom line.

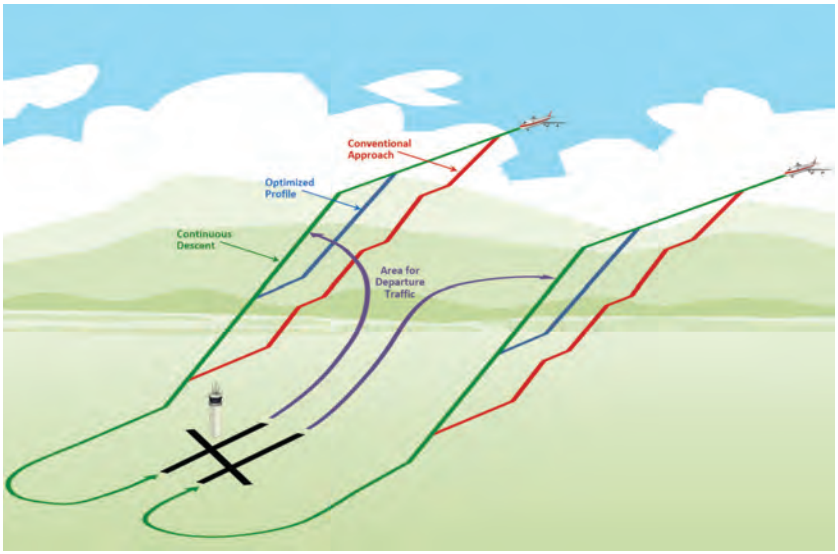

FIGURE 1 The continuous descent approach creates a conflict with traffic departing an airport. The optimized profile preserves much of the continuous descent fuel savings, without reducing capacity or increasing fuel burn for departing flights.

NextGen Trade-Offs

In some cases, however, NextGen procedures may improve environmental performance while producing no improvements or even decreases in some measures of operational efficiency. For example, continuous descent approaches for landing at airports can reduce fuel burn, emissions, and noise impacts by eliminating the level flight segments typical of conventional descent approaches (see Figure 1, above).

Level flight segments during descent, however, are often imposed to accommodate other traffic such as departures; therefore eliminating all level flight segments may adversely affect airport capacity or increase the fuel consumption by other flights. In contrast, optimized deployment of continuous descent approaches, known as optimized profile descents, represent an implicit trade-off across the triple bottom line—maintaining or maximizing throughput by allowing for some level flight segments to manage flows into and out of the airport, but eliminating the unnecessary level segments.

In the future, trade-offs within the environmental dimension may also be necessary—for example, between noise and emissions. Continuous approaches are win–win for fuel and noise, but this is not necessarily the case for all potential changes in the airspace system. Flight paths strictly designed to reduce fuel use may not be acceptable to local communities if the changes concentrate noise over sensitive areas or shift noise to areas previously unexposed. Local communities historically have placed a greater weight on noise reduction in their

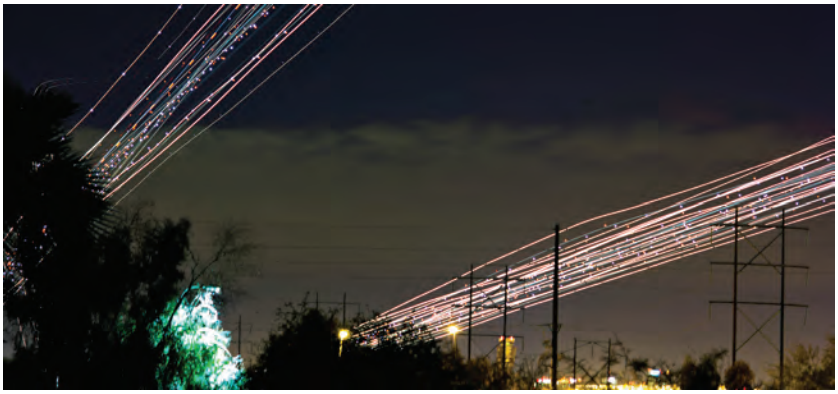

PHOTO: BJAWAK_GILA, FLICKR

Nighttime contrails from aircraft over a Phoenix, Arizona, neighborhood. Efforts to change flight paths for reduced fuel use must be balanced with the noise concerns of surrounding neighborhoods.

trade-offs—but how noise may be weighted in comparison to fuel burn, carbon dioxide emissions, and local air quality is not often explicitly addressed.

In general, translating performance trade-offs into meaningful impacts and considering their properties across the triple bottom line will facilitate improved performance in most if not all of the dimensions. Transparent, thorough trade-off analysis, along with strong collaborative relationships among stakeholders, will be critical in resolving some of these challenges.

Relevant Metrics

Addressing difficult tradeoffs and triple-bottom-line analysis of NextGen to support a reevaluation of priorities—and in general, FAA's move toward social, economic, and environmental sustainability—will require data and analytical capabilities that are integrated and consistent across NextGen programs, as well as detailed performance benchmarking and careful development of metrics across the three sustainability domains.

Much of this work to evaluate the benefits of NextGen and the expected performance improvements in the national airspace system is under way through FAA's Office of Environment and Energy and the Office of NextGen. Opportunities to improve the metrics to support system-level decision making and performance monitoring include ongoing integration of the tools for evaluating trade-offs among the sustainability objectives.

In developing metrics, a first step is to correlate with a desired outcome that FAA can control through investments and actions. For example, flight fuel consumption depends not only on FAA procedures and air traffic management concepts and technologies, but

The Sustainable Aviation Guidance Alliance

Stakeholder Collaboration Yields Practical Resources

KRISTIN LEMASTER

In 2008, a group of airport stakeholders gathered to discuss the need for an industrywide resource that could provide consistent guidance for sustainability planning and for sustainable design and construction. Individual airports had begun developing or improving sustainability plans, as well as sustainable design and construction guidelines to meet sustainability commitments.

Recognizing the duplication in many of these efforts and that many airports lacked the resources to produce sustainability documents, the volunteer stakeholder group founded the Sustainable Aviation Guidance Alliance (SAGA) to pool resources and create consistent, comprehensive, and consensus-based sustainability resources for airports. In the years since, SAGA has proved that a proactive and comprehensive stakeholder collaboration can produce tools and resources that initiate change across an industry and beyond.

SAGA sought to consolidate the available information about sustainability, including introductory material on what sustainability is and how it is applied at airports, processes for planning and maintaining sustainability programs, and sustainable design and construction practices. Participants included members from industry groups—such as the American Association of Airport Executives, Airports Council International–North America, the Airport Consultants Council (ACC), and Airlines for America—and the Federal Aviation Administration (FAA), as well as and various airports and consultants. Approximately 100 people have participated in SAGA—the planning group consisted of 20 volunteers from a diverse set of employers, 10 volunteers executed the work, and approximately 80 volunteers served as reviewers of the final products.

SAGA conducted a comprehensive literature review to identify sustainability initiatives and

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also on factors that FAA does not control, such as air carrier fleet use, operating practices, and fleet composition. Fuel burn therefore is an imperfect metric for describing the environmental performance of the air navigation service provider's operation of the national airspace system.

An example of a metric that overcomes this problem is the United Kingdom's NATS 3Di, which generates an environmental inefficiency score by comparing the trajectory flown by an aircraft with the optimal or airline-preferred trajectory (7). The metric was developed in collaboration with airlines and provides a financial incentive for NATS to improve its annual average 3Di score.

Metrics like 3Di that pinpoint system-level inefficiencies and identify specific measures to improve performance along the social, economic, and environmental dimensions could be used to assess NextGen performance. In summary, a more comprehensive understanding of national airspace system behavior can be facilitated with appropriate sustainability metrics and modeling capabilities; these metrics and models may provide better information for decision makers and may allow for more flexibility in reassessing priorities for NextGen investments.

Acknowledgments

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PHOTO © BRISBANE AIRPORT

On-time flights add to airport efficiency and environmental friendliness.

developed a process for starting, maintaining, and enhancing a sustainability program at an airport. The final products included a searchable online database of approximately 1,000 sustainability practices and a handbook for airport sustainability, the *Sustainable Aviation Resource Guide*, both of which are available on the SAGA website.[a]

The website was developed to serve as a one-stop sustainability resource for airports of varying sizes, geographies, and operating conditions. The handbook and database include content that other industries can apply—such as energy-efficiency measures. A series of conference presentations and committee announcements introduced SAGA's resources to the industry in 2009 to a favorable reception. The resources were used in FAA's development of a Sustainable Master Plan Pilot Program and received the prestigious Jay Hollingsworth Speas Award in 2011 from the American Institute of Aeronautics and Astronautics, the American Association of Airport Executives, and ACC.

Despite the practical value of the searchable database, the content was static and soon became outdated. In addition, because the database was developed through a volunteer effort in a short time, many features that would have enhanced its usability could not be included. To improve the resources, the Transportation Research Board's Airport Cooperative Research Program has launched two projects, Enhancing the Airport-Industry SAGA Website,[b] and Airport Sustainability Practices: Tools for Evaluating, Measuring, and Implementing,[c] both scheduled for completion in 2014.

PHOTO: SIMON LAW, FLICKR

Aircraft towing conserves fuel and is among the many sustainability measures employed by airports and included in the *Sustainable Aviation Resource Guide*.

[a]www.airportsustainability.org.

[b]ACRP Project 02-30, http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3031.

[c]ACRP Project 02-28, http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3029.

Reclaimed Asphalt Pavement with Steel Slag Aggregate

Successful Use in Illinois Pavements

SHEILA A. BESHEARS AND EROL TUTUMLUER

Beshears is Aggregate Technology Coordinator, Bureau of Materials and Physical Research, Illinois Department of Transportation, Springfield. Tutumluer is Professor and Paul F. Kent Endowed Faculty Scholar, Department of Civil and Environmental Engineering, University of Illinois at Urbana–Champaign.

Using recycled materials and by-products in pavements is a sustainable practice that is gaining adoption, particularly for hot-mix asphalt (HMA). HMA materials can be milled off the road surface and recycled.

Reclaimed asphalt pavement (RAP) consists of reprocessed HMA pavement material, such as asphalt and aggregates. RAP often contains high-quality, well-graded aggregates that are coated with asphalt cement but may include steel slag, a by-product of steel making. One approach is to incorporate large quantities of RAP into unbound aggregate base and subbase applications for highway construction.

Problem

Steel slag is an expansive aggregate often added when high frictional properties are required, as in HMA surface courses, particularly when good-quality aggregate is scarce. Steel slag, however, may contain free lime (CaO) and magnesia (MgO), which can react with water and cause the slag to expand.

Volume changes of up to 10 percent or more have been attributed to hydration of the calcium and magnesium oxides in the recycled steel slag aggregate base course, caused by water seeping into the pavement base layer. The amount of expansion depends on the origin of the slag, the grain size and gradation, the hydration of unslaked lime and magnesia, and the age of the stockpile.

PHOTO: ILLINOIS CENTER FOR TRANSPORTATION

Stockpile of slag aggregate.

Solution

Documentation and Research

The Illinois Center for Transportation compiled a synthesis of research results and state highway agency practices (*1*). The findings indicated that pavement structures have used RAP successfully as a granular base or subbase material and that the performance of a RAP base is often comparable to that of a crushed stone base.

The synthesis also revealed that in blending processed RAP materials with virgin aggregates, proper bearing strengths have to be attained, because the RAP bearing capacity is usually less than that of conventional granular aggregate bases. As the virgin aggregate content increases, the dry density and strength properties increase. As a result, characterizing and quantifying the expected range of RAP properties is necessary before application.

Steel slag aggregates often have favorable frictional properties, high stability, and good durability, with resistance to stripping and rutting—therefore they can perform well as base material. The conventional way to control the tendency to expand is to weather the steel slag aggregates in stockpiles until the potentially expansive systems stabilize.

The length of time for stocking depends on the local temperature and rainfall and on the degree of air moisture saturation throughout the year and may range from 3 to 12 months. Most highway departments require at least 6 months for the aging or curing of steel slags. After curing, steel slag can serve as a valuable secondary aggregate.

Project and Findings

The objective of the larger research project was to determine the expansive properties for RAP materials, especially those including recycled steel slag aggregates that could be used as pavement base materials in Illinois (*1*). Additional objectives were to determine the maximum acceptable level of expansion for different RAP aggregate types, the properties and blending proportions with virgin aggregates, and the effects that RAP materials may have on pavement performance.

In the laboratory, researchers applied ASTM Test Method D4792 to 17 Illinois RAP materials and virgin aggregates to determine expansive characteristics. Placed in California bearing ratio (CBR) test molds, the specimens were submerged in a high alkali–cement water solution with a pH of 12 at 70°C; the specimens soaked for up to 60 days to accelerate hydration reactions or until no further expansion was noted.

Some steel slag aggregates showed a potential for expansion of up to 6.2 percent, which is high compared with virgin aggregates, such as siliceous gravel and crushed dolomite, which exhibit minor or almost no expansion (Table 1, right). The lower density RAP materials often exhibited more initial settlement or contraction before any kind of expansion. Surface RAP with 92 percent steel slag aggregates and steel slag RAP recorded maximum expansions of 1.69 percent and 1.46 percent, respectively.

A clear conclusion from the expansion tests was that RAP materials with slag aggregate that was partly coated with asphalt had much lower tendencies to expand than the virgin steel slag aggregates, which showed high expansion potentials. ASTM D2940 limits expansion values to less than 0.50 percent at seven days when materials are tested in accordance with Test Method D4792. Stone matrix asphalt RAP, steel slag RAP, surface binder RAP with 60 percent steel slag aggregates, and surface RAP with 92 percent steel slag aggregates could be used as pavement base course aggregates. Porous and nonporous—that is, virgin—steel slag aggregates, however, should never be used in the bases or subbases without the proper curing specified in ASTM D2940.

TABLE 1 Summary of Average Total Expansion Values for Materials

Material	Average Total Expansion[a] (percent)	Duration of Expansion Test (days)
Virgin Steel Slag Aggregates		
Nonporous steel slag	6.18	49
Nonporous steel slag repeat	5.82	28
Porous steel slag	4.14	49
Steel slag from Illinois District 4	0.28	60
RAP with Steel Slag Aggregates		
Surface RAP (92 percent)	1.69	44
Steel slag RAP, standard composition	1.46	45
Steel slag RAP	1.13	45
Surface binder RAP (60 percent)	0.24	49
Stone Matrix Asphalt RAP	0.93	45

[a]Computed after initial settlement, if any.

Application

Illinois has used steel slag only in HMA surface mixes for years and never has allowed steel slag or RAP containing steel slag in any other layer of the pavement structure because of concerns about expansion. Like most states, Illinois is pursuing environmentally conscious practices and has started applying normal RAP for other aggregate uses, notably in the Chicago area, which has sizable stockpiles of RAP.

The results of this research led to two significant changes in the specifications:

1. Steel slag RAP is allowed in all levels of the HMA mixes.
2. Steel slag RAP can be used wherever normal RAP is used for aggregate applications.

Benefits

Although the changes to the specification are too new to project financial benefits, a few cost savings have resulted. Contractors are now able to stockpile their RAP in a single main stockpile, except when the steel slag RAP will be part of the HMA surface for the beneficial frictional properties. This frees up acreage at the contractor sites for other material.

Before this research, steel slag RAP not used within 2 years was consigned to land fill. Blending steel slag RAP with the other RAP allows the entire HMA pavement to be milled together. The performance of pavement subgrade applications with steel slag RAP is expected to equal that of pavement subgrades built with natural aggregates.

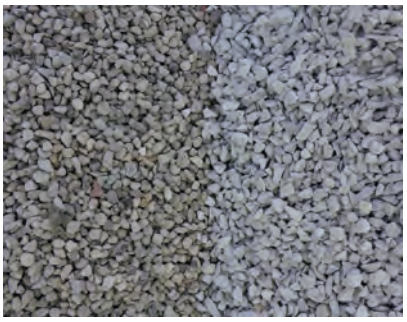

PHOTO: ILLINOIS CENTER FOR TRANSPORTATION

Slag (*left*) and virgin limestone aggregate side by side.

For more information, contact Sheila A. Beshears, Aggregate Technology Coordinator, Bureau of Materials and Physical Research, Illinois Department of Transportation, 126 East Ash Street, Springfield, IL 62704; 217-782-7086 or Sheila.Beshears@illinois.gov; or Erol Tutumluer, Professor, Paul F. Kent Endowed Faculty Scholar, Department of Civil and Environmental Engineering, 1205 Newmark Civil Engineering Laboratory, MC-250, University of Illinois at Urbana–Champaign, 205 North Mathews Avenue, Urbana, IL 61801; 217-333-8637 or tutumlue@illinois.edu.

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Suggestions for Research Pays Off topics are welcome. Contact G. P. Jayaprakash, Transportation Research Board, Keck 488, 500 Fifth Street, NW, Washington, DC 20001 (202-334-2952; gjayaprakash@nas.edu).

Richard de Neufville

Massachusetts Institute of Technology

Throughout his international teaching and consulting career, Massachusetts Institute of Technology (MIT) Professor Richard de Neufville has advanced new professional paradigms and the academic programs that support them. He has guided a shift to an engineering design approach that encompasses the way a system is managed, as well as its physical elements.

"These new paradigms are needed to deal effectively with large-scale technical systems—whose engineering design has been profoundly changing since the introduction of computers—in the context of inevitable great uncertainty about the needs the future will bring," de Neufville observes.

De Neufville received bachelor's and master's degrees, as well as a doctorate, from MIT. He served as an Airborne Ranger in the U.S. Army Corps of Engineers and, from 1965 to 1966, as a White House Fellow in the Lyndon B. Johnson Administration. Returning to MIT, he became director of the MIT Civil Engineering Systems Laboratory in 1970. In 1976, he founded the MIT Technology and Policy Program (TPP), which has become a model for interdisciplinary programs at universities across the globe, including Cambridge University in the United Kingdom and the Delft University of Technology in the Netherlands. MIT recognized de Neufville's work with TPP with an Irwin Sizer Award for the Most Significant Improvement to MIT Education.

"The future is necessarily uncertain. Thus, we have a professional obligation to design systems that can easily adapt to actual future conditions."

"The TPP recognizes our collective responsibility as technical professionals to prepare cadres of young men and women to interact effectively with the policy-making processes," he states. "We need to be sure that those who shape our world will do so with sound understanding of the technological opportunities and consequences."

In the late 1990s, de Neufville was a founding member of the MIT Engineering Systems Division, a multidisciplinary academic group that has become one of the institute's largest graduate programs. He has taught in Australia, France, Japan, Portugal, Singapore, and the United Kingdom and currently is a fellow at the University of Tokyo and at Cambridge University. De Neufville serves on the development team for the Singapore University of Technology and Design (SUTD), a new university implementing a holistic model of engineering education. The school opened in 2012.

"SUTD will give priority to a systems approach that creates broadly conceived technical products and designs," de Neufville explains. "It is a logical extension of the analytic capabilities we have been developing over the past 50 years."

In 2011, de Neufville authored *Flexibility in Engineering Design*, the first volume of the Engineering Systems series by MIT Press. The book's premise is that rigid or fixed engineering design specifications do not adapt easily to changing market demands, economic conditions, technologies, or regulations; de Neufville maintains that flexibility must be built into systems. He notes that this approach can result in a value up to 30 percent higher than expected from systems designed with fixed specifications.

"The future is necessarily uncertain. Thus, we have a professional obligation to design systems that can easily adapt to actual future conditions," he explains.

De Neufville has consulted on flexibility in design for airports, transportation systems, city infrastructure, car manufacturing, oil platforms, and power distribution. Other research areas include policy and strategic planning for public and industrial enterprises, the technical and economic assessment of large-scale projects, and airport systems planning and design. He has consulted for airports all over the world and has assisted with peer reviews of major airport projects in greater Toronto, Canada; Chicago, Illinois; New England; and Atlanta, Georgia.

De Neufville is coauthor of *Airport Systems: Planning, Design, and Management*, which McGraw-Hill recently released in a second edition. He also wrote *Applied Systems Analysis: Engineering Planning and Technology Management* (1990); *Airport Systems Planning* (1976); *Systems Planning and Design: Case Studies in Modeling, Optimization, and Evaluation* (1974); and *Systems Analysis for Engineers and Managers* (1971).

Active in TRB committees since 1971, de Neufville was a founding member of the oversight committee of the Airport Cooperative Research Program (ACRP). He served on the Aviation System Planning Committee from 1998 to 2008 and is a current member of the ACRP project panel on Incorporating Uncertainty and Risk into Airport Air Traffic Forecasting. In 2009, he received the TRB Aviation Group's Francis X. McKelvey Award in Aviation.

"The best research, in my view, thoughtfully attacks issues that may be transformative in the field," he comments. "This kind of research deliberately thinks outside the box and can be the most effective driver of positive change."

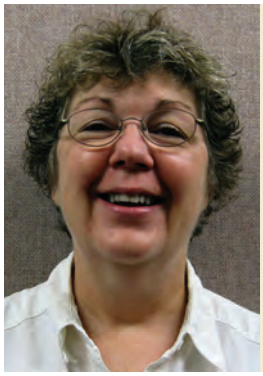
Other honors include an honorary doctorate from the Delft University of Technology and the rank of Chevalier in the Ordre des Palmes Académiques from the French government.

Elizabeth Hilton

Federal Highway Administration

After graduating from the University of Texas, Austin, with a bachelor's degree in civil engineering, Elizabeth Hilton sought a job that would allow her to stay in Austin. She soon joined the Highway Design Division of the Texas Department of Transportation (Texas DOT)—then the State Department of Highways and Public Transportation—as a roadway design engineer. Although her studies had not focused on transportation, Hilton quickly grew to love transportation engineering and public agency work.

At Texas DOT, Hilton started out developing plans, specifications, and estimates for projects in Houston and Dallas. She moved to the agency's Austin District, overseeing the plans for projects that improved mobility in the growing Austin metropolitan area. She credits her expertise in geometric design to the mentoring of early supervisors such as Harold D. Cooner.



"TRB committees have a great opportunity to work with their partners at AASHTO to make sure good research products get implemented."

Hilton's early years at Texas DOT coincided with the industry transition from hand-calculating and drafting design details to automated programs such as the Roadway Design System. Command lines and punch cards gave way to early computer graphics stations and, later, to computer-aided design and drafting software.

By then a registered professional engineer, Hilton served as Director of Field Coordination for Texas DOT's Design Division for nearly 10 years. She was then recruited to create a new plan development section for the division. Always looking for more efficient ways to develop projects, Hilton worked closely with information systems staff to improve the software products in use at Texas DOT.

As Hilton's interest in research grew, she became more involved with Texas DOT's research program and with the National Cooperative Highway Research Program (NCHRP). She managed several large research projects funded by Texas DOT, including one that calibrated the models in the American Association of State Highway and Transportation Officials' (AASHTO's) *Highway Safety Manual* for use in Texas, and developed tools to simplify the use of these models in project development. She also served on several panels for NCHRP research and synthesis projects.

"We're fortunate to have an outstanding community of researchers in the transportation field," Hilton observes. "The hardest part is getting practitioners to use completed research to improve on what they are already doing. TRB committees have a great opportunity to work with their partners at AASHTO to make sure good research products get implemented."

After retiring from Texas DOT in 2009, Hilton joined the Texas Division of the Federal Highway Administration (FHWA) as area engineer and bicycle and pedestrian coordinator. She soon joined FHWA's Design Discipline Steering Committee and provides training on compliance with the Americans with Disabilities Act of 1990 (ADA).

"FHWA is a great place to work," Hilton comments. "The agency supports its staff and is flexible enough to utilize everyone's talents to the greatest extent possible."

In 1991, Hilton joined the TRB Geometric Design Committee, combining an interest in research and geometric design with a desire to improve the state of the practice. When Committee Chair Daniel B. Fambro died suddenly in 1999, Hilton was asked to chair the committee, with transition assistance from past chair John M. Mason, Jr. "We were in the midst of paper reviews for the Annual Meeting, and I thought TRB just needed me to step in on an interim basis since my office was relatively close to Dr. Fambro in College Station. I was surprised when TRB offered me the chair appointment the following year," Hilton recalls. She served as chair until 2006 and headed up the TRB Design Section until 2012. Hilton also served on the Task Force for the Development of a Highway Safety Manual during its developmental period and through the publication of the first edition.

Reflecting on her 22-year involvement with TRB, Hilton notes, "It has been an amazing experience to work with the dedicated professionals who volunteer their time and effort to improve our profession. The relationships I have developed with other transportation professionals have been invaluable to my personal growth and my career."

Hilton also worked with FHWA to develop the Interactive Highway Safety Design Model and, in the early 2000s, represented Texas DOT on the U.S. Access Board's Public Rights-of-Way Access Advisory Committee. She is a member of the Association of Pedestrian and Bicycle Professionals.

In 2008, Hilton received the Gibb Gilchrist Award from Texas DOT for outstanding service in highway engineering.

RESEARCH TAKES OFF—The Airport Cooperative Research Program (ACRP) Oversight Committee met July 14–15 at the National Academy of Sciences building in Washington, D.C., to select projects for the Fiscal Year (FY) 2014 program. The more than 25 projects chosen include research into severe weather impacts, airport wayfinding for the elderly and persons with disabilities, noise modeling, and the Next Generation Air Transportation System.

Photo: Michael R. Salamone, TRB

COOPERATIVE RESEARCH PROGRAMS NEWS

Load and Resistance Factor Design: Minimum Flexural Reinforcement Requirements

According to the American Association of State Highway and Transportation Officials' (AASHTO's) *Load and Resistance Factor Design (LRFD) Bridge Design Specifications,* minimum reinforcement provisions provide flexural capacity greater than the cracking moment, reducing the probability of brittle failure. In pretensioned or posttensioned concrete flexural members, however, increased nominal capacity of a member can result in an increase in its cracking moment. The current minimum reinforcement requirement for posttensioned members is difficult to satisfy, makes the design process iterative, and may lead to less efficient design.

Iowa State University has received a $550,000, 38-month contract [National Cooperative Highway Research Program (NCHRP) Project 12-94, FY 2013] to propose revisions to the AASHTO *LRFD Bridge Design Specifications* minimum flexural reinforcement provisions.

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

Connecting Adjacent Precast Concrete Box Beam Bridges

A recurring problem in bridges constructed with adjacent precast prestressed concrete box beams is cracking in the longitudinal grouted joints between adjacent beams. This leads to reflective cracks in the asphalt wearing surface or concrete deck. The cracking appears to be initiated by stress; once cracking has occurred, chloride-laden water can penetrate the cracks and cause corrosion. NCHRP Synthesis 39 reported the practices used by state highway agencies for the connection details between adjacent box beams. These include partial- or full-depth grouted keyways, keyways grouted before or after transverse posttensioning, grout materials, posttensioned or nontensioned transverse ties, applied transverse posttensioning forces, and cast-in-place concrete decks or no decks. Some states were successful in reducing longitudinal cracking, but others were not.

Iowa State University has received a $450,000, 39-month contract (NCHRP Project 12-95, FY 2013) to develop guidelines for the design and construction of connection details to eliminate cracking and leakage in the longitudinal joints between adjacent boxes.

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

Measuring Pavement Roughness on Low-Speed and Urban Roads

State highway agencies use pavement smoothness—or roughness—as a gauge to monitor network condition, assess construction quality, or optimize investments in preservation, rehabilitation, and reconstruction. States use the International Roughness Index (IRI), which is calculated as the mechanical response of a generic quarter-car, traveling at 50 mph, to the elevation profile of the roadway, to measure highway performance. When used on urban roadways, however, the IRI interprets features such as drainage provisions, sudden grade changes, and crowned intersecting streets as roughness and produces varied calculations when run at slower speeds. Changes in travel speed, as well as stops or near-stops, can further distort or invalidate the measured elevation profile.

Photo: Nicole Schneider, Pedestrian and Bicycle Information Center

An NCHRP project will develop a means of measuring the pavement roughness of urban roads.

The University of Michigan, Ann Arbor, has received a $450,000, 24-month contract (NCHRP Project 10-93, FY 2013) to identify or develop a means for measuring, characterizing, and reporting pavement roughness on low-speed and urban roads.

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

Operations Center of Excellence Incorporates SHRP 2 Research

LINDA S. MASON

In September, representatives from the American Association of State Highway and Transportation Officials, the Intelligent Transportation Society of America, and the Institute of Transportation Engineers, Inc., signed a memorandum of understanding that outlines a strategy for a National Operations Center of Excellence. The center will provide technical leadership and dissemination of best practices, research, and professional education and training to practitioners, policymakers, and researchers, and will incorporate products developed in the Reliability focus area of the second Strategic Highway Research Program (SHRP 2) as its core elements.

(*Left to right:*) Intelligent Transportation Society of America President and CEO Scott Belcher, AASHTO Executive Director Bud Wright, and Institute of Transportation Engineers, Inc., Executive Director and CEO Thomas Brahms after signing a memorandum to create the National Operations Center of Excellence.

SHRP 2 products, such as the Enhanced Knowledge Transfer System, support effective transportation system management and operations to relieve congestion and improve safety and reliability. SHRP 2 Reliability work, which addressed fundamental barriers to progress and the causes of traffic congestion and unreliable travel times, now will be integrated into a substantial body of knowledge in systems operations and management to improve highway system performance. A business plan for the Center is in development.

Mason is Communications Officer, Second Strategic Highway Research Program.

BUILDING A CONFERENCE—Members of the committee for the 11th International Conference on Low-Volume Roads gathered at the National Academies' Keck Center, July 19 in Washington, D.C., to organize a program on research, practice, and technology transfer for low-volume roads. The conference goal is to foster collaboration and to increase the technical literature addressing the engineering and management problems unique to low-volume roads and roadway systems.

Conference Explores Multimodal Transportation Systems

The 2013 Barge and Rail Symposium, cosponsored by TRB, showcased innovative research on multimodal transportation to improve the speed and reliability of freight moving over the U.S. inland waterway and rail systems and to enhance the sustainability and long-term viability of multimodal freight networks. The inaugural symposium convened representatives from industry, government, and academia, August 14–16, in Louisville, Kentucky.

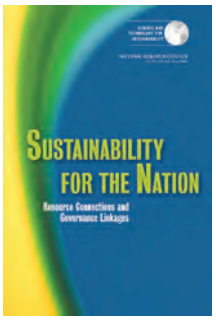
Sessions addressed such critical topics as finding new ways to leverage knowledge about transportations systems' interactions and interdependencies to streamline freight movement. Other presentations examined the steps needed to bolster multimodal efficiency. Participants also visited the Kentucky Railway Museum, McAlpine Locks and Dam, the Falls of the Ohio, and American Commercial Lines' Jeffboat Manufacturing facility.

Conference cosponsors included the Multimodal Transportation and Infrastructure Consortium, the Kentucky Transportation Center, American Commercial Lines, Genesee & Wyoming, Global Transportation Consultancy LLC, Patriot Rail, and the University of Louisville.

For more information, contact Candice Wallace (candice.wallace@uky.edu) or Amy I. Terry (amy.terry@uky.edu) at the Kentucky Transportation Center, University of Kentucky.

Sustainability for the Nation: Resource Connection and Governance Linkages

National Research Council. National Academies Press, 2013; 124 pp.; $46; 978-03-0926-230-9.



Connections between government and nongovernment groups are necessary to sustain the country's natural resources. This report presents insights into high-priority areas for governance linkages, challenges of and impediments to managing connected systems, and more. Featured examples include adaptive management on the Platte River; environmentally friendly stormwater infrastructure in Philadelphia, Pennsylvania; and managing land use in the Mojave Desert.

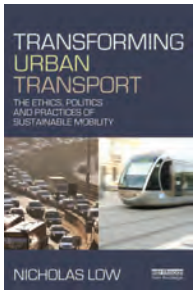
Engaging the Public in Critical Disaster Planning and Decision Making: Workshop Summary

Rapporteurs Theresa Wizemann, Megan Reeve, Bruce Altevogt. Forum on Medical and Public Health Preparedness for Catastrophic Events, Board on Health Sciences Policy, Institute of Medicine. National Academies Press, 2013; 90 pp.; preorder $42; 978-03-0928-891-0.

This summary of a March 2013 workshop addresses the key principles of public engagement during the development, response, and dissemination phases of disaster plans; practical guidance on how to plan and implement a public engagement activity; and tools to facilitate planning.

Transforming Urban Transport

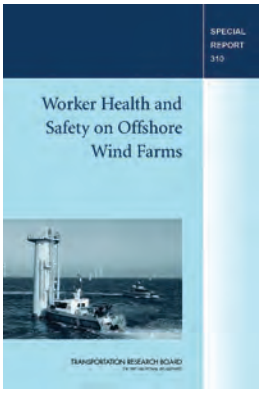
Edited by Nicholas Low. Routledge, 2013; 280 pp.; $74.95; 978-0-415-52903-7.



With examples from Australia, Japan, China, and more, this volume explores new methods of transportation governance in dispersed and concentrated cities, techniques for assessing transportation needs, ways to improve childhood mobility, guidelines for political mobilization, and knowledge-sharing norms. A companion website provides supporting material.

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

TRB PUBLICATIONS



Worker Health and Safety on Offshore Wind Farms

Special Report 310

This report examines the hazards and risks to workers on offshore wind farms on the outer continental shelf through comparisons with the hazards and risks to workers on offshore oil and gas operations; explores the gaps and overlaps in jurisdictional authority for worker health and safety; and evaluates the adequacy of the current safety management system requirements.

2013; 158 pp.; TRB affiliates, $29.25; nonaffiliates, $39. Subscriber categories: safety and human factors; marine transportation.

Meeting Critical Data Needs for Decision Making in State and Metropolitan Transportation Agencies

Conference Proceedings on the Web 9

This volume reports on presentations from a December 2011 conference on the critical role of census data in transportation planning applications. Addressed were the opportunities, limitations, and challenges involved in using census data, data available from the private sector, and data from global positioning systems and other technologies.

2013; 114 pp. Available at http://onlinepubs.trb.org/onlinepubs/conf/CPW9.pdf.

Safe Navigation in the U.S. Arctic

Conference Proceedings on the Web 11

An October 2012 workshop on navigation in the U.S. Arctic is summarized in this volume. Topics include risks of navigation in the Arctic, emergency response needs, and partnerships and international cooperation for vessel traffic management and for infrastructure improvements to enhance navigation safety.

2013; 62 pp. Available at http://onlinepubs.trb.org/onlinepubs/conf/CPW11.pdf.

TRB PUBLICATIONS *(continued)*

Urban and Traffic Data Systems 2012
Transportation Research Record 2308

Patterns of use of transportation modes, regional traffic congestion, demographic characteristics of commuters, route-specific origin–destination tables, traffic ground truth estimation, and thermal image video sensors are among the topics explored in this volume.

2012; 198 pp.; TRB affiliates, $60.75; nonaffiliates, $81. Subscriber categories: data and information technology; operations and traffic management.

Highway Design 2012
Transportation Research Record 2309

The papers in this volume address aspects of highway design, including geometric design; roadside safety; landscape and environment; context-sensitive design; hydrology, hydraulics, and water quality; and utilities.

2012; 217 pp.; TRB affiliates, $60.75; nonaffiliates, $81. Subscriber categories: design; hydraulics and hydrology; highways.

Soil Mechanics 2012
Transportation Research Record 2310

Advancing quality in geoengineering, measurements and analysis of geosynthetics in walls and pavement applications, and cementitious stabilization of problematic soils and recycled materials are subjects addressed in this volume.

2012; 144 pp.; TRB affiliates, $51.75; nonaffiliates, $69. Subscriber categories: geotechnology; pavements; bridges and other structures.

Traffic Signal Systems 2012
Transportation Research Record 2311

Authors present research on performance measures for adaptive signal control, parameters for traffic signal timing, integrated corridor traffic optimization, a portable toolbox for monitoring signal operations, transit signal priority options for bus rapid transit lines, and more.

2012; 194 pp.; TRB affiliates, $58.50; nonaffiliates, $78. Subscriber categories: operations and traffic management; safety and human factors; pedestrians and bicyclists.

Roundabouts and Emergency Evacuation 2012
Transportation Research Record 2312

Papers in this volume include research on public perceptions of roundabouts, estimating roundabout capacity, changes in evacuation decisions between hurricanes Ivan and Katrina, travel time reliability during evacuation, and modeling hurricane evacuation demand.

2012; 163 pp.; TRB affiliates, $55.50; nonaffiliates, $74. Subscriber categories: operations and traffic management; design; safety and human factors.

Structures 2012
Transportation Research Record 2313

Explored in this volume is research on general structures, steel bridges and concrete bridges, tunnels and underground structures, culverts and hydraulic structures, structural fiber-reinforced polymers, and more.

2012; 207 pp.; TRB affiliates, $60.75; nonaffiliates, $81. Subscriber categories: bridges and other structures; highways; security and emergencies.

Bicycles 2012
Transportation Research Record 2314

Electric bikes and transportation policy, flashing beacons at trail crossings, bicycle level of service, self-reported bicycling injuries and cyclists' perceived risk, and bicycle commuting are among the topics examined in this volume.

2012; 128 pp.; TRB affiliates, $51.75; nonaffiliates, $69. Subscriber category: pedestrians and bicyclists.

Traffic Flow Theory and Characteristics 2012, Vol. 1
Transportation Research Record 2315

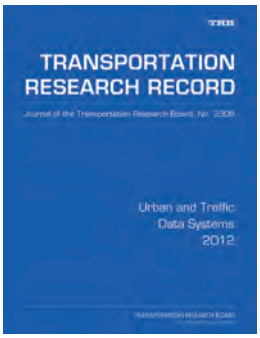
Authors present research on routing strategies, congestion probability and traffic volatility, Gipps' car-following model, travel time variability in vehicular traffic networks, estimating queue dynamics at signalized intersections from probe vehicle data, and more.

2012; 196 pp.; TRB affiliates, $60.75; nonaffiliates, $81. Subscriber categories: operations and traffic management; planning and forecasting.

Traffic Flow Theory and Characteristics 2012, Vol. 2: Driver Behavior; Pedestrian and Simulation Modeling
Transportation Research Record 2316

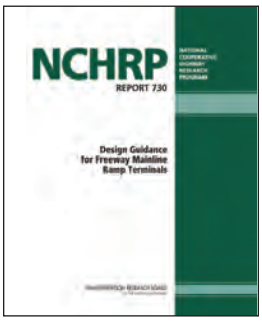
Topics addressed in this volume include driver anticipation in car following, an integrated lane change model with relaxation and synchronization, and modeling concepts for mixed traffic.

2012; 139 pp.; TRB affiliates, $51.75; nonaffiliates, $69. Subscriber categories: operations and traffic management; planning and forecasting; pedestrians and bicyclists.



The TRR Journal Online website provides electronic access to the full text of more than 13,000 peer-reviewed papers that have been published as part of the Transportation Research Record: Journal of the Transportation Research Board *(TRR Journal) series since 1996. The site includes the latest in search technologies and is updated as new TRR Journal papers become available. To explore the TRR Online service, visit www.TRB. org/ TRROnline.*

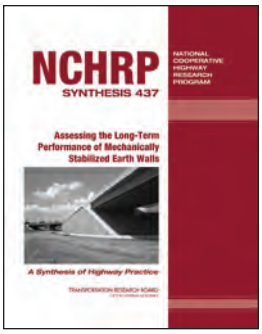
TRB PUBLICATIONS *(continued)*



Developing Countries 2012
Transportation Research Record 2317

Buses as low-carbon mobility solutions for urban India, car ownership policies in Chinese megacities, and the impact of bus rapid transit systems on road safety in Bogotá, Colombia, are among the subjects explored in this volume.

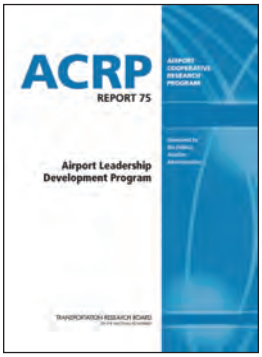
2012; 138 pp.; TRB affiliates, $51.75; nonaffiliates, $69. Subscriber categories: safety and human factors; planning and forecasting; environment.



Safety Management, Emergency Management Systems, Operator Education, School Transportation, and Older Drivers 2012
Transportation Research Record 2318

Authors present research on tools for road safety management, pricing for traffic safety, novice drivers' compliance with road rules, parental attitudes on children's active school commuting, immobility levels and mobility preferences of the elderly, and more.

2012; 147 pp.; TRB affiliates, $55.50; nonaffiliates, $74. Subscriber category: safety and human factors.



Design Guidance for Freeway Mainline Ramp Terminals
NCHRP Report 730

Guidance is presented for the design of freeway mainline ramp terminals based on driver and vehicle behavior.

2012; 120 pp.; TRB affiliates, $45; nonaffiliates, $60. Subscriber categories: highways; design.

Guidelines for Timing Yellow and All-Red Intervals at Signalized Intersections
NCHRP Report 731

Presented is a framework for signal timing that can be easily implemented by state and local transportation agencies.

2012; 83 pp.; TRB affiliates, $40.50; nonaffiliates, $54. Subscriber category: operations and traffic management.

Methodologies to Estimate the Economic Impacts of Disruptions to the Goods Movement System
NCHRP Report 732

This report addresses the impact of bottlenecks and interruptions to the flow of goods through the nation's major freight corridors and intermodal connectors, the dynamics of that flow in response to disruptions, and the full public and private economic impact.

2012; 95 pp.; TRB affiliates, $42.75; nonaffiliates, $57. Subscriber categories: economics; freight transportation; planning and forecasting.

Assessing the Long-Term Performance of Mechanically Stabilized Earth Walls
NCHRP Synthesis 437

This synthesis explores methods to assess the long-term performance of mechanically stabilized earth walls—particularly state and federal agency wall inventories—and highlights inspection and assessment methods.

2012; 48 pp.; TRB affiliates, $32.25; nonaffiliates, $43. Subscriber categories: bridges and other structures; highways; maintenance and preservation; railroads.

Expedited Procurement Procedures for Emergency Construction Services
NCHRP Synthesis 438

Examined are the procurement procedures used by state departments of transportation and federal agencies to repair and reopen roadways in emergency situations.

2012; 106 pp.; TRB affiliates, $45; nonaffiliates, $60. Subscriber categories: construction; highways; security and emergencies.

Airport Leadership Development Program
ACRP Report 75

This report provides guidance to current and future airport leaders to assess, obtain, and refine leadership skills for the airport industry. An accompanying CD-ROM includes assessment forms, PowerPoint presentations, and participant workbooks and materials.

2013; 326 pp.; TRB affiliates, $74.25; nonaffiliates, $99. Subscriber category: aviation.

Guidebook for Incorporating Sustainability into Traditional Airport Projects
ACRP Report 80

This report describes sustainability and identifies ways to apply sustainable initiatives to traditional airport construction and to everyday maintenance projects. The print edition of the report contains an airport sustainability assessment tool on CD-ROM.

2012; 93 pp.; TRB affiliates, $50.25; nonaffiliates, $67. Subscriber categories: aviation; environment.

Winter Design Storm Factor Determination for Airports
ACRP Report 81

This guidebook identifies the relevant factors in defining winter design storm factors for use in determining the size of airport deicing runoff man-

TRB PUBLICATIONS *(continued)*

agement systems and components. It also provides a decision support tool, a review of regulations, and suggestions for target levels of service.

2012; 49 pp.; TRB affiliates, $34.50; nonaffiliates, $46. Subscriber category: aviation.

Airport Wildlife Population Management
ACRP Synthesis 39

A supplement to ACRP Synthesis 23, *Bird Harassment, Repellent, and Deterrent Techniques for Use on and Near Airports*, this volume provides direct population control techniques for reducing wildlife collisions with aircraft and summarizes the ecological foundation of wildlife population control and management.

2013; 69 pp.; TRB affiliates, $39; nonaffiliates, $52. Subscriber categories: aviation; environment; security and emergencies.

Issues with Airport Organization and Reorganization
ACRP Synthesis 40

Examined in this volume are organizational design and current trends and practices in airport management.

2013; 32 pp.; TRB affiliates, $33; nonaffiliates, $44. Subscriber categories: administration and management; aviation.

Methods for Forecasting Demand and Quantifying Need for Rural Passenger Transportation: Final Workbook
TCRP Report 161

This report presents step-by-step procedures for quantifying the need for passenger transportation services and likely demand. The report is supplemented by a downloadable Excel spreadsheet and by a methodology report, *TCRP Web-Only Document 58*.

2013; 70 pp.; TRB affiliates, $39; nonaffiliates, $52. Subscriber categories: administration and management; public transportation.

Transit Station and Stop Adoption Programs
TCRP Synthesis 103

Explored are transit agency programs in which local organizations, individuals, or other partners "adopt" a transit station or stop, periodically performing duties such as removing litter, maintaining vegetation, or reporting suspicious activity.

2013; 59 pp.; TRB affiliates, $36.75; nonaffiliates, $49. Subscriber categories: policy; public transportation; safety and human factors; security and emergencies; terminals and facilities.

Use of Electronic Passenger Information Signage in Transit
TCRP Synthesis 104

This synthesis documents U.S. and international use of electronic passenger information signage in terms of the underlying technology, sign technology, characteristics of the information, resources required, and related decision processes.

2013; 100 pp.; TRB affiliates, $43.50; nonaffiliates, $58. Subscriber categories: data and information technology; public transportation; safety and human factors; security and emergencies.

Analysis of Existing Data: Prospective Views on Methodological Paradigms
SHRP 2 Report S2-S01B-RW-1

This report investigates structured modeling paradigms for the analysis of naturalistic driving data.

2012; 73 pp.; subscriber categories: highways; safety and human factors. Available at http://onlinepubs.trb.org/onlinepubs/shrp2/SHRP2_S2-S01B-RW-1.pdf.

Improving Our Understanding of How Highway Congestion and Price Affect Travel Demand
SHRP 2 Report S2-C04-RW-1

This report includes mathematical descriptions of the range of highway user behavioral responses to congestion, travel time reliability, and pricing. Explored are the effects of demographic characteristics, car occupancy, value of travel time, value of travel time reliability, situational variability, and toll aversion bias on demand and route choice.

2013; 182 pp.; subscriber categories: highways; planning and forecasting. Available at http://onlinepubs.trb.org/onlinepubs/shrp2/SHRP2_S2-C04-RW-1.pdf.

Identification of Utility Conflicts and Solutions
SHRP 2 Report S2-R15B-RW-1

Presented are matrices that enable users to organize, track, and manage the conflicts that can arise when utility lines are located under highways.

2012; 171 pp.; subscriber categories: data and information technology; highways; maintenance and preservation; planning and forecasting. Available at http://onlinepubs.trb.org/onlinepubs/shrp2/SHRP2_S2-R15B-RW-1.pdf.

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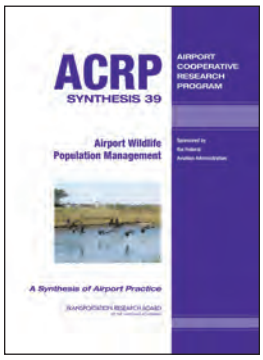

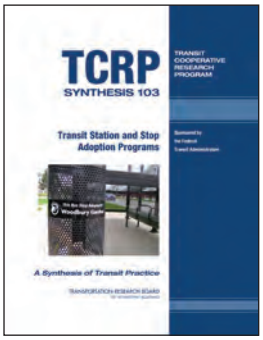

CALENDAR

TRB Meetings

December

12–15 2nd Conference of the Transportation Research Group of India*
Agra, India

2014

January

12–16 TRB 93rd Annual Meeting
Washington, D.C.
www.TRB.org/AnnualMeeting

February

4–5 Road Dust Best Management Practices Conference*
Minneapolis, Minnesota

March

3–4 Transportation Planning, Land Use and Air Quality Conference*
Charlotte, North Carolina

April

1–4 Joint Rail Conference*
Pueblo, Colorado

9–11 5th International Transportation and Economic Development Conference*
Dallas, Texas

14–16 5th International Conference on Women's Issues in Transportation*
Paris, France

14–17 Transport Research Arena Conference*
Paris, France

16–18 4th International Conference on Roundabouts
Seattle, Washington

22–25 NAFTANEXT: Energizing Sustainable Trade Corridors Across North America—The Intersection of Energy, Environment, Jobs, and Growth*
Chicago, Illinois

27–30 Innovations in Travel Demand Forecasting 2014
Baltimore, Maryland

28–30 10th National Conference on Transportation Asset Management
Miami, Florida

May

6–8 American Association of State Highway and Transportation Officials Geographic Information Systems for Transportation Symposium*
Burlington, Vermont

21–22 Development of Freight Fluidity Performance Measurements
Washington, D.C.

26–28 GeoShanghai International Conference 2014*
Shanghai, China

TBD Marine Transportation System Research and Technology Coordination Conference
Washington, D.C.

June

TBD American Society of Civil Engineers 2nd Transportation and Development Institute Congress*
Orlando, Florida

29–July 2 North American Travel Monitoring Exposition and Conference (NATMEC): Improving Traffic Data Collection, Analysis, and Use
Chicago, Illinois

July

7–11 7th International Conference on Bridge Maintenance, Safety, and Management*
Shanghai, China

9–11 5th International Conference on Surface Transportation Financing: Innovation, Experimentation, and Exploration
Irvine, California

15–18 9th International Conference on Short and Medium Span Bridges*
Calgary, Alberta, Canada

20–23 GeoHubei International Conference*
Hubei, China

21–23 14th National Conference on Transportation Planning for Small and Medium-Sized Communities: Tools of the Trade
Burlington, Vermont

Additional information on TRB meetings, including calls for abstracts, meeting registration, and hotel reservations, is available at www.TRB.org/calendar. To reach the TRB staff contacts, telephone 202-334-2934, fax 202-334-2003, or e-mail TRBMeetings@nas.edu. Meetings listed without a TRB staff contact have direct links from the TRB calendar web page.

*TRB is cosponsor of the meeting.

INFORMATION FOR CONTRIBUTORS TO

TR NEWS

TR News welcomes the submission of manuscripts for possible publication in the categories listed below. All manuscripts submitted are subject to review by the Editorial Board and other reviewers to determine suitability for *TR News*; authors will be advised of acceptance of articles with or without revision. All manuscripts accepted for publication are subject to editing for conciseness and appropriate language and style. Authors receive a copy of the edited manuscript for review. Original artwork is returned only on request.

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

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

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

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

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

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

SUBMISSION REQUIREMENTS: Manuscripts submitted for possible publication in *TR News* and any correspondence on editorial matters should be sent to the Director, Publications Office, Transportation Research Board, 500 Fifth Street, NW, Washington, DC 20001, telephone 202-334-2972, or e-mail jawan@nas.edu.

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

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

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

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