Delivering Sustainable Infrastructure: Programs and Tools

**FEDERAL HIGHWAY ADMINISTRATION**

**INFRASTRUCTURE VOLUNTARY EVALUATION SUSTAINABILITY TOOL (INVEST)**

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**ABSTRACT**

This paper and presentation will summarize an initiative by the Federal Highway Administration (FHWA), as part of their Sustainable Highways Program, to define best practices for the planning, design, construction, and operations and maintenance of sustainable highways and to develop a tool for transportation practitioners to integrate sustainability best practices into highway projects and programs.

**Introduction**

The FHWA objective is to support transportation agencies in making their projects and programs more sustainable. This FHWA initiative identifies best practices to help agencies and organizations integrate sustainability into the full range of transportation planning, project development, and operations and maintenance activities.

**Methods**

During 2010, the methods used for this initiative included research of principals and best practices for sustainable highways; conducting outreach with industry stakeholders; preparing a Compendium of Sustainable Practices, and then building a self-evaluation tool for sustainable highways. This work was developed with cooperation and input from federal, state, and local transportation agency officials, and professional organizations such as the American Association of State Highway and Transportation Officials (AASHTO) and the American Society of Civil Engineers (ASCE.)

Development of INVEST is continuing in 2011 with further input from industry stakeholders, refinement of the Tool, conducting evaluations of projects and programs using the Tool, working with a stakeholder panel, and launching a new and expanded version of the Tool.

**Results**

The principal initiative of the Sustainable Highways Program has been the launch of beta and pilot test versions of a web-based tool called the Infrastructure Voluntary Evaluation Sustainability Tool (INVEST). This tool provides three opportunities for users: to learn about sustainability, to browse the sustainable highway criteria, or to evaluate or score their own project or agency’s programs and practices. The criteria are best practices that are aligned around the sustainability triple bottom line for balancing principles relating to economic, environmental, and social equity concerns.

INVEST is a compendium of these criteria for sustainable highway projects and programs. Each criterion describes a particular best practice, the requirements to achieve points for the criterion, and sources of documentation that will likely be used to determine if the criterion was met. The criteria are organized into two broad groups: system and agency-level and project-level criteria. System and agency criteria are concerned with the management, planning, and
operations and maintenance of a roadway network. Project criteria are concerned with the development of a specific project, including planning, design, and construction.

Discussion & Conclusion

INVEST provides the first sustainability evaluation tool that encompasses the entire transportation life cycle, including system planning, project planning, design, construction, and operations and maintenance. Because this is a voluntary self-evaluation tool, agencies will determine how best to incorporate sustainability into their projects and programs. This tool affords an opportunity to develop a sustainability score that can be used to support decision-making or to share an agency's commitment to sustainability with external audiences. The Tool emphasizes a balanced, interdisciplinary approach to achieving sustainability that provides opportunities for professionals in environmental, planning, engineering, construction, and operations and maintenance fields to understand and improve sustainability performance in transportation.

The website is a first generation test version that will be refined over time to respond to the experiences of users as they review and apply it on projects and programs.

FEDERAL HIGHWAY ADMINISTRATION INFRASTRUCTURE VOLUNTARY EVALUATION SUSTAINABILITY TOOL (INVEST)

Sustainability is the capacity to serve the needs of the present without compromising the ability of future generations to meet their needs. Given diminishing economic and natural resources, sustainability initiatives have become increasingly prevalent throughout the federal government. To broaden support for sustainable transportation practices, the Federal Highway Administration (FHWA) recently established the Infrastructure Voluntary Evaluation Sustainability Tool (INVEST) to help transportation practitioners integrate sustainability best practices into highway and other roadway projects.

SUSTAINABILITY AND HIGHWAYS

Transportation projects and programs serve many different and sometimes competing objectives in addressing safety, mobility, environmental protection, livable communities, and asset management. The goal of sustainability is to help decision-makers make balanced choices among environmental, economic, and social equity concerns. These are often called the “Triple Bottom Line” of sustainability (see Figure 1).

A sustainable approach to highway planning, design, construction, operations and maintenance seeks to integrate environmental measures throughout a highway’s lifecycle to achieve economic and social equity benefits while being cost-effective. It is an important lens through which to view transportation projects and programs. It enables transportation agencies and project sponsors to make decisions that benefit the future as well as the present.

INFRASTRUCTURE VOLUNTARY EVALUATION SUSTAINABILITY TOOL (INVEST)

INVEST allows agencies to evaluate their projects against existing sustainability best practices, called criteria. The Tool is voluntary and is not intended to rank highway projects or compare transportation agencies against each other. Rather, the Tool was designed to educate and offer support to those transportation agencies interested in incorporating sustainable highways practices into their transportation projects and programs. Though measuring sustainability is an imperfect science, INVEST can help agencies learn more about sustainability practices in roadway planning, design, and construction; track and assess progress against these practices; make informed decisions about sustainability tradeoffs; and communicate highway sustainability benefits and goals to stakeholders.

The pilot test version of INVEST was released in April 2011 at http://www.sustainablehighways.org (Figure 2). The Tool is structured around a scoring function that allows state, regional, and local agencies to accumulate points based on sustainability best practices that are incorporated into a transportation project. INVEST allows an agency to review all of the criteria and select those criteria that are applicable to the project being scored. Depending on the size of the project, the tool can be applied in its basic format, which includes twenty (20) criteria, or in its extended format, consisting of thirty (30) criteria. The basic scorecard is applicable to small reconstruction and bridge replacement projects that do not expand the capacity of the roadway; preservation projects for extending the service life of existing facilities and for safety enhancements; and restoration projects for restoring pavement structure, ride quality, and spot
The extended scorecard is intended for larger projects with more significant changes and investments and therefore more opportunities to apply sustainable solutions. These include construction projects for a new roadway facility or structure as well as major reconstruction projects that add travel lanes to an existing roadway or bridge.

The score is then automatically tallied, and the project is assigned a bronze, silver, or gold-level status based on the project’s sustainability characteristics.

FHWA developed INVEST with substantial input from independent users, industry trade organizations, state transportation agencies, and the American Association of State Highway Transportation Officials (AASHTO). The Tool was presented at numerous conferences and seminars, and the FHWA project team held multiple webinars to demonstrate the INVEST’s functionality and to demonstrate how, as a voluntary tool, it can benefit decision-making and project outcomes. According to FHWA Associate Administrator Gloria Shepherd, “The feedback received from AASHTO and other stakeholders was instrumental in helping us clarify our intentions, focus the tool, and simplify the criteria and scoring process. In the pilot test version, FHWA also reiterated that using INVEST is a voluntary exercise intended to raise awareness and encourage the implementation of more sustainable practices.”

The pilot test version of INVEST will be active through 2011 with several state, regional, and local agencies testing the tool’s application using real-world projects in development. FHWA anticipates a Version 1.0 release of INVEST by early 2012. As users gain familiarity with the application, its intent, and its functionality, the Sustainable Highways Program will add two major modules related to highway planning and highway operations and maintenance.

**WHAT IS THE PURPOSE AND INTENT OF THIS TOOL?**

INVEST identifies characteristics of sustainable highways and provides information and techniques to help agencies and organizations integrate sustainability best practices into highway and other roadway projects. The Tool is intended to provide a method for practitioners to evaluate their transportation projects and to encourage progress in
sustainability. **It is not required and it is not intended to encourage comparisons across transportation agencies and projects.** FHWA is developing INVEST with ongoing input from state and local transportation agency officials and staff and professional organizations such as AASHTO and the American Society of Civil Engineers (ASCE). FHWA plans to continue to update this tool as the transportation sustainability field advances.

**WHAT IS SUSTAINABILITY?**

One way of defining sustainability is the capacity to endure.

The goal of sustainability can be described with the "triple bottom line" concept, which includes giving consideration to three primary principles: Social (also known as social equity or people), Environmental (also known as ecology, earth, or planet), and Economic (also known as money or profit). The goal of sustainability is the satisfaction of basic social and economic needs, both present and future, and the responsible use of natural resources, all while maintaining or improving the well-being of the environment on which life depends.

The concept of sustainable development was described in a 1981 White House Council on Environmental Quality report, "If economic development is to be successful over the long term, it must proceed in a way that protects the natural resource base..." The Brundtland Commission of the United Nations (1987) further defined sustainable development as "development which meets the needs of current generations without compromising the ability of future generations to meet their own needs."

**WHAT IS A SUSTAINABLE HIGHWAY?**

FHWA views sustainable highways as an integral part of sustainable development. A sustainable highway should satisfy life cycle functional requirements of societal development and economic growth while striving to enhance the natural environment and reduce consumption of natural resources. The sustainability characteristics of a highway or roadway project should be assessed and considered for implementation throughout its lifecycle, from conception through construction, operations, and maintenance.

Sustainability in highways should be addressed with the understanding that highways are one part of transportation infrastructure, and transportation is one aspect of meeting human needs. In addition to addressing environmental and natural resource needs, the development of a sustainable highway should focus on access (not just mobility), moving people and goods (not just vehicles), and providing people with transportation choices, such as safe and comfortable routes for walking, cycling, and transit.

Sustainable transportation may be described or defined in many ways that broadly address environmental, social and economic impacts including safety, affordability, and accessibility of transportation services. Transportation agencies address sustainability through a wide range of initiatives, such as Intelligent Transportation Systems (ITS), livability, smart growth, recycling, planning and environment linkages, and addressing requirements of the National Environmental Policy Act (NEPA).

Transportation planning processes that incorporate these values and integrate the elements of sustainability should be the foundation from which to implement sustainability decisions as a project moves forward. Measures of project and program success include a wide range of indicators, such as travel performance, gains achieved through material selection, and construction methods.

**WHY MEASURE SUSTAINABILITY?**

Measuring sustainability can help track and assess progress, encourage broad participation, evaluate sustainability tradeoffs, meet or anticipate new requirements, reward excellence, and communicate benefits and goals.

**Track and Assess Progress**

Measuring sustainability allows organizations to track and assess progress resulting from their sustainability efforts and investments. INVEST establishes standard and qualitative measures for sustainability that will enable agencies, organizations, program managers, and project managers to set sustainability goals, track progress, and apply management strategies.
Encourage Broad Participation in Sustainability

Measuring sustainability encourages broad participation in establishing highway sustainability goals for both agencies and projects. INVEST encourages increased application of the principles of sustainability by presenting best practices and establishing standard and qualitative measures for sustainability.

Evaluate Sustainability Tradeoffs

INVEST can help users better evaluate sustainability tradeoffs. Every highway project involves tradeoffs and decisions often become more difficult when two or more options are not directly comparable. INVEST can help with these decisions, as criteria are assigned points based on their sustainability impact.

Communicate Benefits and Goals

Measuring sustainability enables owner organizations to communicate sustainability goals and benefits to stakeholders.

HOW IS SUSTAINABILITY MEASURED?

As sustainability has gained focus in the past few decades, organizations are placing more emphasis on how to measure sustainability. One method for measuring the sustainability of highways is to assess a project against existing best practices. The sustainability best practices that are included in INVEST go beyond the basic requirements in current highway project development guidelines. Using sustainability as a metric generally means an expansion of the traditional business reporting framework to take into account social and environmental performance in addition to economic performance (the Triple Bottom Line). These three key principles should be measured, but they do not, of themselves, provide a measurement system. Therefore, many organizations are developing organization-specific or industry-specific measurement tools and best practices to help them achieve the appropriate balance across Social, Environmental and Economic principles.

What about Our Other Project Goals?

Highway and road projects are built and operated for many different reasons and are designed to accomplish many different goals. Sustainability can be thought of as encompassing the multiple goals of effective transportation projects. Safety, mobility, environmental protection, livable communities, asset management and many other objectives all have a place in sustainability. It is an important lens through which to view a transportation project, and enables transportation agencies and project sponsors to make decisions that benefit the future as well as the present. The idea of sustainability does not limit the value or importance placed on individual goals for a project or organization. Decisions about policy, projects, and operations should consider balancing the principles of sustainability, but there is no requirement to do so for every decision. INVEST provides an opportunity to consider sustainability with other performance measures in the decision making process without attempting to mandate an agency’s values or choices.

Safety

For the FHWA, safety has a unique role in sustainability as the key component of the social principle. The FHWA’s Safety Program is committed to work with state and local partners and others in the transportation community to develop and promote programs and technologies to reduce the number of fatalities and injuries on our nation’s roadways. FHWA’s emphasis on safety fits within the overall sustainability definition and recognizes that an organization may choose to emphasize specific sustainability components, such as safety. Like other important transportation objectives, safety also stands by itself as a way to measure or evaluate a project. The Highway and Traffic Safety best practices that are included in within INVEST represent the latest approaches to evaluate safety performance and mitigate risks. Using these approaches go above and beyond past methods.

WHAT IS THIS TOOL?

INVEST is a collection of sustainability best practices, called criteria, intended to help transportation practitioners measure sustainability in roadway projects. The purpose of this tool is to identify these criteria, to assist organizations in researching and applying those criteria, and to establish an evaluation method to measure the benefits and progress of sustainable highway projects.

The pilot test version of INVEST has two project scorecards for evaluation of projects. The website enables selection of the project type, which pre-identifies applicable criteria for consideration.
The two project scorecards that are available for testing include:

**Basic Scorecard**
- Small reconstruction and bridge replacement projects that do not expand capacity of the roadway
- Preservation projects (3R) for extending service life of existing facilities and for safety enhancements
- Restoration projects (2R) for restoring pavement structure, ride quality, and spot safety

**Extended Scorecard**
- New construction projects for a new roadway facility or structure where nothing of its type currently exists
- Major reconstruction projects that add travel lanes to an existing roadway or bridge

**Goals**

There are a number of important goals associated with scoring projects, including to:
- Encourage more sustainable practices in roadway planning, design, and construction;
- Provide a standard quantitative means of roadway sustainability assessment;
- Allow informed decisions and trade-offs regarding roadway sustainability;
- Enable owner organizations to recognize the benefits of sustainable road projects;
- Communicate roadway sustainability to stakeholders.

**HOW DOES IT MEASURE SUSTAINABILITY?**

INVEST is based on a collection of sustainable best practices called criteria. Each criterion describes a particular sustainable practice and assigns it a point value (or "weight") according to its relative impact on roadway sustainability. The points associated with the criteria that are achieved for a given project are added together to give a total score. That score can then be used directly for sustainability tracking, internal information, project modifications, etc.

The fundamental basis for weighting the criteria is based on both principles and benefits of sustainability.

**Principles of Sustainable Highways**

A sustainable highway should be planned or replaced, financed, designed, constructed, inspected, operated and maintained in a way that provides sustainable benefits related to three principles: **Social, Environmental, and Economic**. These principles can be metrics for evaluation, with a focus on both natural laws and human values. Natural Laws encompass the essential understanding that humans live and operate within the context of ecosystems with finite resources (the Environmental principle). Human values cover both the Social and Economic principles. The Social principle can be broadly understood as seeking quality of life for all; that is, the ultimate satisfaction of basic human needs. The Economic principle can be defined in terms of the efficient or productive use of public capital, including the need to avoid deterioration of capital assets.

Highway project development (including project planning, design, and construction) should seek to apply these principles. These principles are useful because they begin to define specific results that can be achieved by improving highway sustainability. They begin to provide distinct reasons for highway project development to incorporate such diverse concepts as climate change, environmental protection, judicious use of funds, regional air quality improvement, construction quality incentives, recycling promotion, social equity, and environmental management system use. If done effectively, the result should be more sustainable highways.

**Relating Criteria to Principles**

Each criterion can be traced to at least one of the three sustainability principles: Environment, Social, and Economic. This "mapping" is important because it provides the basis by which a criterion can be considered to contribute to sustainability (see Table 1). Criteria mapping may involve some subjective judgment; but, where practical, mapping an item back to sustainability is done using empirical evidence with proper citations. The goal is to create an evaluation system where each criterion is, to the extent possible, shown through existing research to have an impact on sustainability.

Mapping criteria to sustainability principles can assist users in selecting criteria to pursue based on the type of project or desired sustainability goals and objectives. Importantly, the nature of sustainability requires users to make trade-offs between or among different aspects of sustainability. For instance, one might have to select between using recycled material that must be trucked over a long distance or using locally provided virgin material. Both options (recycled
material vs. local material) relate to sustainability (e.g., Environmental and Economic principles). Decisions regarding these types of trade-offs are likely to be at least partly based on the specific project and the interests of its owners and stakeholders. INVEST allows users to choose from a long list of criteria to fit the specific project or goals.

Table 1: List of INVEST Project Development Criteria, Mapped by Sustainability Principle and Project Scoring Tool Categories. Source: FHWA.

<table>
<thead>
<tr>
<th>Criterion Number and Title</th>
<th>Triple Bottom Line Principles</th>
<th>Project Scoring Tool Categories</th>
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<tbody>
<tr>
<td></td>
<td>Environmental</td>
<td>Social</td>
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<tr>
<td>PD-1: Cost Benefit Analysis</td>
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<td>PD-2: Highway and Traffic Safety</td>
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<td>PD-3: Context Sensitive Project Development</td>
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<td>PD-4: Lifecycle Cost Analyses</td>
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<td>PD-6: Educational Outreach</td>
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<td>PD-7: Tracking Environmental Commitments</td>
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<tr>
<td>PD-8: Habitat Restoration</td>
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<tr>
<td>PD-9: Stormwater</td>
<td>✔</td>
<td>✔</td>
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<tr>
<td>PD-10: Ecological Connectivity</td>
<td>✔</td>
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<tr>
<td>PD-11: Recycle &amp; Reuse Materials</td>
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<td>PD-12: Create Renewable Energy</td>
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<td>PD-13: Site Vegetation</td>
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<td>PD-14: Pedestrian Access</td>
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<td>PD-15: Bicycle Access</td>
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<td>PD-16: Transit &amp; HOV Access</td>
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<td>PD-18: Scenic, Natural, or Recreational Qualities</td>
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<td>PD-27: Construction Equipment Emission Reduction</td>
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<td>PD-29: Construction Quality Control Plan</td>
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<td>PD-30: Construction Waste Management</td>
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Sample Criteria

The following is the INVEST (pilot test version) of the Habitat Restoration criterion.

**GOAL**

Offset the loss and alteration of natural (stream and terrestrial) habitat caused by road construction. Restore and protect natural habitat beyond regulatory requirements.

**REQUIREMENTS**

**3 Points:** Either of the requirements below must be met for credit. The credit can be obtained through project-specific mitigation or through the use of banking.

**Requirement 1:** For projects *required to mitigate* habitat impacts through restorative practices.
- Implement a restoration/preservation approach that restores and/or preserves more area by at least an additional 5 percent beyond what is required by law or regulation, such that the total area of restored and/or preserved habitat equals 105 percent of total required mitigation area.

**Requirement 2:** For projects *not required to mitigate* habitat impacts
- Implement a habitat restoration effort that:
  - Restores an area equal to the total disturbed surface area of the roadway project.
  - Include ecological design or engineering elements that are expected to meet the goals stated above.
  - Lists responsible parties and funding or documented commitment for restoration activities and subsequent monitoring efforts if needed.

**SOURCES**

The project is considered to have met this credit if the requirements above can be reasonably substantiated through the existence of one of the following documentation sources (or equal where not available):

1. Biological evaluation, ecological or environmental assessment, or state environmental permit documents that are based on an evaluation of the benefits to the natural system.
2. Restoration/preservation plan.
3. Completion of restoration activities or preservation coincides with, or occurs prior to, opening to traffic.
Ecology Related Criteria

While 27 of the 30 criteria have benefits to the environment, there are four that have direct ecological benefits, including:

- **PD-7: Tracking Environmental Commitments.** Goal: Ensure that environmental commitments made by the project are completed and documented in accordance with all applicable laws, regulations and issued permits.
- **PD-8: Habitat Restoration.** Goal: Offset the loss and alteration of natural (stream and terrestrial) habitat caused by road construction. Restore and protect natural habitat beyond regulatory requirements.
- **PD-9: Stormwater.** Goal: Improve stormwater quality from the impacts of the project and control flow to minimize their erosive effects on receiving waters using management methods and practices that reduce the impacts associated with development.
- **PD-10: Ecological Connectivity.** Goal: Provide or improve wildlife, amphibian, and aquatic species passage access and mobility across roadway facility boundaries.

HOW ARE THE CRITERIA ORGANIZED?

There are thirty (30) Project Development criteria in the pilot test version of INVEST. These criteria are concerned with the development of a specific project, once the general need and proposal for a solution to a transportation problem has been programmed. They involve project planning, design, and construction decisions related to a specific project.

The Project Development criteria are organized into two project scorecards that may be selected for evaluation of projects. The website has been set up to enable selection of the project type, which pre-identifies applicable criteria for consideration.

The two project scorecards that are available for testing are described in further detail below.

1. **Basic Scorecard** for Small Reconstruction/Preservation/Restoration Projects. This category is for application to smaller highway and bridge projects including: small reconstruction and bridge replacement projects that do not expand capacity of the roadway; preservation projects (3R) for extending service life of existing facilities and for safety enhancements; and restoration projects (2R) for restoring pavement structure, ride quality, and spot safety. The Basic scorecard is tailored to smaller projects that have less opportunity to apply sustainable solutions because of the project scope and scale. This Basic scorecard offers 20 sustainability best practice criteria for consideration and evaluation for projects in this category.

2. **Extended Scorecard** for New Construction/Major Reconstruction Projects. This category is for application to larger highway and bridge projects including: new construction projects for a new roadway facility or structure where nothing of its type currently exists; or major reconstruction projects that add travel lanes to an existing roadway or bridge. The Extended scorecard applies to projects that have more opportunity to apply sustainable solutions because the scope and scale of the project includes more significant changes and investments that are being made for the roadway or bridge. This Extended scorecard includes the same criteria as the Basic scorecard, plus 10 additional sustainability best practice criteria, for a total of 30 criteria.

HOW ARE THE CRITERIA WEIGHTED?

The pilot test version of INVEST includes weighting for the Project Development criteria.

The Goal

The overall goal of weighting is to make the point value for each criterion commensurate with its potential to promote sustainability.

Why Weight Criteria?

When using a set of criteria to evaluate performance toward meeting a goal, a key question is the extent to which the criteria are equally important in meeting that goal. If the criteria are of unequal importance, the measures of success can be improved by weighting the relative importance of the criteria. When assigning weights, the contribution to sustainability achieved from the worst likely outcome to the best likely outcome for one criterion should be compared to
another. In other words, larger weights are assigned to criteria that are likely to have the largest impact on sustainability from project to project.

**HOW ARE PROJECTS SCORED?**

The following steps outline the process for scoring an individual roadway project using the Project Development criteria in either the Basic or Extended Scorecard. The overall process includes gathering information about a project, reviewing criteria to see which ones to incorporate, using the online tool to create a scorecard, and then scoring the highway project. INVEST can be used to plan a project or to evaluate performance during development or after completion of the project.

**Step 1: Identify the Project Phase**

The most benefit comes from incorporating sustainability as early as possible in project development. Project development includes planning, design, and construction. Criteria are organized by phase based on the phase in which the decision to incorporate the sustainable feature or action is made, not necessarily when it is executed. If the decision to incorporate sustainability does not occur until construction, many of the criteria may be unachievable.

**Step 2: Establish the Project Context**

Every project has a unique context. The scope, setting, phase, decision processes and stakeholders affect the opportunities to incorporate sustainability on any project. Understanding the project’s context is critical to successful application of sustainability goals. Context should be viewed as both a constraint and an opportunity.

FHWA, in describing Context Sensitive Solutions, defines context as the natural or built environment created by the land, topography, natural features, buildings and associated features, land use types, and activities on property adjacent to streets and on sidewalks, and a broader area created by the surrounding neighborhood, district, or community. Context also refers to the diversity of users of the environment.

**What is the Scope?**

Project scope is the defined work that needs to be accomplished for a project. A scope is an understanding of what is to be included or excluded from a project. The project’s scope must be understood in order to determine appropriate sustainability goals and solutions. For example, an overlay project would be a good candidate for paving criteria, but solutions related to drainage or lighting may not apply.

**What is the Setting?**

The setting refers to the physical setting of the project. This includes the overall land use (urban, suburban, or rural) and the zoning (commercial, residential, or industrial). The land use adjacent to a road greatly influences the way the road is used by motorists, pedestrians and bicyclists. This must be understood to determine appropriate sustainability goals and solutions.

**Who is Affected by the Project?**

It is important to allow for meaningful participation from all stakeholders who may be affected by the project in order to consider their input in the project development decision making process. Involvement must be early, inclusive, continuous and tailored to each project in order to reach the desired outcomes for the project.

Some aspects of the project might be viewed positively by one stakeholder group and negatively by another. For example, substantial regional traffic might be a positive for the owner of an auto oriented business and a negative for the area’s residents. Descriptions of the project should use objective, value-neutral language to reflect the perspectives of all stakeholders without judging which aspects are good or bad.

Most, if not all, projects have multiple stakeholders who may have interest in guiding the application of sustainable solutions into a highway project. Each stakeholder is likely to have different opinions; not all points of view can be fully accommodated.
Where Is the Project in the Decision-Making Process?

It is important to take into account where users are in the decision-making process for any given project. Where users are in the decision process will likely have a significant influence on the types of sustainable criteria that are considered, prioritized, and incorporated into a project. For example, the choice to consider inclusion of transit lanes on a highway project must be considered early on in the understanding of the project purpose and in development and evaluation of alternatives. While later on in project development, such as in final design, the choices that remain are primarily solutions that can potentially improve sustainability in construction. The earlier these sustainability best practices can be considered in the project development process, the greater the number of sustainability concepts that can be incorporated.

What Are the Desired Outcomes of the Project?

What are the desired outcomes of the project, as defined by the stakeholders, and how do sustainability goals fit within them?

How Do You Prioritize Criteria in a Cost-Constrained Environment?

Implementing the principles of sustainability should lead to a wise and cost-effective use of resources that supports long-term benefits. This is particularly important in times of limited availability of funds. Sustainable elements should only be selected after considering their value and cost compared to the value of other sustainable elements or other important project or network features. Because financial resources are limited, all decisions to include sustainable elements necessarily involve trade-offs. Paying for some set of features means that money won’t be available for others. Evaluating the cost-effectiveness of the sustainable element is therefore critical in deciding which criteria to choose.

A cost-effective analysis is especially important when seeking to achieve multiple objectives. Sustainable elements should be considered as a whole, recognizing how they fit together to achieve the highest possible sustainable value given the funding available. Without a comparative valuation of the sustainable features, the benefits of the sustainable elements might be “sub-optimized,” in other words, achieve less than is possible. For example, project funding used for an on-site renewable energy facility that reduces energy use and emissions from operational equipment might come at the cost of not having enough funds to pay for intelligent transportation features that could reduce congestion. The energy-savings and emission reductions from the renewable energy site might be more than offset by those that could have been achieved had the funds been used to pay for ITS features that would have relieved congestion.

INVEST assumes that transportation agencies undertake this kind of analysis in making project and systems level decisions, but it does award points for more advanced efforts at cost-benefit analysis and financial sustainability.

Step 3: Find Relevant Criteria

Each criterion contains a brief description, the goal, the point value, specific requirements, and suggested sources of documentation. Initially, criteria should be evaluated to determine if they are applicable to the project.

Does the Criterion Apply to the Project Context?

Before selecting criteria that an agency could incorporate into a project, identify the context of the project and ensure that the criteria the user is selecting are consistent with that context as identified in Step 2.

It is not expected that one project will meet all the sustainability criteria included within INVEST because the context of each project is unique and applying each criterion may not fit each project’s context. For example, if the project is a highway in a developed and dense urban environment, applying solutions for ecological connectivity may not be applicable. Likewise, if the project is a rural interstate project, improving pedestrian, bicycle or transit infrastructure may not be appropriate.

Does the Criterion Meet Project and/or Agency Goals?

Selected criteria must fit the agency's strategies and approaches (for example, reducing greenhouse gas emissions). To do this, the criteria can be sorted by the benefits of sustainability. Criteria can also be sorted by sustainability principles (environmental, social, and economic) in addition to by project phase (system planning, project development, and operations and maintenance).
Are the Strategies and Approaches Achievable?

Each criterion has an overall goal, a concise statement that reflects a larger concept. For example, Reduce the overall consumption of fossil fuels by non-road construction equipment.

For each applicable criterion, evaluate the Strategies and Approaches section for examples of best practices, strategies and approaches that meet the intent of the criterion. Analyze these strategies and approaches to determine if the criterion is applicable or achievable on the project.

**Step 4: Perform a Self-Evaluation of the Project**

Once a user has selected applicable criteria they can opt to save their scorecard. This will allow users to evaluate their project using the selected criteria. Although the scorecard allows the user to filter criteria to maintain a focus on the relevant criteria, overall scoring is still based on the total points for all criteria within Project Development. Therefore, criteria eliminated when building the scorecard are still counted as not achieved and will limit the final score. The achievement levels are based upon percentages of the total available points.

For each criterion, users will be asked a question or series of questions to determine whether their project meets the scoring intent of each criterion. Based on their responses, INVEST will provide the project a score. Criteria eliminated when building the scorecard will effectively reduce the overall score that can be achieved. Users are encouraged to try different variations of criteria to determine which accomplishes greater sustainability. This is particularly important given that all projects and programs proceed under a defined budget and decisions with respect to paying for one set of criteria involve trade-offs regarding the other criteria for which no funds remain.

**WHAT DOES THE SCORE MEAN?**

INVEST can be used in a number of ways, including as a planning tool, a decision-making tool, and an evaluation tool. The user can choose to what extent to measure success against the absolute scale of how many overall points are achieved by a given project.

- INVEST may be used to score a project based on total points achieved. At this early point in its development, the Tool only contains rough estimations of the different achievement levels (including bronze, silver, gold, and platinum). These levels will need to be further refined to ensure that they are both practical and consistent. This may be accomplished as the tool is tested and evolves based on feedback. In addition, because there is not a system for third-party certifications, scores are considered an un-official recognition by FHWA that a project has met a threshold level of sustainability. In order to achieve recognition as a Sustainable Highway Project, the project evaluated must earn at least 30 percent of the total points.

These levels are subject to revision with new versions of INVEST and may change in the future as the Tool is updated.

As INVEST is tested and knowledge of sustainable practices increases in the transportation community, FHWA intends to validate and revise the graded recognition levels.

**Achievement Levels**

The total points a project earns can be compared to a number of “achievement levels” that serve as relative benchmarks for sustainability achievement. At this early point in its development, these achievement levels have been set initially but have not yet been calibrated (see Table 2). Over time, achievement levels may change to ensure that they are both practical and consistent. This may be accomplished as the tool is tested and evolves based on feedback. In addition, because there is not a system for third-party certifications, scores are considered an un-official recognition by FHWA that an agency or project has met the threshold level of sustainability. The general logic is:

- **BRONZE.** Earn at least 30% of the available points.
- **SILVER.** Earn at least 40% of the available points.
- **GOLD.** Earn at least 50% of the available points.
- **PLATINUM.** Earn at least 60% of the available points.
Table 2: Number of Points Required for Each Achievement Level and Scorecard. Source: FHWA.

<table>
<thead>
<tr>
<th>Achievement Level</th>
<th>Number of Points Required for Each Level</th>
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<tr>
<td></td>
<td>Basic Scorecard</td>
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<td>Total # Points</td>
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<td>BRONZE (30%)</td>
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<td>SILVER (40%)</td>
<td>34</td>
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<tr>
<td>GOLD (50%)</td>
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<tr>
<td>PLATINUM (60%)</td>
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</tr>
</tbody>
</table>

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Michael Culp is the Team Leader for the Sustainable Transport and Climate Change Team in the FHWA Office of Natural Environment in Washington, DC. He leads policy development and program initiatives relating to sustainability, climate change adaptation and mitigation. He has 18 years of experience with FHWA, focusing primarily on planning and environmental programs and policy. Michael holds a B.S. in Civil Engineering and an M.A. in Transportation Policy.

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**Sustainability in Project Delivery at ODOT**

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**INTRODUCTION**

The Oregon Department of Transportation’s (ODOT’s) long-standing commitment to sustainability is outlined in the Oregon Transportation Plan, ODOT’s values statements, and the ODOT Sustainability Plan. ODOT is working hard to integrate sustainability into its day-to-day business practices and to develop a culture of sustainability that emanates throughout the entire agency.

The agency created a multi-volume Sustainability Plan that addresses the sustainable functions of ODOT’s internal operations and the management of the broader transportation system. At this time, Volumes I and II of the plan are complete and are being put into practice throughout the agency. Volume I outlines what sustainability means to ODOT. The development of Volume I was essential for laying the groundwork of sustainability at ODOT. This context setting document is needed before taking on the complex issues of setting specific goals and performance measures for sustainability at ODOT.

Volume II sets goals, strategies, and performance measures for ODOT’s internal operations, such as its facilities and fleet. Volume III, in development, will focus on the sustainable management of the statewide transportation system. A key piece of Volume III is incorporating sustainability into ODOT’s design and construction practices, often referred to as project delivery.

To address this need, ODOT convened a Sustainability in Project Delivery Committee. The committee is composed of ODOT staff with a wide-range of expertise. Members include the State Maintenance Engineer, State Materials and Construction Manager, a Region Manager, and representatives from Geo-Environmental, the Bridge Delivery Unit, the Director's Office, and Technical Services.

Over the first few meetings the committee worked on developing a work plan and identifying the main tasks for its work. The following are the four main tasks for the committee:

1) Define what sustainability means for ODOT project delivery;
2) Continue momentum of current sustainability practices and measures already occurring in project delivery, OTIA III Bridge Program and Greenroads;
3) Effectively communicate about sustainability within project delivery, both internally and externally; and
4) Determine the best tools to manage and implement sustainability within projects.

**BACKGROUND OF PROJECT-LEVEL SUSTAINABILITY AT ODOT**

Incorporating sustainable measures into ODOT projects is not a new concept. ODOT's Oregon Transportation Investment Act (OTIA) Bridge Program and ODOT's pilot of the Greenroads Rating System (hereinafter “Greenroads”) represent two examples of how ODOT was already starting to work on project-level sustainability prior to convening the committee. Both programs incorporate sustainability measures at a project-level, so by taking a closer examination the committee was able to formulat some lessons learned. The following two sub-sections give a brief overview of how these programs demonstrate sustainability on the project-level.

**OTIA III Bridge Program**

The Oregon State Legislature passed House Bill 2041, funding the third OTIA program in 2003. This program provided $1.3 billion in bonds to repair or replace hundreds of aging bridges on the state highway system, known officially as the OTIA III State Bridge Delivery Program. One of the explicit goals of the program was to repair bridges in a sustainable manner.

ODOT’s Context Sensitive and Sustainable Solutions (CS³) approach was developed for the OTIA III program. CS³ incorporates sustainability at the project-level in a number of ways such as reusing materials, using renewable low-
carbon fuels, promoting workforce development, and using life cycle costing to inform decision-making. CS³ allows ODOT to build the most sustainable bridges possible in a context-sensitive manner.

Many of the bridges in the OTIA III Program are either finished or in the construction phase and the agency is already learning valuable lessons from the program. The OTIA III program highlighted some of the complexity and difficulty in data collection for performance measures, in particular for tracking the reuse and recycling of construction materials. A few of the lesson learned from the Construction Waste Management (CWM) process and tracking the reuse, recycling, and disposal of materials, include:

1) Many construction contractors are not appropriately bidding this CWM work and therefore, ODOT and the Oregon Bridge Delivery Partners (OBDP) do not necessarily have the monetary means to require contract compliance. ODOT is working on a process to obtain better contract compliance.

2) A questionnaire was sent to all contractors in 2010; the most frequent comment from contractors was that the CWM program was onerous on paperwork.

3) For the first few years of the CWM program, reporting on reuse, recycling, and disposal amounts was done at the end of each year, this meant contractors really did not have to think about what they did with their waste except for one time a year. Starting in 2009-2010, quarterly reporting was required by contractors, now ODOT and OBDP are receiving more accurate reporting numbers and are able to correct reporting mistakes during the year, instead of waiting until the end of the year (Underwood 2011, 34).

Now in the eighth year of the program, the agency is beginning to see some more accurate data on reuse and recycling and other sustainable performance standards. The committee is looking at these lessons learned to create an approach that can be used agency-wide.

One of the success stories or results from the OTIA III program was that many of the performance standards were incorporated into the 2008 ODOT standard specifications. They are now contract requirements that will apply to all future ODOT projects. Some of the now-adopted specifications include:

- Idling restrictions for diesel engines;
- Requirement to prioritize reuse over recycling and recycling over disposal, unless reuse and recycling are infeasible, i.e. there is no facility able to take the material or the cost of transportation plus reuse/recycling exceeds the cost of disposal;
- Requirement to provide reuse, recycling, and disposal options selected in the pollution control plan along with estimated amounts and justification for the options selected; and
- Requirement to locate staging areas away from sensitive populations.

The OTIA III Program is a great example of how sustainability can be integrated into ODOT’s projects; however it also highlights where there is more work to be done. ODOT must continue to develop a more streamlined process of implementing sustainability into its project delivery process; including developing a tool so everyone involved on a project is aware of the expectations for sustainability, and creating a more accurate and user friendly mechanism for tracking performance. This program is also a great example of how ODOT worked with the construction community to implement sustainable practices, while still keeping a balance so as not to interfere with on time project delivery.

Greenroads

ODOT is currently in the process of evaluating a few pilot projects, in various levels of completion, based on the Greenroads sustainability performance metric. Greenroads was developed out of the University of Washington in consultation with CH2M HILL. The Greenroads performance metric awards points for more sustainable practices during the design and construction phases of roadway projects and awards a certification level based on the number of points earned, much like the LEED program does for buildings.

While flexibility is a huge part of Greenroads, eleven Project Requirements must be completed for certification. These requirements are:

- Environmental Review Process
- Lifecycle Cost Analysis
- Lifecycle Inventory
- Quality Control Plan
- Noise Mitigation Plan
• Waste Management Plan
• Pollution Prevention Plan
• Low-Impact Development
• Pavement Management System
• Site Maintenance Plan
• Educational Outreach

There are also a number of “Voluntary Credits” that a project team can choose to pursue or not. The points associated with the Voluntary Credits achieved are added together to give a final Greenroads score. The Voluntary Credits are divided into the categories of:

• Environment & Water
• Access & Equity
• Construction Activities
• Materials & Resources
• Pavement Technologies

Each Voluntary Credit is awarded a point value (from 1 to 5) based on its weighted relative impact to sustainability. Certification level is based upon the completion of the eleven requirements and the total voluntary points earned by the project.

Many of these requirements and credit categories align with the seven focus areas of the ODOT Sustainability Plan and ODOT’s vision for sustainability within project delivery. These Greenroads pilots are helping ODOT tangibly assess how sustainable its projects are, while still being consistent with ODOT’s values and Sustainability Plan.

The three projects chosen for these pilots were at different stages in project delivery, but all were already through the initial design phase. Although the Greenroads metric did not influence design decisions, project managers and teams have indicated various benefits to using a performance metric. Initial results from using Greenroads on two of three ODOT pilot projects (the third will be finished by the conference) illustrated to the committee that:

1) ODOT project staff liked getting feedback from a checklist and getting “credit” for their sustainability work.  
2) Another benefit was receiving local press and local interest in the project, and using it as a communication tool.  
3) ODOT scored favorably in Greenroads without making too many modifications to its practices. However, to get the most amount of points, ODOT would have to change its practices in some key areas or “weak areas”.  
4) The Greenroads process is somewhat cumbersome and expansive. For widespread use in the agency, Greenroads needs to become more efficient and streamlined to apply statewide, or should only be used on ODOT’s larger, more visible projects to maximize the benefits of using such a tool.

These pilots are shaping ODOT’s current thinking about sustainability at the project-level. In fact, the committee is exploring the idea of using some sort of checklist for project teams, a more simplified version of Greenroads that is more targeted to specific project types. ODOT and the committee are still exploring this concept, but thus far, feedback from the pilots demonstrates the clear benefits of a tool like Greenroads. Finally, a tool like Greenroads may be useful for some of ODOT’s larger, more visible projects, especially in terms of communicating with the public and stakeholders about the project’s sustainability features.

**PROCESS**

**Strategy Review and Development**

One of the first activities performed by the committee was to review the sustainable strategies from various performance metrics, including Greenroads, the FHWA Sustainable Highway Self-Evaluation Tool (INVEST), STARS, and GreenLITES; and take inventory of the sustainable strategies already used on ODOT projects. These tools and their strategies were compared and contrasted by the committee. Based on the criteria and credits in these tools, the committee developed a list of potential strategies for use on ODOT projects which most align with the ODOT Sustainability Plan.

Many of the sustainability performance metrics have very similar strategies, encompassing the general themes of reducing waste, maximizing resources and efficiencies, and considering the community and environmental context of a
project. When making a list of potential strategies for use on ODOT projects the committee selected strategies that fit within the ODOT mission and the way the agency does business.

**Program vs. Project Level Discussion**

One of the big issues the Sustainability in Project Delivery Committee has been grappling with is determining at what level sustainability should be addressed, the program-level or project-level. In order to help answer this question, we asked all of the committee members to complete a survey. On the survey the committee was asked: “Is this strategy best addressed at a program- or project-level?”

For the survey, program-level was considered for those strategies that are best implemented early on, before a project is assigned a project team. These strategies are agency-wide and could be made by changes to ODOT’s specifications, guidelines, policies or directive. Project-level strategies are those that are decided upon and implemented by the project team and tailored to fit the physical, financial and regional characteristics of a single project. Project-level decisions are made starting in preliminary engineering and through construction for a project.

The results for the survey were quite interesting, and demonstrated that there was no clear agreement on which strategies should be handled on a program- or project-level. In fact, for 11 out of the 30 potential strategies on the survey, comments from the committee explicitly stated the strategies should be implemented on both a program- and project-level. Other key findings include:

- Many responses highlighted the need for flexibility and context considerations, therefore a project-level implementation would be the best option.
- Expressed a need to establish program-level standards to set policy (general wording) but decisions on how individual strategies should be actually be implemented should be made at the project-level (i.e., agreements with the construction contractors).
- There are some strategies like, “ensuring that bridge crossings span the functional floodplain” and “instituting environmental monitors for projects”, that should be included in programmatic permitting agreements with partner resource agencies.

Although the Sustainability in Project Delivery Committee has not finished its work, this survey exercise and the discussions at the various committee meetings underline that sustainable strategies will need to be addressed at both the program- and project-level. This process also emphasized that ODOT staff have varying opinions as to how strategies should be implemented, and it seems as though this is based quite a bit on the position within ODOT the member holds.

**Definition of Sustainability in Project Delivery**

As the committee continued its discussion on potential strategies and program- or project-level implementation, many members also expressed the need to define sustainability in terms of project delivery. The first step in developing a definition for sustainability in project delivery was to look at ODOT’s existing policies and definitions of sustainability. These existing definitions include the Oregon Sustainability Act of 2001 (ORS 184.421), Goal 4 (Sustainability) of the Oregon Transportation Plan, and the ODOT “Sustainability” Value Statement, which was adopted in 2010.

Next the committee looked through the Project Delivery Leadership Team Operational Notices, which outline many of the basic functions, responsibilities, and guidance of the Project Delivery Unit. There are quite a few references to sustainability topics embedded in these Operational Notices, and the definition that the committee wrote, embodies those that are particularly important for delivering sustainable projects. Below is the definition of sustainability for project delivery, as decided upon by the committee:

For ODOT, sustainability within project delivery means we are responsible for making development and construction decisions to ensure projects are focused on balancing economic, environmental, and community well-being in a manner that protects the needs of current and future generations, and accounting for the following values:

- Maintaining or Improving traffic mobility, safety, and access across all modes
- Stimulating Oregon's economy, and developing a diverse workforce
- Employing cost-effective, innovative and efficient solutions
- Optimizing the system through life cycle cost considerations
- Being environmentally responsible, encouraging conservation and protection of natural resources
Being sensitive to community and social values
- Taking opportunities to capitalize on innovative funding opportunities which support a viable transportation system
- Providing equitable transportation solutions
- Reducing fossil fuel consumption and greenhouse gas emissions
- Minimizing waste during construction

This definition is the foundation of ODOT’s effort, regardless if sustainability is implemented at a program- or project-level. This definition is consistent with ODOT’s broader sustainability value statement, but also gives clear direction as to how sustainability applies to project delivery.

Self-Assessment

Another step the committee completed was to do a self-assessment of the agency’s progress in implementing the list of identified sustainable strategies. This was necessary because there was a feeling by some of the committee members that ODOT was already doing all of these sustainable measures, and really there was little point to use a checklist or some other type of sustainability tool. In order to get a clearer picture of where ODOT is in terms of sustainability in its project delivery, the committee was asked to participate in a self-assessment exercise.

The members were asked to fill-in a spreadsheet, filling in a box next to each potential strategy with red, yellow, or green rating:

- Red = ODOT does not do this strategy
- Yellow = This might be common practice but there is no program OR this strategy is only done on an intermittent basis
- Green = ODOT does this strategy and there are clear written policies or standards

The committee was to make a rating for each strategy in terms of its status at both a program- and project-level at ODOT. So it was completely possible for a strategy to get a red rating in program-level, but a yellow or green rating in project-level. For example, the strategy *use alternative or efficient energy sources in systems operations* was rated red for the program-level because ODOT does not have a policy or directive for this in their projects, however the same strategy was rated yellow for project-level because on a project-by-project basis ODOT is using alternative energy (solar, wind) and energy efficient lighting systems.

This exercise visually showed the committee where ODOT is doing well in implementing certain strategies. For areas rated green, the committee made a commitment to better standardize and communicate our successes. In other areas, yellow and red, this exercise highlighted where more work needs to be done.

PRELIMINARY FINDINGS

Although the Sustainability in Project Delivery Committee is still in the early stages of its work, it is possible to draw some conclusions or key findings. The following are a few key preliminary findings that will continue to guide the work of the committee:

1) **Establish sustainability as an agency-wide goal** – A transportation agency that plans to or wants to successfully integrate sustainability into its project delivery process, needs to have determined that sustainability is a key value and goal of the entire agency.

2) **Both Program- and Project-Level** – The committee is still dealing with the question of program- versus project-level decisions and strategy integration, but there is at least an initial consensus that it needs to be both. In order to be most effective, ODOT will need program-level policy, but project-level guidance that can account for the context and circumstances of an individual project.

3) **Fit into Existing Programs and Processes** – For sustainability strategies to be successful, they need to be integrated into how the agency does business, not be perceived as an extra or “add-on”. The committee is working on the best way to integrate sustainability into existing processes and initiatives like Practical Design and the existing Project Delivery processes. By making sustainability a part of these established processes, it reduces confusion for Project Teams, helps streamline work, and overall, just makes sustainability a part of what we do, not a separate program.

4) **Keep Performance Metric in Toolkit** – Due to the economic realities that face departments of transportation, the “typical” project will be preservation or safety, as opposed to the larger modernization projects. These preservation projects do not necessarily lend themselves to a performance metric tool like Greenroads or
FHWA’s INVEST, because the projects are “too small” to for it to make sense to spend the time collecting paperwork, etc. for certification. That said, the committee does feel that having these types of performance metric tools still in the ODOT “toolkit” will be useful on the larger, more visible, or controversial projects, so the agency can clearly demonstrate and communicate about the sustainability aspects of the particular project.

FUTURE WORK AND NEXT STEPS

The Sustainability in Project Delivery Committee is making tremendous progress towards integrating sustainability into ODOT projects, but they are just starting to develop the tools and actions for addressing sustainability within the project delivery process. The committee has identified a couple of next steps, to guide its work over the next months. There are a couple of next steps in progress at the moment:

1) **ODOT Specific Tool Development** – Although the committee has decided to keep a metric like Greenroads in the ODOT toolkit for evaluating sustainability on projects, the committee is also committed to developing an ODOT specific tool or checklist for project teams.

2) **Communication** – As addressed earlier, ODOT is already doing quite a bit in terms of sustainability on its projects, however as an agency we have not done the best job in communicating our success stories to either an internal or external audience. Therefore, the committee is in the process of developing handouts, factsheets, webpages, etc. that will highlight the good work we are doing in sustainability.

CONCLUSION

ODOT and the Sustainability in Project Delivery Committee will continue to work on integrating sustainability into the day-to-day work of the agency, including the project delivery process. The process so far has focused on laying the groundwork, evaluating lessons learned, and defining sustainability in terms of project delivery. The committee is now turning its focus to actual tool development and implementation. Finally, the committee will continue to work on internal and external communication, highlighting the good work the agency is doing, but also set up a network to help ODOT staff learn about the most up-to-date and cutting edge sustainability practices.

BIOGRAPHICAL SKETCHES

**Margi Bradway** is ODOT’s Sustainability Program Manager. The Sustainability Program provides central oversight and coordination and is a resource to staff and the public about sustainability and sustainable transportation. She is an attorney with a background in environmental science. After law school at Lewis and Clark, Margi worked for the U.S. Environmental Protection Agency and the Oregon Department of Justice in the Natural Resources Division. Margi practiced law at Stoel Rives, LLP for many years before focusing on transportation policy. During Margi’s tenure, ODO has reduced its energy use significantly and become a leader in the state and in the nation on sustainability and sustainable transportation policies. Margi sits on and facilitates quite a few sustainability and climate change related committees, including the ODOT Sustainability in Project Delivery Committee, which is focused on the integration of sustainability into the project delivery process and the development of effective tools to assist that process. Margi was also the recipient of the NEPA Environmental Excellence Award in 2009 for her work on the climate change analysis for the Columbia River Crossing Project.

**Liz Hormann** has been a Sustainability Planner at ODOT since December 2009. Liz earned her degree in political science at Macalester College, in St. Paul, Minnesota. During her semester abroad she worked on climate change adaptation and other environmental issues at the Scottish Parliament, where she interned for the former Environmental Minister. At ODOT she works on a host of sustainability issues ranging from updating ODOT’s recycling policy to integrating sustainability into the project delivery process to creating an employee transportation options program. She also helps lead the development of an ODOT climate change adaptation strategy and plan.

REFERENCES

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ABSTRACT

Introduction

Transportation decisions are largely driven by economics and, to a lesser extent, environmental and social factors. Though, transportation decisions have shifted in the last 15 years to more fully consider environmental factors (i.e., NYSDOT’s “Environmental Initiative”), the three factors of sustainability (environment, social equity and economics) are often presented as competing factors rather than harmonizing factors in the decision-making process. Addressing all three realms on equal footing will go a long way to ensure balanced decisions and to streamline processes.

Methodology and Results

New York State Department of Transportation (NYSDOT) is taking sustainability to a new level, incorporating the “Triple Bottom Line” thinking (economic, social, environmental) beyond the operational level (the “how”) and the more tactical level (the “what”) by expanding it to a strategic level (the “why”).

NYSDOT recognizes that sustainability is an overarching principle. This paper will touch on NYSDOT’s sustainability ethic established through its GreenLITES (Green Leadership in Transportation and Environmental Sustainability) program and highlight NYSDOT’s recent efforts to incorporate sustainability principles into its asset management, comprehensive program update and capital investments decisions.

Conclusion

NYSDOT is working to refine innovative tools to ensure strategic, tactical and operational transportation decisions that further social, economic and environmental sustainability. Our goal is to integrate ecological, structural, safety, and economic needs into the transportation decision-making process.

TRANSPORTATION SUPPORTING A SUSTAINABLE SOCIETY

NYSDOT is taking action on several levels to embrace its role in supporting a sustainable society. As evident in the Department’s mission statement -- “It is the mission of the New York State Department of Transportation to ensure our customers - those who live, work and travel in New York State -- have a safe, efficient, balanced and environmentally sound transportation system.” – NYSDOT understands sustainability is about balancing what is beneficial to people while considering what is economically sound and environmentally compatible.

NYSDOT defines sustainability in its working sustainability vision, mission, definition and overarching strategies drafted as follows:

- **NYSDOT Sustainability Vision:** Exemplify how transportation supports a sustainable society.
- **NYSDOT Sustainability Mission:** To fully integrate sustainability into the Department’s decisions and practices in planning, designing, constructing, maintaining and operating New York State’s transportation system. NYSDOT will also model and advance sustainability in managing its internal resources.
- **NYSDOT Sustainability Definition:** Consistent with the Brundtland Commission sustainability definition (World Commission on Environment and Development 1987), NYSDOT understands that a sustainable society manages resources in a way that fulfills the social (community), economic and environmental needs of the present without compromising the needs and opportunities of future generations.
A transportation system which supports a sustainable society is one that:

- Allows individual and societal transportation needs to be met in a manner consistent with human and ecosystem health with equity within and between generations.
- Is safe, affordable, accessible, operates efficiently, offers choice of transport mode, and supports a vibrant economy.
- Protects and preserves the environment by limiting transportation emissions and wastes, minimizes the consumption of resources and enhances the existing environment as practicable.

**Over-arching Sustainability Strategies:** NYSDOT will advance sustainability by following these strategies:

- Develop, advocate and advance Department sustainability goals and strategies through interaction with Main Office and Regional employees, program areas, workgroups and external stakeholders.
- Incorporate sustainability concepts into the Department’s procedures, investments, policies, manuals, specifications, programs, projects and practices.
- Use the Sustainability Steering Committee as a feedback loop so that constructive participation is vetted through Executive Management.
- Develop and use sustainability measures and indicators to better manage NYSDOTs internal resources and programs.
- Facilitate partnerships through sharing of ideas and best practices.
- Evaluate the costs and benefits (societal, environmental, and economic) of transportation investments over life-cycles as well as fiscal cycles.

**CONSIDERING SUSTAINABILITY AT ALL LEVELS OF DECISION MAKING**

The topic of addressing sustainability in transportation systems is explored in Jeon and Amekudzi (2005). They found there is no standard way in which sustainable transportation is considered. However, the three-dimensional framework of economic development, environmental preservation, and social development is the substance of several definitions of sustainable transportation and other infrastructure systems (Jeon and Amekudzi 2005). Deakin’s (2001) working paper on sustainable development and sustainable transportation notes that, increasingly, the idea of sustainability has come to be understood as a collective process for considered decision-making and action, and not simply a particular end-state or outcome.

Fundamentally, sustainability is about making responsible decisions, considering the implications of our actions now and into the future. There are three levels of management decision making: strategic, tactical and operational (Encyclopedia of Business and Finance, 2001). To truly be integrated into an agency’s culture, sustainability should be factored into all three levels.

- **Strategic decisions** (the “why”) set policies and define overall objectives, are comprehensive, long term, and relatively general. Strategic decisions focus on the broad, enduring issues for ensuring an agency’s effectiveness over a long period of time.
- **Tactical decisions** (the “what”) focus on more intermediate-term issues such as interpreting policies and objectives, and providing guidelines for operational decision making. The tactical planning in an organization is more specific than strategic planning, dealing more with issues of efficiency rather than with long-term effectiveness.
- **Operational decisions** (the “how”) are focused, short term, and specific. Operational decisions focus on day-to-day activities within the agency such as efficient, cost-effective application of resources to solving problems and meeting objectives.

By making environmentally, socially and economically responsible decisions at all levels, transportation agencies can play a vital role in supporting society and the greater good.

**Putting Our Money Where Our Mouth Is – Incorporating Sustainability into NYSDOT’s Comprehensive Program Update and Capital Investment Decisions**

As NYSDOT’s approach to sustainability matures, it is evident that a more strategic approach is essential to truly integrate sustainability principles into all that we do. To that end, NYSDOT is taking action to incorporate the “Triple Bottom Line” of sustainability in its programming and investment decisions, factoring economic, environmental and social aspects into its comprehensive program, asset management and capital investment decisions.
According to AASHTO, “America’s transportation system has served us well, but now faces the challenges of congestion, energy supply, environmental impacts, climate change, and sprawl that threaten to undermine the economic, social, and environmental future of the nation.” (AASHTO 2009). Understanding this, NYSDOT recognizes it is essential to choose a course of action that preserves our extensive transportation system in a sustainable manner. NYSDOT is adopting a strategy to develop a sustainable program, one that maximizes return on investment, extends the life of its assets, and provides its customers a safe, reliable, balanced and environmentally sound transportation system.

NYSDOT’s Comprehensive Program Update, through strategic investment in its transportation system – investments in pavements, bridges, public transportation, rail, aviation and ports, and a long-term focus on preserving its assets – will help build the foundation for future economic growth of New York State. These critical decisions will impact the State’s citizens, economy, and environment for decades to come. Accordingly and appropriately, sustainability is integral in NYSDOT’s Program Update process.

As part of its programming, NYSDOT will implement creative and low-cost ways to increase multi-modal, non-polluting and less-polluting forms of transportation. In doing so, NYSDOT’s actions will reduce waste, improve safety for all users, increase livability, implement “smart growth” principles and utilize sound environmental practices.

To ensure that NYSDOT is making good decisions, the Department identified four guiding principles to meet the needs of its customers. Each of the “Forward Four” principles – Preservation First; System not Projects; Maximize Return on Investment; Make It Sustainable – individually emphasize a sustainable approach to consider economic competitiveness, environmental stewardship and social equity; collectively they ensure integration of sustainability into NYSDOT’s decisions and investments.

By adhering to these principles, NYSDOT strives to keep the transportation system safe and maximize the life of existing infrastructure while working to improve livability and promote economic development within the context of limited financial resources. It is important to ask the right questions and make decisions based on how to preserve existing investments and assets, how to provide the best transportation system to customers, and how to do it in a fiscally responsible manner.

Preservation First - “Sustainability Begins With Preservation”, as noted in the Whole Building Design Guide (2010) and touted by the National Trust for Historic Preservation. Accordingly, the primary focus of NYSDOT’s program update is on system preservation and safety. Such a strategy is a cost-effective approach that provides a solid foundation for a sustainable future and supports the triple bottom line of sustainability.

- **Economy**: Preserving linkages to communities and businesses, and slowing or reversing the rate of infrastructure deterioration in areas that will most benefit, supports economically viable communities and makes economically sound, cost-effective and affordable decisions for now and for the future.
• **Social:** Where we invest matters. A preservation strategy focuses our funds on the right treatment at the right time in the right place. The right place considers public benefits such as safety, access/proximity to emergency services, businesses, schools, modal choices as well as corridor services such as freight movement and transit.

• **Environmental:** Preservation maximizes the use of existing materials and infrastructure, reduces waste and minimizes footprint.

**System not Projects** – Just as it is important to look at our natural landscape from an ecosystem perspective rather than individual elements, it is important to consider the transportation infrastructure as a system rather than a collection of individual projects. As noted by Aronson (1997), instead of focusing on the individual pieces, systems thinking involves a broader view, looking at larger and larger numbers of interactions. A more holistic approach to transportation decisions considers projects in the context of the larger transportation system, community network and landscape. In its decisions, NYSDOT will consider and prioritize projects in a manner that treats them as key components or critical links within the larger transportation system.

**Maximize Return on Investments** - Sustainable programs are structured to maximize all forms of return on investments. It all comes down to responsible decisions. Emphasis is on proper management of assets with appropriate treatments, at appropriate times, and at the appropriate locations. It is important to measure economic benefits as well as capture the non-economic benefits of a transportation project, including the effects on user costs, the environment, CO$_2$ emissions, and other environmental and social aspects.

**Make it Sustainable** - A sustainable approach to programming considers the relative and cumulative value of transportation assets as they benefit the public, economy and environment. In this way, the decision-making process looks broadly at the wider benefits of the work NYSDOT does with each Comprehensive Program:

- **Economic competitiveness:** improve efficiencies in work/business travel and freight movement; improve tourism access and inter-modal connectivity; develop investments which complement or enhance the strategic investments proposed by Regional Economic Development Councils.
- **Social equity/community:** improve accessibility for transit; recreation; education; health care; support smart growth, complete streets and livability; increase safety; weigh climate-associated risk to transportation infrastructure.
- **Environmental stewardship:** increase energy efficiency and reduce greenhouse gas emissions; reduce resource consumption; limit impacts that encroach on the environmental footprint; improve air quality.

There is the overarching need to consider sustainability, both from a program/system-wide and project level perspective.

**Program Perspective for Sustainability**

Preserving specific assets is important, yet it is the combination of all of these assets that establishes the system and supports future quality of life and the economy of the State. To that end, NYSDOT is developing its programs within the context of the system as a whole. Recognizing current fiscal constraints, NYSDOT is considering its investment strategies in a manner that not only continues to maximize public benefits but is affordable over the long term. Programs structured around the concept of sustainability maximize return on investment, including recognizing trade-offs between the projects that are and are not selected, and deliver a safe, efficient, balanced and environmentally sound transportation system. Sustainability concepts are overarching and used throughout the program development process.

**Project Perspective for Sustainability**

Sustainability concepts are also incorporated into individual projects as they are developed, and into the overall process of program selection. Additionally, specific New York State legislation has been passed (Smart Growth Infrastructure Policy and Complete Streets) that require certain considerations in project development. The substance of these bills requires NYSDOT as well as localities to be more sensitive to the needs of their assets by non-automobile users and to maximize the utility of the currently built environment. As appropriate, NYSDOT is also considering projects in the context of the state’s energy plan and draft Climate Action Plan.

The primary focus of a sustainable Comprehensive Program is to preserve critical linkages using appropriate preservation treatments for highways and bridges. When looking at transportation infrastructure needs from an asset management perspective, it is important to consider community needs and context as well as the natural environment.
It is important to stress that preservation is more than crack-sealing and filling potholes. A sustainable transportation program should include low-cost improvements to make the road networks safer, more livable, and welcoming. When preserving and enhancing the transportation system, transportation agencies have the opportunity to design and operate the entire roadway and right of way with all users in mind - including bicyclists, public transportation vehicles and riders, and pedestrians of all ages and abilities. The same concept holds true when considering the context of the natural environment. Transportation systems should be designed to be as permeable as practicable for fish and wildlife resources, connecting terrestrial and aquatic habitats traversed by the highway system.

Even small projects can make meaningful improvements. In repaving projects, for example, an edge stripe can be shifted to create more room for cyclists and a culvert posing a barrier to fish can be replaced with a more appropriately designed culvert. Such decisions, however, must be sensitive to the context of the community and natural environmental to avoid inappropriately and indiscriminately applied practices that may be costly and unwarranted.

**GreenLITES: Initial Tools for Making Sustainability Decisions**

Sustainability is an over-arching principle. At NYSDOT, we are incorporating sustainability into our programs, projects and initiatives.

NYSDOT’s sustainability ethic has been evolving and maturing over the last 5 years, largely due to the Departments GreenLITES program. GreenLITES is primarily an internal management program for NYSDOT to measure its performance, recognize good practices, identify where it needs to improve and provide a way to demonstrate how NYSDOT is advancing sustainable practices.

NYSDOT began the GreenLITES Project Design certification program in 2008 and the program quickly expanded to be a collection of tools, metrics, and spreadsheets in design, operations, planning and regions. GreenLITES Project Design and Operations are self-certification tools that distinguish transportation projects and operations based on the extent to which they incorporate sustainable choices. McVoy, et al (2010) describe NYSDOT’s GreenLITES program evolution from its environmentally based beginnings to a more comprehensive approach in support of a sustainable society.

The GreenLITES Project Design and Operations tools work well for “operational” type decisions in the Strategic/Tactical/Operational decision-making model. However, to completely integrate sustainability into its decision-making process NYSDOT quickly realized it needed to address the larger question of “How do we select the ‘right’ sustainable projects?” This led to the development of the Project Solicitation Tool (at the “what” or tactical level) and the Regional Sustainability Assessment Table (at the “why” or strategic level).

The Draft Project Solicitation Tool is a questionnaire that helps NYSDOT, Metropolitan Planning Organizations (MPOs) and other project sponsors determine how consistent a project is with seven identified sustainability goals; this, in turn, serves as a discussion point when deciding what projects to include in long term capital infrastructure program submissions.
The Regional Sustainability Assessment Table is a tool used by NYSDOT regions to develop and assess regional long term sustainability goals from a more holistic perspective and across program areas using the triple bottom line realms of economy, environment and communities. The table provides a template to identify sustainability current states, desired future states and plans for accomplishing future states in all three sustainability realms as they relate to specific desired NYSDOT outcomes.

The suite of GreenLITES tools helps NYSDOT to better align sustainability efforts in planning, design, construction, maintenance and operations and has set the groundwork for incorporating sustainability into our programming and investment decisions.

PUTTING IT TO THE TEST - APPLYING SUSTAINABILITY DECISIONS TO PAVEMENT ASSET

It is one thing to embrace sustainability as a concept; the true test is how it is implemented. Consistent with the approaches discussed, NYSDOT is addressing sustainability in pavement management by moving decisions beyond the operational level (the “how”) to a more tactical level (the “what”) and expanding it to a strategic level (the “why”) with its proof-of-concept Public Benefit model for the pavement asset.

Operational – Specifications

NYSDOT makes sustainable operational decisions for pavement management through the establishment of specifications which allow and encourage, but do not mandate, the use of a variety of “environmentally friendly” additives and/or recycled material in its pavement applications. By not mandating the use of recycled material, the contractor is allowed to use best professional judgment that considers cost and circumstances (e.g., distance from mineral source, hauling costs, material availability). The best sustainable choices will reduce social and environmental impacts while not sacrificing performance or cost effectiveness.

NYSDOT’s most common choices are warm-mix asphalt, which reduces energy required to heat the asphalt and reduces associated toxic emissions; recycling, which reduces vehicle emissions and use of resources; and thin treatments, which results in energy and material savings.

Other choices may include recycled rubber in binder; tire shreds; reclaimed asphalt pavement (RAP); asphalt shingles; cold-in-place recycling (CIPR); hot-in-place recycling (HIPR) and heater scarification; recycled concrete aggregates (RCA); recycled glass; permeable (porous) pavements; and recycled plastics.

There are varying social, environmental and economic benefits to these treatments. Though these are sustainable operational choices, their influence is more local rather than on the overall transportation system.

Tactical - Pavement Preservation Model

NYSDOT has an established Pavement Preservation Model (PPM) that enables managers to make system-wide economically sustainable decisions for pavement preservation. The PPM identifies pavement conditions and other criteria to prioritize on-the-ground areas for work over a ten-year period based on infrastructure maintenance matrices and budgets.

The cornerstone of a pavement preservation strategy is the application of lighter preventative maintenance treatments on a relatively frequent basis. As a pavement ages, the asphalt oxidizes, making it more brittle and susceptible to cracking. As these cracks develop, water infiltrates through the cracks, down into the base and subbase layers. In colder climates, this water freezes and expands, and when it thaws, it leaves voids in the base and subbase, and reduces the strength of the pavement structure making it even more susceptible to more severe distress.

Preventative maintenance treatments, such as chip seals, microsurfacing, paver placed surface treatments and thin HMA overlays seal existing cracks, rejuvenate the pavement and keep surface water out of the underlying pavement layers. They are most appropriate for pavements with light to moderate distress, and if they are used on pavements with too much cracking, they usually have a very short service life.

In New York State, these treatments have an average service life of 3-5 years for chip seals up to 7-9 years for full single course HMA overlays when used on appropriate candidates. In addition, these treatments are relatively inexpensive, costing $30,000-$70,000 per lane-mile. If a pavement requires a moderate treatment, such as a mill and fill or cold in place recycling, the cost can run up to $135,000-$200,000 per lane-mile (four times as expensive). And if a pavement is allowed to deteriorate to the point where it needs major repairs or reconstruction, the cost can be
$500,000-$1 million (sixteen times more expensive). Over the life of a pavement, it is therefore more economical to apply a preventative maintenance treatment every 8 years than to reconstruct the pavement in the 24th year.

A preservation first strategy uses far less natural resources than full reconstruction because these treatments do not affect the base and sub-base layers. These treatments use less energy as they require less material to be hauled over a smaller distance and fewer construction vehicles. In addition, pavements that receive frequent light treatments stay smoother over their lifetimes, reducing fuel use and greenhouse gases.

NYSDOT’s PPM is used to develop future work plans and estimates future pavement conditions and improvement needs for highways in New York State. The principal strategy of the PPM is to maximize the number of vehicles traveling on good pavement at the lowest possible long term cost. The model prioritizes pavement maintenance projects based on cost/vehicle miles traveled (VMT), resulting in preservation on high priority roads. The end result is the lowest cost solution with the highest benefit to the most people.

Though applying preservation treatments is an economically sustainable “tactical” practice to keep our good pavements in good condition, this model does not factor in social or environmental aspects; consequently, some low-volume roads may be at risk of suffering further deterioration. This, in turn, may have deleterious effects on land use, community cohesion and the economy. For instance, a low volume road that supports the forest product or agricultural industry may be at risk if social and environmental factors are not considered.

**Strategic – Public Benefit Model**

To explore how NYSDOT might take the pavement preservation model one step further, a team explored how to enhance the model to consider the environmental, economic, and societal benefits of NYSDOT’s maintenance and capital work on the transportation infrastructure. The team developed a proof-of-concept sustainability model that filtered the output of projects (i.e., the “optimum mix”) from the pavement preservation model through the public benefits lens, including weighted values for access/proximity to “landmarks” such as emergency services, businesses, schools etc. To measure the social, economic and environmental benefits, the output values were converted to dollars for program and connector benefits.

The environmental benefits are quantified in terms of fuel savings and greenhouse gas (GHG) emissions from improved pavement smoothness. Multiple research studies have analyzed the relationship of pavement roughness to vehicle fuel consumption and excess user costs. These studies show that International Roughness Index (IRI) and fuel consumption have a direct relationship; the higher the roughness, the higher the fuel consumption for trucks and automobiles. Gillespie and McGhee (2007) provide an excellent synthesis of the topic in their research paper, “Get In, Get Out, Come Back! What the Relationship Between Pavement Roughness and Fuel Consumption Means for the Length of the Resurfacing Cycle”. NYSDOT used this paper as the basis for its analysis, and developed formulas that relate differences in IRI to mile per gallon for trucks and automobiles.

The social values are quantified in terms of access to jobs, businesses, emergency services, schools, public transportation, etc. The economic benefits of pavement preservation are quantified by jobs created and cost savings by applying the right treatment at the right time in the right location.

NYSDOT’s Public Benefit Model, which factors in social, environmental and economic sustainability facets into its pavement preservation model, has potential to equip NYSDOT to make strategic decisions on critical infrastructure improvements beyond simply economic considerations.

**MESSAGING DECISIONS – THE VALUE OF TRIPLE BOTTOM LINE LANGUAGE**

Articulating decisions using the “Triple Bottom Line” terminology of sustainability, factoring in economic, environmental and social aspects, has great potential to serve NYSDOT as it makes and justifies its decisions to the various stakeholders. For instance, the public may focus on the social issues; resource agencies and environmental advocacy groups may emphasize environmental features; and government officials may stress economics at this fiscally constrained time. Hard decisions need to be made; it is incumbent upon the agency to demonstrate that its decisions are fiscally, socially, and environmentally sound to serve the public. By showing how decisions relate to and help people and can be desirable to society, partners and stakeholders, NYSDOT may gather more support and less criticism, gaining credibility and public trust.
CONCLUSION: SUSTAINABILITY AND ASSET MANAGEMENT

Asset management and sustainability go hand-in-hand; it’s about making responsible decisions at all levels. Having a strong asset management framework and process in place will improve the ability to make good strategic decisions; decisions that support the long-term goal of providing a safe and reliable transportation system for customers in a fiscally responsible and sustainable manner.

An asset management system which includes sustainability as an over-arching principle will help transportation agencies look strategically and critically at investment choices and better inform those involved in the decision-making process.

NYSDOT’s Forward Four principles – Preservation First; System Not Projects; Maximize Return on Investment; Make It Sustainable – will serve to guide NYSDOT as it incorporates sustainability into its decisions. Using these principles, NYSDOT is developing a holistic approach that supports responsible decisions and invest funds in a manner that not only preserves the most important assets but that best meets the needs of those who rely on the transportation system.

The anticipated outcome is a strategy and process for capital investment and resource allocations resulting in cost-effective investments to preserve and manage the multi-modal transportation assets of the state in an economically, environmentally and socially sustainable manner.

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BIOGRAPHICAL SKETCHES

Debra Nelson is the Assistant to the Director of the 5,000 member Operations Division for NYS Department of Transportation. Deb serves on the Commissioner’s Comprehensive Asset Management/Capital Investment Team to develop an investment strategy, framework and process to preserve and manage the multimodal transportation assets. Debra is a Certified Ecologist and Professional Wetland Scientist involved in statewide and national efforts on environmental stewardship and sustainability in transportation, serving on projects of the National Cooperative Highway Research Program, Strategic Highway Research Program and National Highway Institute. She serves on the TRB Committee on Ecology and Transportation and is the Chair of the International Conference on Ecology and Transportation.

Paul Krekeler manages NYSDOT’s GreenLITES program. Paul has worked at NYSDOT for more than 25 years where he has been involved with other agency-wide transformational programs such as context sensitive solutions, performance management, and the executive leadership institute.

Michael Rossi is a Professional Engineer in NYSDOT’s Office of Technical Services, Pavement Management Group. Mike has been instrumental in the development of NYSDOT’s Pavement Preservation Model and the proof-of-concept Public Benefit Model.

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MOSAIC: A COMPREHENSIVE TOOL FOR SUSTAINABLE HIGHWAY CORRIDOR PLANNING IN MARYLAND

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ABSTRACT

The Maryland State Highway Administration (SHA) has initiated major planning efforts to improve transportation efficiency, safety, and sustainability on critical highway corridors through its Comprehensive Highway Corridor (CHC) program. As part of the CHC initiative, SHA has funded a research project, titled “Comprehensive Highway Corridor Planning with Sustainability Indicators” to develop a Model Of Sustainability and Integrated Corridors (MOSAIC). MOSAIC will assist SHA in selecting the most sustainable corridor improvement option for its Highway Needs Inventory and long range transportation planning processes. The ultimate goal of this research project is to integrate MOSAIC and sustainable highway planning into existing SHA processes, streamline the environmental screening procedure, and help SHA achieve its mobility, safety, social-economic and environmental stewardship objectives. In this research, six categories of sustainability indicators (mobility, safety, socio-economic impact, natural resources, energy and environment, and cost) and more than thirty sustainability performance measures have been developed as evaluation criteria for the selection of highway corridor improvement options. The first version of MOSAIC considers two highway improvement options, including adding a general-purpose lane and converting at-grade intersections to grade-separated interchanges. Ongoing efforts will expand the highway improvement options in MOSAIC to also include road diet, bus rapid transit, bus-only lanes, high occupancy vehicle lanes, high occupancy toll lanes, freight truck-only lanes, light rail transit, and express toll lanes. Various quantitative models have been developed to analyze the impacts of these alternative corridor improvement types on identified sustainability indicators. The impacts on various sustainability indicators are then weighted based on policy considerations and SHA priorities. MOSAIC has been applied to the US 15 corridor north of Frederick, MD, to demonstrate the feasibility and usefulness of this comprehensive tool for sustainable highway corridor planning. Planned future research will integrate MOSAIC tool into SHA’s Enterprise GIS system, which is expected to further streamline MOSAIC input and output processes, making the tool ready for statewide applications in Maryland.

1. INTRODUCTION

In order to improve transportation, environmental, and livability conditions for Maryland residents and visitors, the Maryland State Highway Administration (SHA) has initiated major planning efforts to improve critical highway corridors. The SHA is also committed to integrating safety, mobility, environmental stewardship, and socio-economic objectives in its transportation planning process and Comprehensive Highway Corridors (CHC) program. To support its sustainability initiatives, SHA has funded the development of a Model Of Sustainability And Integrated Corridors (MOSAIC), which defines sustainability indicators, analyzes the sustainability impact of corridor improvements, and identifies environmental mitigation needs early in the planning process. The sustainability indicators include mobility, safety, air quality, energy consumption, pollution and greenhouse gas emissions, natural resource impact, socio-economic measures, and costs. When implemented at the highway needs assessment and long-range planning stages, MOSAIC can help SHA identify the corridor improvement option that best balances these sustainability indicators, and avoids improvement options with major negative environmental impacts that often lead to costly and lengthy environmental screening and mitigation procedures. Different from microscopic traffic simulation (e.g. Synchro, Vissim) and EPA emission models (e.g. MOVES) that provide detailed pollution and greenhouse gas (GHG) emission estimates for a particular project with a predetermined improvement type, MOSAIC integrates sustainability objectives early in the project planning process, considers multiple improvement types, incorporates a more...
comprehensive set of sustainability indicators, and provides high-level impact analysis with minimum requirements on staff time and other resources.

A transportation corridor planning study usually consists of several sequential steps including problem identification, study organization, determination of goals and evaluation criteria, development/evaluation of initial alternatives, development/evaluation of detailed alternatives, financial analysis, alternative selection, transportation plan updates, project development, and project implementation. The impacted communities and interested stakeholders may also be involved in each corridor planning step. The greatest benefit of and the most streamlined process for transportation corridor improvement are obtained when the relevant agencies and stakeholders are involved early in the planning process, when environmental impact mitigation is provided in a proactive and systematic fashion, when multiple corridor projects are considered at the program level (instead of on a project-by-project basis), and when decisions are driven by clear goals and objectives, high-quality data and valid objective modeling tools. For instance, the concept of “environmental banking” allows highway agencies to provide mitigation in advance of the actual needs for replacement/restoration of wetlands and habitat. A negative impact in one corridor can be balanced cost-effectively by benefit in another corridor. However, the successful application of such proactive measures would require a prior knowledge of the likely sustainability impact of multiple corridor improvement projects, so that the appropriate type and amount of mitigation efforts can be planned ahead systematically.

This paper summarizes the methods employed in MOSAIC for estimating the sustainability impacts of various corridor improvement options. These impacts are categorized into six major groups: mobility, safety, socio-economic, natural resources, energy and emissions, and cost. The current project is focus on comparing the sustainability impact of both the do-nothing case and two highway corridor improvement options, namely adding a general-purpose lane to the existing roadway and building grade-separated interchanges. Future research will improve MOSAIC to consider multimodal improvements in highway projects, such as bus rapid transit, light rail, bus-only lane, HOV/HOT operations, park-and-ride, express toll lanes, truck-only lane, bike/pedestrian facilities, ITS/ATIS deployment, access management, and local land use plans.

After an extensive review of the literature and best practices elsewhere and several discussions with SHA project liaisons and many other SHA staff members from both the Office of Planning and Preliminary Engineering (OPPE) and other offices, the UMD research team has defined a comprehensive set of sustainability indicators that are incorporated and quantitatively evaluated in MOSAIC (see Table 1).

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<th>Energy, Environment and Natural Resources</th>
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<td>Within Smart Growth –PFA Boundaries</td>
<td>Travel Time Savings, Delay, Speed, LOS</td>
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<td>Pollution emissions</td>
<td>Compatibility with Existing Land Use</td>
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<td>Fuel Consumption</td>
<td>Economic Impact</td>
<td>Accident Counts, Rate and Severity</td>
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<td>Quantity of and degree of disturbance on Impacted Cultural/Historical Sites, Steep Slopes, Highly Erodible Soils, Wetlands, Waterways, Floodplains Forests, Critical Areas, Springs/Seeps, Bedrock/Geology Areas, Natural Species, Storm Water Facilities, etc.</td>
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2. REVIEW OF CURRENT PRACTICES

To ensure MOSAIC is developed upon the best practices and prior lessons from other states, the research team has conducted a comprehensive review of integrated sketch/high-level transportation planning strategies and tools from various State Departments of Transportation (state DOTs) and other government agencies in and outside of the U.S.. The following subsections summarize and briefly discuss the four major tools relevant to comprehensive highway corridor planning: Sketch Planning Analysis Spreadsheet Model (SPASM) and Surface Transportation Efficiency Analysis Model (STEAM) introduced by Federal Highway Administration, Sustainability Enhancement Tool (SET) developed by Texas Department of Transportation (TTI), and Efficient Transportation Decision Making (ETDM) developed for the Florida Department of Transportation (FDOT).

SPASM and STEAM

Sketch Planning Analysis Spreadsheet Model (SPASM) and Surface Transportation Efficiency Analysis Model (STEAM) are early corridor-level planning tools that assist decision-makers in assessing multimodal alternatives and demand management strategies from various aspects. These tools are able to provide useful first cut information on economic efficiency of the improvement by estimating transportation costs and benefits, social and environmental impacts, and measures of cost-effectiveness at the system and corridor level. The major indicators that SPASM and STEAM incorporated are travel time savings, emission and fuel consumption savings, external costs, and capital costs.

SPASM is an EXCEL or LOTUS based spreadsheet produced by FHWA. Five alternative transportation improvement categories modeled in SPASM are: transit system improvements, highway capacity improvements, HOV improvements, auto use disincentives, and a combination of the above actions. SPASM then estimates the effects of each improvement alternative on highway speeds and subsequent changes in highway usage, emissions, and fuel consumption. The final SPASM output shows the following aggregated estimates by modes for each proposed alternative: user benefits, including travel time, out-of-pocket cost savings, and fuel cost savings; costs to public agencies, including capital costs, vehicle operating costs and other operating costs; revenue transfers, which are "benefits" shifted from users to public agencies; external costs, including pollution costs and other external costs; net benefits (or costs); and benefit/cost ratio.

SPASM meets users' needs for decision-making through benefit and cost analysis. However, it can only be used in limited sketch-planning situations owing to several simplifying assumptions, especially with respect to demand modal shift estimation. Instead, SPASM provides the basic idea and methods for the development of a more advanced model in benefit and cost analysis on various corridor-level projects, such as STEAM.

The first version of the Surface Transportation Efficiency Analysis Model (STEAM) was introduced by the Federal Highway Administration (FHWA) in 1997. STEAM was the first FHWA computer-based impact analysis product to use input directly from the four-step travel demand modeling process for detailed, system-wide analysis of alternative transportation investments at regional and corridor levels. FHWA released STEAM 2.0 in 2000 to expand the scope of the model to address environmental justice measures.

Compared to SPASM (discussed in Section 3.4), STEAM is an enhanced modeling tool that can be applied more widely. Most of the advantages of the STEAM model result from its coupling with travel demand models, and are described in detail herein. These advantages, of course, come with higher model implementation costs. The outputs STEAM provided include: scenario annual results showing the scenario results of base case, improvement case, changes separately for each mode, and summary of a benefit-costs analysis; market sectors that describe the characters of each improvement alternatives; and risk outputs which demonstrate the probability distributions for each result metric.

However, the amount of indicators analyzed by SPASM and STEAM are far from enough in comparison to our Comprehensive Highway Corridor Planning with Sustainability Indicators project. Meanwhile, the methodologies behind many existing indicators of SPASM and STEAM have been replaced by new methods and tools. However, the framework of these two tools helped us in developing and scoping initial models for MOSAIC.

SET

The Texas Department of Transportation (TxDOT) developed the Sustainability Enhancement Tool (SET) between 2006 and 2008. The SET strategic plan has five goals for improving the sustainability of transportation improvements: reduce congestion, improve safety, increase economic opportunity, enhance the value of transportation assets, and improve air quality.
SET is valuable for project screening in the very early stages of project evaluation by using a multi-criteria decision-making (MCDM) approach as the basis for the sustainability evaluation and is able to evaluate a base case scenario and up to three future cases. (Ramani 2009) SET is able to identify the extent of sustainability in the highway mode at the “sketch-planning” level, and to rank the projects by comparing certain projects at different locations, or among various alternative planning scenarios at a given location. The outputs from SET are categorized either by the goal-wise sustainability indicators for the entire study section or by the link-wise sustainability indicator values. The result in the goal-wise performance is helpful for the users to identify which goals were not being met, the graph of the aggregate index values by link can tell the users which links performed worse than the average, and thus, provide users the key point that should be achieved in a sustainable manner.

SET requires the user to insert data inputs for each indicator into a number of Excel worksheets for each current and future corridor improvement scenario under consideration. The application would be made more user-friendly if a GIS tool was incorporated to load for current roadway alignments while also allowing users to specify a future alignments. In this way, available GIS data for each indicator along with data from travel demand models could be automatically loaded into the spreadsheet application.

ETDM

The Efficient Transportation Decision Making (ETDM) Tool, supported by Florida Department of Transportation (FDOT), is a web-based systematic tool that integrates land use, social, economic, environmental, and transportation considerations by the active participation of federal, state, and local agencies early in the planning process in order to expedite environmental review and project completion, reduce costs, and create better environmentally-sound transportation solutions.

The Florida ETDM and Environmental Screening Tool (EST) system allows transportation planners to efficiently screen the affected natural resource areas of a proposed highway corridor alignment/improvement in a web-based environment. Users enter the project alignment by loading GIS data or by drawing the alignment with Internet mapping software. GIS analysis is then automatically performed on the proposed alignment for potential environmental effects. The GIS analysis identifies and quantifies natural, cultural, and community resources within 100', 200', 500', and one mile buffer distances. Transportation planners can use this information to quickly identify potential problems or mitigation needs early in the project-development cycle (e.g. at the long-range planning or short-term programming stage). They can then make adjustments to the alignment as necessary before the project proposal is reviewed by other state environmental and natural resource agencies. Once the final planning-stage alignment has been chosen, the GIS analysis is saved in the ETDM database, and is available for subsequent review by Federal and State agencies and for the NEPA process.

Although ETDM provides substantial information on projects for early and continuous involvement of agencies and the public, and establishes coordinated time schedules for agency action, it cannot generate its own results by applying certain models or methods. In addition, ETDM is not able to tackle the project improvements types relevant to managed lanes. Therefore, ETDM acts better in providing qualitative results rather than quantitative ones for the new construction of roadways.

Other Corridor Planning Tools with Sustainability Indicators

Other corridor planning applications with sustainability indicators we reviewed include: EPA’s MOBILE and Motor Vehicle Emissions Simulator (MOVES) emission analysis tools, Colorado Department of Transportation (CDOT) ’s Strategic Transportation, Environmental and Planning Process for Urbanizing Places (STEP UP), Maine Department of Transportation (MDOT) ’s Integrated Transportation Decision-Making (ITD) Process, Virginia Department of Transportation (VDOT)’s Dashboard web-based performance measurement tool, the Measurement Framework for Highway Capacity Decision Making developed for the second Strategic Highway Research Program (SHRP2), etc.. A broader literature review was also conducted on the sustainability indicators adopted by state agencies, as well as other organizations both within and outside of the U.S., which can be found in the full project report (Zhang et al. 2011).

3. METHODOLOGY

The methodology behind the MOSAIC tool is introduced in this section following the sequence of six categories of sustainability indicators: mobility, safety, socio-economic impact, natural resources, energy and environment, and cost. Further detailed methodology on the modules developed for MOSAIC can be found in the technical research report, titled “Comprehensive Highway Corridor Planning With Sustainability Indicators” (Zhang et al. 2011).
Mobility

In MOSAIC, the mobility impact is evaluated using two major indicators: travel time savings and travel reliability. The general steps for estimating both of these indicators are shown in Figure 1.

The corridor under consideration should be first divided into several sections based on Average Annual Daily Traffic (AADT). Ideally, each section should have uniform traffic flow characteristics such as traffic volume, number of lanes, etc. Each section may include more than one intersection or interchange. Based on intersection/interchange locations, a section is further divided into multiple links. With sections and links defined, the methodology for estimating travel time can then be applied to individual section for peak and off-peak trips. Intersection-level travel time will then be aggregated to corridor-level estimates.

Travel time savings are computed for each improvement scenario compared with the base-case scenario for both peak and off-peak periods respectively. Since the roadway speeds are sensitive to AADT per lane according to Texas Transportation Institute's Urban Mobility Report (Schrank 2007), adding one general lane will reduce the travel volume for each lane, and thus, reduce the roadway travel time. Meanwhile, the grade-separated interchanges will relieve the traffic delay at the intersections of the arterial streets by replacing the traffic signal or stop-sign control, and also, by increasing the traffic speed at intersections.

Reliability is measured as the additional travel time (in minutes, percent extra time, etc.) that travelers endure under worse-than-normal traffic conditions. We evaluate travel reliability by incorporating the concepts of Reliability Index and Travel Time Index, which indicate the extent to which the longest travel times (including peak and off-peak ones) exceed the average travel time based on the distribution of travel times for a given section of roadway over a period of time (day-to-day or month-to-month). The Reliability Index for the entire corridor is calculated as the average across all sections, weighted by vehicle miles traveled (VMT) on each section, where a higher Reliability Index indicates less reliable travel conditions.

Safety

Two indicators, crash rates and severe crash rates, lead to the crash condition in MOSAIC. Crash Rate is measured as the expected number of crashes per year for a certain corridor, and MOSAIC considers severe crashes as crashes that involve fatalities and/or injuries. The procedure for evaluating safety is presented in Figure 2.
We apply the Safety Performance Function (SPF) method from the most recent Highway Safety Manual (2010) to estimate total crash rates for both roadways and intersections. The expected number of crashes at the corridor level can be computed as:

\[ N = \sum_i \left( N_{r_i} \times \prod C M F_{r_i} + N_{i_i} \times \prod C M F_{i_i} \right) \]

If a section within the corridor has 12-feet lane width, 6-feet shoulder width, paved shoulders, no left or right turn lanes, and 30-feet median width in its multi-lane segments, the expected crash rates at this base section can be denoted as \( N_r \) for its roadways, and \( N_i \) for its intersections. If roadway and intersection configuration on a highway section is not the same as that of the base condition, the actual crash rates should be adjusted with Crash Modification Factors (CMFs).

As shown in Figure 2, the crash rates in the base case are affected by both the major and minor roads’ AADT, as well as the geometry configurations of roadways and intersections. The expected crash rates (crash rates per mile) for the entire corridor can then be obtained by incorporating CMFs for the corridor.

Severe crash rates can be measured in two ways. The first method employs estimates on the percentage of severe crashes along the corridor; while the second method uses empirically estimated coefficients, which replace the coefficients in the total crash rate equations, for severe crash rate estimation.

**Socio-economic Impact**

The socio-economic factors that are affected by new transportation improvements and considered by MOSAIC include economic benefit, noise, livability, and aesthetic impacts.
Economic Impact

We apply the methodology developed by the U.K. Department of Transport in its 2005 “Wider Economic Benefits and Impacts on GDP” study (U.K. DOT 2005) to calculate the economic benefits due to agglomeration economies induced by transportation investment.

Economic benefits from agglomeration effects (WB) is the sum for all zones of the change in effective density (ED) in each zone multiplied by the productivity elasticity, output per worker, and employment in that zone, where ED was formulated by aggregating the product of the number of employees and the cost of travel. Thus, since the new improvements reduce the corridor travel time, bring closer together for firms and business sectors, they will contribute to the growth of GDP along the corridor and region economic benefits.

Livability

Livability as a socioeconomic indicator includes a variety of factors that should be considered in analyzing the effectiveness of highway corridor improvements. We combine qualitative and quantitative methods to measure livability from two aspects: land use compatibility and transportation accessibility. Land-use types MOSAIC considered include: industrial, commercial, recreational, agricultural, low and high density residential, high and medium density mixed use, and transit oriented development. Transportation accessibility along the corridor includes accessibility for through traffic, and local-area accessibility that primarily serve local residents and business. Based on this definition, livability is enhanced if highway corridor improvements are compatible with existing or planned future land use and improves accessibility to activity locations.

Noise

The impact due to traffic noise depends on both local land-use patterns and corridor traffic conditions. The buffer distance is set as 1/4-mile between noise receptors (i.e. residential and business developments) and the highway corridor centerline.

The noise metrics criteria used for analysis vary by different types of land-use and are categorized into three major types. The next step is to estimate the noise exposure within 50 feet, in order to obtain the project noise exposure rate at any location within the buffer distance. Finally, since the receivers in our analysis are defined in GIS in terms of different land use types and their areas, the Noise Impact Level and Average Noise Exposure within the buffer distance are obtained by considering the average existing noise exposures along the corridor.

Aesthetics

Aesthetics is a branch of philosophy dealing with the nature of beauty, art, taste, and the creation and appreciation of beauty. More broadly, scholars often define aesthetics as the “critical reflection on art, culture and nature.” For highway aesthetics, we primarily consider four elements: facility compatibility with the surrounding natural environment, land use attractiveness in the vicinity of the highway corridor, visual appeal, historical roads and historical site protection.

An on-line survey has been developed and distributed in the MOSAIC development process. The survey results help us understand the perceived impact of highway improvement on various aesthetics indicators. In general, survey shows individuals believe the impact of the two particular highway improvement types have minimum impact on aesthetics (scores close to 0). But there are clear concerns that adding a general-purpose lane may have negative impact on historical roads and historical sites. The final score for aesthetics is computed as the weighted sum across all four aesthetics elements.

Natural Resources

In this version of MOSAIC, we measure the natural resource impacts by the areas of impacted natural resources along a highway corridor. After comprehensive literature review, we have set the buffer distance for the analysis as 1/4 mile for roadway improvements, and 1/2 mile for intersection improvements.

Corridor roadway and intersection geometry and GIS shapefiles containing natural resource information are first merged into ArcGIS. Each individual section of the US-15 corridor designated by the MOSAIC user is buffered using the ArcGIS proximity toolset with the given improvement type's impact distance. The area of each natural resource type within the buffer is then computed with ArcGIS query tools.
Once the necessary natural resource information within the buffer zones is obtained in GIS and subsequently imported into MOSAIC, we can compute the percentage of impacted land within the buffer area for each type of natural resource. Higher percentages indicate more severe impact on particular types of natural resources. Impacts on different types of natural resources (e.g., parks, streams, wetlands, historical places, easements) are weighted equally in MOSAIC Beta Version 2. This will be adjusted in future versions based on inputs from the SHA.

For the two improvement types analyzed in Phase One of the project: adding a general purpose lane and building grade-separated interchanges, the natural resource impact will either be negative or neutral at best. Other multimodal highway improvement types, such as transit investments, HOV/HOT lanes, and road diet to be considered in future project phases, can produce positive impact on natural resources.

**Energy and Emissions**

The general steps for energy and emission estimation in MOSAIC are illustrated in the flowchart provided in Figure 3. Users should first divide the corridor into several sections mainly based on AADT level. Then, per-mile Pollution emissions, greenhouse gas emissions as well as the energy consumptions rates will be obtained separately with regard to the corresponding conditions in terms of section-by-section travel speeds in peak and off-peak periods, rural restricted or unrestricted, urban restricted or unrestricted streets. After considering daily traffic volume in peak and off-peak periods, section lengths and width, we obtain the total fuel consumption, pollution emission, and greenhouse gas emission along the corridor.

Per-mile emission rates and fuel consumption rates for Maryland at different speeds are obtained by running MOVES2010a, the Motor Vehicle Emission Simulator developed by U.S. Environmental Protection Agency, for year 2010 and 2040. Emission rates are obtained from MOSAIC in grams per mile, while fuel consumption rates are in BTUs. At this stage, the types of pollution emissions MOSAIC covers are Carbon Monoxide (CO), Nitric Oxides (NOx), and Particulate Matter (PM10) and Carbon Dioxide (CO2).
Highway Improvement Costs

To estimate project cost (PC), we utilize two Maryland-specific data sources. The SHA maintains a website which includes all in-progress and recently-completed major construction projects (SHA, 2010). From this database, we first compile the cost data for all projects which include costs for four major categories of the project: planning, engineering, right-of-way, and construction. Based on project descriptions, we divide all relevant projects into three different categories: adding a lane by widening an existing roadway, adding a lane by reconstructing a roadway, and constructing a new interchange on an existing road. We also separate the projects into urban and rural categories. From this dataset, we have estimated the average costs for projects that have been completed in the last 3 years.

![Diagram of cost estimation process]

The SHA also provides a cost-estimation guide for contractors (SHA, 2009), which provides construction cost estimates of $6 million/lane-mile to add a 12-foot lane, $5.5 million to construct one lane-mile of roadway on a new location, and $40 million to construct a full diamond interchange. In the end, we combine our cost estimates based on the SHA project database with the cost estimates in the guidelines for contractors to produce cost estimates in MOSAIC. The whole process is demonstrated below in Figure 4.

4. MOSAIC CASE STUDY RESULTS

The segment of US-15 from Biggs Ford Road to PA-MD border line was selected as the candidate corridor for case study, which is shown in Figure 5. The study area was divided into five sections according to SHA’s short-term comprehensive highway corridor planning study. Section one is a 7-mile rural arterial with seven intersections and four lanes in each direction; Section two is also a 6-mile rural arterial with four lanes each way and has six intersections; Sections three and four are rural freeways with two interchanges each respectively measuring 8-miles and 18 miles long; Section five is an 8-mile rural freeway with seven intersections and four lanes each way. Two improvement plans were applied to this US-15 corridor for case study: (1) Adding one general purpose travel lane in each direction on all roadway sections; and (2) Upgrading all at-grade interchanges to grades-separated interchanges for arterial sections with no change to freeway sections.
The required input data for each section along the selected US 15 corridor should be implemented by the users first. These data are categorized into six main categories: general data, economic data, land-use and transport data, aesthetics data, ecological and historical impact data, and typical intersection data. Certain input information is optional in MOSAIC, which allows users to further calibrate their analysis, given access to more refined input information.

MOSAIC compiles separate output databases for each improvement case. These databases contain raw numerical output data organized by corridor section for each of the six MOSAIC modules (Mobility, Safety, Socio-Economics, Natural Resources, Energy and Emissions, and Cost). The impact of each improvement case in the six impact categories is then weighted and scaled based on either default or user-defined weights to produce a final weighted impact measure. These output databases are used by MOSAIC to run interrelated impact modules (e.g., energy and environmental impact can only be assessed after mobility impact is estimated) and to provide a basis for a variety of graphical and summary outputs, which can be easily incorporated into reports and presentations by MOSAIC users.

After submitting the input data and running MOSAIC analysis modules, model outputs were generated in three forms: (1) Numerical outputs in separated databases; (2) Graphical outputs; and (3) Final summary reports. Results from the section-by-section analysis show that improvement plan 2, upgrading intersections to grade-separated interchanges, has less negative impact on sustainability indicators related to mobility and cost along section 5, energy, and pollution/GHG emissions along sections 1 and 5, as well as the safety along sections 1, 2, and 5, compared to adding one general purpose travel lane in each direction. (see Figure 6) The corridor-level analysis results categorized by the six sustainability indicator groups demonstrate that both improvement types have overall positive impact on mobility, energy and emissions, socio-economics, and cost for the study area along US 15, and both have moderate negative impact on natural resources. As for safety, improvement plan 2 will benefit while improvement plan 1 will have negative impacts on safety. Converting arterial street at-grade intersections to grade-separated interchanges along US15 is a more desirable corridor improvement option than building more capacity on this corridor according to the six sustainability indicator categories (see Figure 7). If equal weights are given to all six sustainability indicator categories (e.g., mobility is equally as important as safety, as energy and emission, as natural resources, and so on), we find the final overall sustainability score for improvement plan 1 to be 0.127, and 2.006 for improvement plan 2. Again, the final scores indicate that building grade-separated interchanges for the case study corridor would be more effective in improving sustainability than building more travel lanes. This finding remains valid for most combinations of weights assigned to different sustainability indicator categories.
Figure 5. Section Analysis Results.

Figure 6. Corridor Analysis Results.

As stated earlier, MOSAIC also provides the option for users to define the weights of these indicators. Shown below in Figure 8, the weighting system allows users to easily scale final scores, and help users identify the best improvement case according to users’ goals (different SHA divisions may have different goals). Individual weights are numerically shown to the left, while relative weights are shown to the right.
5. CONCLUSIONS AND FUTURE RESEARCH

The case study results for US 15 within Maryland demonstrate that MOSAIC performs well when applied in analyzing two existing highway improvement types: adding a general-purpose lane and converting at-grade intersections to grade-separated interchanges. It’s also able to provide numerical and graphical outputs for users after estimating the impact of these improvement types on six categories of measures of effectiveness: mobility, safety, socio-economics, natural resources, energy and environment, and cost. MOSAIC is a benefit not only in assisting SHA in multimodal highway corridor improvement decision-making, but also by demonstrating SHA’s commitment to incorporating social, economic, environmental, and sustainability considerations in its transportation planning process.

![Figure 8. MOSAIC Research Roadmap.](image)

Although the current MOSAIC tool is already fully functional, future phases of this research project will complete the research tasks outlined in the research roadmap demonstrated in Figure 9 to deliver an eGIS (Enterprise Geographical Information System)-based MOSAIC tool that considers multimodal highway improvement options. The multimodal improvements in highway projects that MOSAIC will incorporate in phase two include improvement types such as road...
diet (i.e. reduce number of lanes), bus rapid transit, light rail, bus-only lane, HOV/HOT operations, park-and-ride, express toll lanes, truck-only lane, bike/pedestrian facilities, ITS/ATIS deployment, access management, and local land use plans. MOSAIC will also be further developed into the GIS-based tool that can be fully integrated into the SHA eGIS. This MOSAIC-eGIS integration will produce a user interface that is easy to understand, easy to use, and ready to be incorporated into various existing SHA processes, which will further streamline MOSAIC input and output processes, making the tool ready for state-wide applications in Maryland.

BIOGRAPHICAL SKETCHES

Dr. Lei Zhang is an Assistant Professor in the Department of Civil and Environmental Engineering at the University of Maryland-College Park (UMD). He received his B.S. in Civil Engineering from Tsinghua University, and his M.S. in Civil Engineering and Applied Economics and a Ph.D. degree in Transportation Engineering from the University of Minnesota. Dr. Zhang directs the Transportation Systems Research Lab at UMD, which employs interdisciplinary approaches to model the interdependencies between transportation, land use, and economic systems, analyzing the full impact of engineering and planning decisions to ensure efficient resource allocation and sustainable development in the broad domain of transportation. Dr. Zhang has published more than 80 peer-reviewed journal and conference papers on topics including transportation planning, transportation economics and policy, travel behavior, advanced travel demand modeling, and traffic operations. He has received external funding support from various Federal and State government agencies and private foundations in the U.S., totaling $4.3 million. Dr. Zhang is a Member of several Transportation Research Board (TRB) Committees (Transportation Economics, Travel Behavior and Values, and Travel Survey Methods). He recently served as the Chair of the Transportation Science and Logistics Cluster of the Institute for Operations Research and Management Sciences (INFORMS), and Co-Chair of the U.S. Department of Transportation Expert Panel on Multimodal Passenger Travel Demand.

Mingyang Ji is currently working as the graduate research assistant for the Department of Civil and Environmental Engineering at University of Maryland. She received her B.S. degree in Transportation Engineering and minor in Safety Management from Civil Aviation University of China, and is expected to obtain her M.S. degree in Transportation Engineering from University of Maryland in August 2011 with the thesis topic: Comprehensive Highway Corridor Planning with Sustainability Indicators. Her major contributions to MOSAIC was on determining its methodology for measuring and evaluating more than thirty sustainability indicators, which incorporated the transportation and land-use performance theories, Highway Safety Manual, EPA's policies and Motor Vehicle Emission Simulator (MOVES), economic agglomeration, and pivot-point mode choice models. Mingyang was also involved in the process of data collection and model results analysis on MOSAIC's case study along US 15 corridor.

Nicholas Ferrari currently works for the University of Maryland Department of Civil Engineering as a Transportation Graduate Research Assistant. After completing his bachelor’s degree in Civil Engineering at the University of Maryland, he has continued studying at the University of Maryland College Park, to obtain his master’s degree in transportation engineering. Mr. Ferrari has been involved as both a programmer and researcher for the SHA's MOSAIC project. His chief contributions include the creation of the spreadsheet MOSAIC program and the data collection and analysis of the US 15 corridor case study.

Gregory Slater is a 1997 Graduate of Towson University in Geography and Environmental Planning, a 2007 Graduate of the University Of Maryland National Leadership Institute, a 2009 Graduate of the MDOT's State Highway Administration’s (MDSHA) Advanced Leadership Program and a registered GISP (GIS Professional). Mr. Slater’s career has focused on data driven decision support coupled with performance management. His career started as consultant to the City of Baltimore City on a major data driven public utility initiative, then he went to MDSHA in the Office of Highway Developments, Plats and Surveys Division. Before being appointed as SHA's Planning Director, he served as the Chief of the Design Technical Services Division. As Planning Director, Mr. Slater continues to focus on data driven decision support and establishing relationships to develop sustainable solutions for Maryland. Through this approach, MDSHA is very focused on sustainability, climate change, linking of planning and safety, GIS based asset data warehousing for a comprehensive asset management approach, and multimodal planning solutions that focus on community and industry input. The data driven approach is designed to build fully context sensitive solutions by gathering input from all involved and thinking big picture with the solutions.

Reena Mathews, Eric Beckett, Jessica Silwick work in the SHA's Office of Planning and Preliminary Engineering and were instrumental in guiding the delivery of the CHC - MOSAIC Phase I project.
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