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SUSTAINABILITY IN THE HIGHWAY PROJECT DELIVERY PROCESS

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Sustainability in the Highway Project Delivery Process

The Federal Highway Administration (FHWA) has set a high priority on ensuring a sustainable highway network by considering economic, social, and environmental impacts during project development. Although aspects of sustainability are routinely considered in the delivery of highway projects, a national standard to assess sustainability does not exist. In fact, a variety of approaches have been created across the country to assess highway sustainability.

To address this issue, FHWA has initiated research to develop a framework for assessing the sustainability of highway projects. This framework is expected to use criteria to rate the degree that all aspects of sustainability (economy, equity, and environment) have been incorporated into the planning, design, construction, and maintenance of highway facilities. The resulting sustainable highway criteria will be piloted on existing highway projects and vetted by highway stakeholders. The final criteria will be incorporated into an internet-based tool that transportation agencies can use to easily and consistently assess highway sustainability. This research will be completed by the end of 2010.

This paper will provide an overview of opportunities to consider sustainability in the delivery of highway projects as well as current practices. The four sections of the report are: The Project Delivery Process, Use of Recycled Materials in Highway Applications, Warm Mix Asphalt, and Adapting to Climate Change Impacts.

The Project Delivery Process

Sustainability can be effectively addressed in many aspects of the highway project delivery process. This paper will discuss highway project delivery in seven stages:

- Long-range transportation planning,
- Transportation programming/funding,
- Project planning/National Environmental Policy Act (NEPA) process,
- Alignment process and highway design,
- Construction activities,
- Construction materials and resources, and
- Operations and maintenance

Some of these stages, such as long-range planning, do not necessarily refer to highways alone, but cover broader transportation issues. However, they are highly relevant because highway infrastructure investments are still the most significant contributor to overall transportation expenditures. Each stage is described below, along with a discussion of how sustainability is relevant at that level.

Sustainability in the Long-Range Transportation Planning Process

Long-range transportation plans (LRTPs) provide an opportunity for stakeholders in transportation to consider a wide range of concerns, including sustainability, as they set strategic long-term transportation goals for a region or state. Long-range transportation plans are the foundation for subsequent corridor or project-level transportation studies and for development of statewide or metropolitan transportation programs. They offer an important opportunity to examine environmental, economic, and community concerns on a statewide or regional scale.

Since the early 1990s, long-range transportation planning in the United States has been anchored by Federal requirements for States and metropolitan regions with more than 50,000 people to develop periodic, formal long-range transportation plan documents (FHWA, 2009). Federal requirements do not call for consideration of sustainability in

LRTP development. At present, therefore, most State or metropolitan planning organization (MPO) LRTPs do not address sustainability as a specific theme. However, many State departments of transportation (DOTs) include sustainability principles in strategic plans. The thematic content of any LRTP, which is guided by Federal surface transportation law, includes several mandated "planning factors" that are closely related to sustainability, including economic vitality, safety, accessibility and mobility, the environment, and integration and connectivity. Additionally, emerging issues related to sustainability—such as climate change and public health—are relevant in the transportation planning sphere. Each of these is discussed below.

Emerging Sustainability-Related Issues in Long-Range Transportation Planning

As the long-range planning process evolves, state DOTs and MPOs will consider a range of emerging sustainability-related issues:

- Public Health and Transportation—In recent years, the prevalence of sedentary lifestyles in the United States has increased. Americans of all ages are becoming less active and are suffering from associated diseases. Many experts have concluded that reliance on the automobile is a contributing factor. In addition, pollutant emissions associated with transportation are estimated to represent 30 percent of all air quality pollution in urban areas and are known to cause a broad range of health issues (National Emissions Inventory, 2010).
- Climate Change and Transportation—In the United States, transportation is the second largest source of greenhouse gas (GHG) emissions (the first is electricity generation). A 2008 FHWA report explored opportunities to reduce GHG emissions from transportation, including switching to alternative fuels, using more fuel efficient vehicles, and reducing the total number of miles driven. It also discussed how long-range transportation planning activities can contribute to these strategies. A number of local and national efforts (e.g., *Climate Change and the Highway System: Impacts and Adaptation Approaches*, National Cooperative Highway Research Project (NCHRP) 20-83(05)) are underway to better incorporate climate change into long-range transportation planning.
- Collaborative Decision-Making—In general, according to the Strategic Highway Research Program's 2010 report on *Framework for Collaborative Decision Making on Additions to Highway Capacity*, practitioners are being encouraged to take collaborative approaches to developing LRTPs (ICF 2010).

Sustainability in Transportation Programming and Funding

Through a process known as transportation program development, State DOTs and MPOs develop transportation programs that match priority project-level transportation needs with implementation funds. This is accomplished through the short-range Transportation Improvement Program (TIP) and Statewide Transportation Improvement Program (STIP) processes. A successful transportation program ensures that short-term, project-level spending decisions support progress in achieving long-term transportation goals, which, in turn, support national, State, and local interests. Development of a State or metropolitan transportation program is usually a collaborative effort among the State DOT and local and Federal partners. Transportation programming is the time when broad sustainability goals established in long-range planning can be translated into explicit targets associated with implementation of a specific set of projects.

The MPO prepares the TIP , which identifies the transportation projects and strategies from the long-range metropolitan transportation plan that will be undertaken over the following 4 years. The TIP is the region's way of allocating its limited transportation resources among the various capital and operating needs of the area, based on a clear set of short-term transportation priorities. The STIP, which the State DOT prepares, is similar to the TIP in that it identifies statewide priorities for transportation projects and must be fiscally constrained.

At present, transportation programming requirements do not require explicit consideration of sustainability. Some of the factors that are commonly considered part of sustainability are part of the programming process. This includes air quality conformity, the congestion mitigation and air quality program, and the Federal transportation enhancements program.

Sustainability in the Project Planning/NEPA Process

Project-level planning is a cooperative process, led by State DOTs, that fosters the involvement of all users of a transportation system. This includes businesses, community groups, environmental organizations, freight operators, and the public. The planning phase helps agencies identify project needs, community concerns, and potential solutions.

The NEPA is a Federal law, approved January 1, 1970, that outlines policies to protect the environment. It requires officials to review environmental information before project-level decisions are made and actions taken. The planning and NEPA processes provide a framework in which planners and stakeholders can consider many factors, including sustainability concerns, prior to finishing design and construction of proposed projects.

FHWA has published a helpful decision makers' guide to transportation planning that explains the basics of the planning phase of project development (FHWA, 2007). In addition, the Council on Environmental Quality, which oversees NEPA policy,has published a citizens' guide to NEPA (CEQ, 2007). At present, Federal planning and NEPA-related legislation does not refer to sustainability. Many factors that are commonly required to be considered during project-level planning work and NEPA review, however, are directly related to sustainability concerns. This includes economic development analysis and consideration of impacts on the natural and human environment. Emerging programs and processes are also relevant at the project planning level. These are discussed below.

Emerging Sustainability-Related Issues in Project Planning/NEPA Analysis

As the project planning and NEPA processes continue to evolve; State DOTs and MPOs are considering a range of emerging sustainability-related issues via new processes:

- **"Planning and Environmental Linkages" Philosophy**—In many States, early consideration of economic, social, and environmental issues before a NEPA document is prepared is an increasingly common part of project planning. FHWA has promoted the "Planning and Environment Linkages" (PEL) approach for bringing about a collaborative and integrated transportation decision-making process. PEL occurs early in the transportation process when decision makers consider environmental, community, and economic goals and carry these goals through to the project development and environmental review process, and on to design, construction, and maintenance. (FHWA, 2009) In late 2009, FHWA published a guide for State DOTs, MPOs, and local transportation agencies interested in developing individual programs to measure success toward linking transportation planning and environmental analysis (Volpe, 2009).

- **Context Sensitive Solutions (CSS)**—Over the last decade, planning practitioners have begun to endorse and implement the concept and principles of CSS, which is a cohesive philosophy for ensuring that transportation projects are designed collaboratively by an interdisciplinary team to fit the physical setting. This is accomplished by supporting community values and preserving scenic, aesthetic, historic, and environmental resources while maintaining safety and mobility. NCRHP Report 480, *A Guide to Best Practices for Achieving Context Sensitive Solutions*, provides a comprehensive introduction to the principles of CSS (CH2M HILL, 2002).

- **Project-Level Sustainability Rating Programs**— The New York State Department of Transportation's GreenLITES program (Leadership In Transportation and Environmental Sustainability) is one example of a State's efforts to recognize transportation project esigns that incorporate a high level of environmental sustainability . GreenLITES, a project rating program, involves a self-certification that distinguishes among transportation projects and operations based on the extent to which they incorporate sustainable choices. It is based in part on the Greenroads rating system (Muench et al., 2010).

Sustainability in the Alignment Process and Highway Design

Among the most critical processes for implementing sustainability at a project level are alignment selection and highway design. Environmental, economic, and social impacts must be addressed during this stage in practical terms within the context of real constraints. The constraints are the physical boundaries (such as ecosystems), financial considerations (for example, life-cycle costs), and human needs (including safety and accessibility) established during the project development and stakeholder involvement processes. In essence, at the start of the design process, sustainability becomes more easily quantifiable because the project-level decisions during design and construction have a higher level of detail than those made at planning and operational levels.

Project-level environmental impacts for highway siting and design are highly regulated by U.S. law. For example, the NEPA environmental review process requires investigation of short-term, long-term, and cumulative impacts of design and construction. Furthermore, many existing U.S. regulations govern the allowable short-term impacts on environmental quality such as the chemical pollutant discharges governed by the National Pollutant Discharge Elimination System permitting process and the Clean Air Act.Highways impact or change the overall integrity of watersheds and surrounding areas through habitat destruction, fragmentation, and degradation (Southerland, 1994; Ament et al., 2008). Habitats can be destroyed with removal or change of vegetation, loss of pervious surfaces, or intrusion into sensitive riparian areas and wildlife territory. Highways also form linear barriers that break up or block watershed habitats and can prevent crossings of species through that area. Degradation, in general, means that pollutants or other impacts from highways, such as construction or traffic noise, reduce the pre-existing environmental quality of a watershed. This includes practices that are often indirect considerations for stormwater management, such as replacement of native vegetation (which aids in flow control and treatment) with new invasive species, or new more erodible soils (Forman and Alexander 1998). An important consideration is that relatively small changes in overall water elevation can cause detrimental changes in populations of aquatic organisms and vegetation (City of Seattle 2009).

Clearly, highways interact in a very complex way with the surrounding environment and this complexity is inherently difficult to manage at a project level. Watershed managers are now recognizing this difficulty and many advocate alternative watershed-level approaches to match the overall scale of the issues at hand (City of Seattle, 2009). Most current best practices involve avoidance or minimization of footprints, presumably to avoid impacts as well as to minimize costs. This is especially true in highway bridge alignments that span or are placed within waterways.

Some examples of documented sustainable practices in the area of highway design and alignment include:

- **NCHRP Report 565**—
(Huber et al., 2006) provides an example relevant for projects using low impact development approaches for stormwater quality management (and flow control) in a highway environment.

- **Interstate 90 Snoqualmie Pass East Mitigation Project**—State officials used a variety of solutions, including bridges, culverts, overpasses, and fencing to manage wildlife connectivity in aquatic and terrestrial habitat along this stretch of highway (WSDOT 2009)

- **Western Federal Lands Highway Division (WFLHD) Roadside Revegetation Process**—WFHLD identifies a detailed and comprehensive approach to site vegetation that describes the actions and major steps needed to establish vegetation (Steinfeld et al., 2007).

- **Central Artery/Tunnel, Boston, Massachusetts**—The Central Artery/Tunnel project (the "Big Dig"), now managed by MassDOT, had "the most comprehensive and stringent construction noise control specification of any public works project in the country" (Thalheimer 2000) and helped develop the FHWA *Highway Construction Noise Handbook* (Knauer et al., 2006).

Sustainability in Highway Construction Activities

Construction activities refer to those activities that occur within the confines of the defined work zone for a specific transportation infrastructure construction project. Thus, construction activities address the means and methods of construction. By this definition, operation and fuel consumption of a fleet of excavators onsite is included, but the hauling of excavated materials beyond the work zone boundary to a dumping facility is not. These activities and practices can be designed in many ways to improve sustainability at the project implementation level.

Perhaps the most obvious way that construction activities relate to sustainabilityis the operation of machinery in the work zone. The machinery consumes energy and generates emissions during operation thataffect human health and the area's ecology. However, in analyzing 12 papers on pavement construction, Muench (in press) found that construction activities as defined here generally contribute less than 5 percent of the energy use and CO_2 emissions totals involved in materials production, transportation, and onsite construction. Other more obvious emissions, such as site erosion and stormwater runoff, affect ecology and perhaps human health, but in comparison to the life of a highway, they have only a short duration, which makes them less influential, but nonetheless important enough to be regulated by U.S. law.

Perhaps less obvious, but more influential, are construction activities that influence: (1) the durability of the final product through the quality of construction, (2) workforce employment/development, and (3) community impacts during construction. Construction quality can influence durability and thus relate to the necessary level of maintenance/preservation and effective life span of the highway, which, in turn, affects ecology through materials consumption and economy through associated costs.

Workforce employment has been a strong motivator for current construction activities under the American Recovery and Reinvestment Act (Recovery Act). An estimated 262,000 construction-sector jobs have been produced or saved by Recovery Act funds through 2009 (Executive Office, 2010). Perhaps more important, but less directly measurable, is the workforce development (i.e., training) that goes with employment. Highway construction typically comes with a multitude of training (e.g., apprentice safety and environmental training) and creates the workforce experience needed to maintain U.S. highway infrastructure.

Finally, community impacts such as road closures, construction traffic, and construction noise can affect large numbers of people even for a relatively small project footprint.

Some examples of sustainable practices in the area of highway construction activities include:

- **Washington State Department of Transportation (WSDOT) Environmental Management System (EMS**)—In 2005, WSDOT instituted an EMS that provides staff and contractors with requirements, written procedures, training, defined roles, an inspection-improvement plan and performance measures related to construction environmental compliance (WSDOT 2010).
- **Earthwise Excavation**—The U.S. Environmental Protection Agency (EPA) highlights Earthwise Excavation (EPA, 2009) for using 100 percent biodiesel (B100) during the summer months and B90 with anti-gel additives from December through February.
- **U.S. EPA Tier 4 Standards**—These standards, being phased in by the EPA from 2008-2015 for nonroad equipment, require reductions in particulate matter and NOx by about 90 percent. The EPA documents several case studies (EPA 2009), including efforts during the Central Artery/Tunnel project and I-95 New Haven Harbor Crossing Improvement Program.
- **Missouri DOT's (MoDOT) Green Credits Program**—In 2009, MoDOT worked with EPA Region 7 to launch a pilot program that offers monetary incentives for contractors who use environmentally friendly practices on MoDOT's highway construction jobs. The pilot program, called Green Credits, was patterned after the Leadership for Energy and Environmental Design rating system. MoDOT hopes that Green Credits will encourage contractors to generate new ideas for green highway construction, and in the process, promote clean air, increase recycling, and reduce GHG emissions. Green Credits categories include practices such as reuse of materials, reduced air emissions, and use of alternative fuels.

  Under this program contractors who meet or exceed project goals for each category earn credits with monetary awards. Conversely, if a contractor establishes a Green Credits goal but fails to meet it, that contractor must pay damages.

Sustainability in the Use of Construction Materials and Resources

Construction raw materials, such as asphalt and concrete, and resources such as fuels and electricity are the fundamental building blocks of any highway project. Most of these materials and resources are produced using methods or processes that are heavily reliant on the use of non-renewable resources for production, which can be extremely energy intensive and have high environmental impacts. Fortunately, these elements of the highway system are the most tangible, quantifiable parts of a highway project and ultimately are easiest to manage when initially addressing sustainability. A sustainable approach to management of these materials and resources should, at minimum:

- Use a life-cycle perspective for costs as well as environmental emissions,
- Promote recycling and reuse activities that minimize need to extract materials,
- Be sourced regionally,
- Reduce the need for non-renewable fuels and resources, and

Manage construction waste responsiblyA life-cycle perspective offers a systematic way to approach management of construction materials and resources, as well as operational activities, that can have ecological, economic, and ultimately social benefits from reducing long-term environmental impacts as well as agency and user costs. Further, expectations for durability and long life times can be realized through responsible design, construction, and maintenance of these fundamental highway elements. Two useful tools for weighing alternatives during initial project-level decision making are life-cycle cost analysis (LCCA) and life-cycle assessment.

Examples of sustainable practices relating to the use of construction materials and resources include:

- **California Department of Transportation (Caltrans) LCCA Procedures Manual**—Caltrans has developed a manual that describes LCCA procedures for use in Caltrans projects based on the software model RealCost. (Caltrans, 2007; Land, 2007).
- **NCHRP Report 565: *Evaluation of Best Management Practices for Highway Runoff Control Guidelines Manual***—This report contains detailed examples of using life-cycle cost analysis to evaluate stormwater management alternatives for highway projects (Huber et al., 2006).
- **Pavement Life Cycle Assessment Tool for Environmental and Economic Effects (PaLATE)**—This software tool from the Consortium of Green Design and Manufacturing at the University of California, Berkeley, can be used to perform an environmental life-cycle assessment to determine emissions and energy use based on total materials used on a roadway project, including options for recycled material alternatives (Horvath, et al., 2007).
- **Solid State Lighting, Interstate 35W Saint Anthony Falls Bridge**—The Minnesota Department of transportation, in cooperation with the U.S. Department of Energy, installed light-emitting diodes for the bridge lighting systems to provide uniform lighting while reducing operational energy use and maintenance requirements (Pacific Northwest National Laboratory, 2009)
- Texas Department of Transportation **Waste Tracking System**—The State initiated a 5-year plan to incorporate a progressive waste management strategy into its agency practice. Since 2007, this system has saved nearly 2 million tons of virgin aggregate by incorporating a variety of materials recycling options into the general agency practice (Davio, 2000; CMRA, 2009).

Sustainability in Operations and Maintenance

Operations and maintenance refers to the functioning of highway infrastructure during normal use. Operations are strategies employed to effectively and efficiently use existing highway capacity (e.g., intelligent transportation systems) as well as routine operation and powering of traffic signals, signage, and lighting. Maintenance refers to those activities involving roadway maintenance, stormwater system cleaning and repair, roadside vegetation management, snow and ice control, traffic control infrastructure maintenance and repair, and general cleaning. Even in the case of operations and maintenance, the concepts of sustainability can be incorporated to ensure less traffic disruption and the use of more appropriate materials.

Operations and maintenance can most strongly relate to ecology, economy, equity, expectations, and extent sustainability components. Operations directly affects how a highway or highway system is used over its life cycle, which influences broad metrics such as mobility, congestion, and access. This, in turn, relates to energy consumed and emissions generated by traffic and traffic control (which has ecological impacts), the ability to move people and freight (equity and economic impacts), and the financial and environmental cost of all these items.

Maintenance can affect the life cycle of a highway and its ability to meet user requirements; it also involves the use of materials and industrial compounds for repair and cleaning, organizational practices, including employment, and environmental justice.

Some examples of sustainable practices in the area of operations and maintenance include:

- **Oregon Department of Transportation (ODOT) Solar Highway**—ODOT provided the land in an I-205 interchange near Portland for SunWay 1 (a limited liability company managed by Portland General Electric) to build and operate a 104 kW solar array that supplies about one third of the interchange illumination energy (ODOT, 2010).
- **Ramp metering in Minneapolis, MN**—A 2001 report analyzing a 6-week shutdown of the ramp metering system found among its conclusions: (1) 1,160 ton annual increase in emissions with no ramp metering, (2) 26 percent increase in crashes with no ramp metering, and (3) a 5:1 benefit/cost ratio for ramp metering. Note: the Research and Innovative Technolgy Administration's Intelligent Transportation System (ITS) Web site (http://www.its.dot.gov/index.htm) catalogs thousands of benefits and costs associated with ITS strategies.
- **Maryland State Highway Administration (MSHA**)—MSHA used a herd of about 40 goats to combat an invasive plant species on 8 acres of meadow and bog land near Hampstead, Maryland. Goats were chosen instead of a lawnmower in an attempt to minimize impacts on the threatened bog turtles living in the area.

Use of Recycled Materials in Highway Applications and Low Emission Production

As virgin materials become scare and the volume of by-product materials generated in our society and the cost of disposal continues to increase, there is increased pressure and incentive to recover and recycle these materials for use in secondary applications. Because the construction of highways requires large volumes of materials, transportation agencies have become participants in these recycling efforts. From a highway engineering perspective, recovered materials should be used in such a manner that the expected performance of the highway will not be compromised.

FHWA supports and promotes the use of recycled highway materials in pavement construction in an effort to preserve the natural environment, reduce waste, and provide a cost effective material for constructing highways. The primary objective is to encourage the use of recycled materials in the construction of highways to the maximum economical and practical extent possible with equal or improved performance when compared to non-recycled materials.

FHWA has focused on maximizing the use of Reclaimed Asphalt Pavement (RAP), Reclaimed Asphalt Shingles (RAS), and Recycled Concrete as Aggregate (RCA) as viable materials to be used in the highest end use possible in the construction of highway pavements and bridges. In addition, FHWA has advanced and promoted technologies to conduct in place recycling where an existing roadway is removed, rejuvenated, and replaced all in one construction operation, thus eliminating the need for haul and reprocessing of materials at an off-site location.

Increasing the Use of Reclaimed Asphalt Pavement (RAP)

Currently about 90 million tons of both asphalt and concrete are recycled each year, with RAP the most recycled material in the construction industry.

As the existing highway system is maintained, rehabilitated, and reconstructed, asphalt pavement is reclaimed, becoming RAP and can be recycled into new asphalt mixtures to improve our highways' condition. The addition of RAP decreases the amount of virgin binder and aggregate required to make an asphalt mixture resulting in reduced costs and less demand for natural resources. In 2006 and again in 2008 sharp rises in asphalt costs coupled with diminishing supplies of quality aggregate stimulated increased use of RAP in the United States asphalt paving industry. The most economical use of RAP is as a binder and aggregate source in new hot mix asphalt (HMA). FHWA has defined these high RAP mixtures as those that contain percentages of RAP over 25 percent by weight of the mix.

One of the primary challenges facing highway agencies is ensuring proper use of high RAP while maintaining a quality, well performing pavement infrastructure. Despite over 30 years of RAP use in HMA, questions remain on the correct approach for designing HMA with high percentages of RAP.

Asphalt Recycling in the United States

Many highway agencies in the United States have specifications that limit the amount of RAP used in certain asphalt pavement layers or mixture types. In 2007 the American Association of State Highway and Transportation Officials (AASHTO) and FHWA conducted a survey among all 50 States and Ontario, Canada (Jones 2008). The results showed that the majority of State transportation department specifications allow the use of RAP in HMA mixtures, with the average rate of use estimated at 12 percent. Moreover, RAP is typically permitted in subsurface, base and shoulder mixtures, but is restricted in surface/wearing courses.

Very few States have restrictions of little or no RAP due to concerns regarding performance. A majority of State transportation departments are comfortable using up to 19 percent RAP in HMA. Over 60 percent of State transportation departments permit high RAP in the intermediate and surface layers; however about 25 percent actually use high RAP in the intermediate and surface layers.

The most common barriers to using more RAP according to the 2007 survey were lack of specifications, lack of processing or high variability of RAP, poor experiences, and concerns about RAP availability.

State transportation departments use AASHTO M 323 *Standard Specification for Superpave Volumetric Mix Design* for guidelines on using RAP in asphalt mix design; however a specification has not been developed solely dedicated to incorporating RAP, especially in higher percentages, in the design of asphalt mixtures. Another primary concern when using RAP is the perceived inherent variability in the material. Without proper processing or production techniques, this variability is compounded when high amounts of RAP are used.

National Efforts to Increase RAP Use

Three key requirements must be satisfied for acceptance of and to further increase asphalt pavement recycling. Recycled asphalt pavements must be:

1. Cost effective,
2. Perform well, and
3. Environmentally responsible.

To satisfy these requirements, FHWA has developed a targeted program to encourage asphalt pavement recycling that includes the following elements:

- Encourage the use of recycled material in the construction of highways to the maximum economical and practical extent possible with equal or improved performance.
- Promote the use of RAP because the utilization of RAP can have the greatest economic, environmental, and engineering impact in HMA pavements.
- Specific goals include increasing the amount of highway construction and rehabilitation projects that use RAP and to increase the amount of RAP used in specific projects. In order to meet these objectives, three overarching tasks were identified.

Establishment of a Public and Industry Working Group

FHWA initiated an Asphalt Pavement Recycling Expert Task Group (ETG), referred to as the RAP ETG, to promote best practices for increased RAP use. The ETG is comprised of experts on the use of RAP in asphalt paving mixtures from FHWA and other Federal highway agencies, State transportation departments, industry, and academia and has a dedicated website at www.moreRAP.us.

Funded, Coordinated Research and Demonstration Projects

An on-going NCHRP project titled *Improved Mix Design, Evaluation, and Materials Management Practices for Hot Mix Asphalt with High Reclaimed Asphalt Pavement Content* has as its goals; to evaluate and propose necessary changes to the existing specifications, such as AASHTO M 323 and AASHTO R 35 (**PRACTICE FOR SUPERPAVE VOLUMETRIC DESIGN FOR HOT MIX ASPHALT (HMA))**, to account for HMA containing high RAP content and develop a mix design and analysis procedure.

Demonstration Projects and Monitoring

Several demonstration projects have been initiated using high percentages of RAP. The objectives of the field projects are to document the mixture design process, production, construction, performance testing, and identify best practices learned. Efforts are underway to capture performance metrics on the use of RAP throughout the country.

Increasing the Use of RAS

Over 11 million tons of RAS are produced each year as a result of manufacturers' waste and discard from the replacement of roofs in residential housing infrastructure. RAS can be added to new asphalt mixtures in small amounts replacing expensive virgin binder. This waste product could supply 2.75 million tons of binder nationally each year based on an estimate of a 25-percent asphalt binder content, which is enough binder to overlay or resurface approximately 80,000 lane-miles of pavement.

Using tear-off shingles presents several potential challenges that do not exist with manufactured waste shingles. Tear-off shingles have aged because of weathering exposure, possibly causing brittleness that could affect the durability of the pavement. In addition, asbestos was used in domestic shingles in small amounts prior to the mid-1980s. Extensive testing indicated that asbestos has been detected in only very small amounts in very few samples; therefore, it may not be a huge obstacle to shingle use. Another potential problem concerns deleterious materials such as metal flashing, nails, paper, and wood that may not be removed properly during the recycling process.

Some states allow the use of tear-off shingles or are experimenting with it. The Web site of the Construction Materials Recycling Association (CMRA) provides information at - http://www.shinglerecycling.org/ for shingle recycling in asphalt mixes based on the experiences of several States or reported in references, research, recycling, etc..

Generally, the early performance of pavements containing recycled tear-off shingles has been good. Even though it is a waste material, it may offer some benefits, such as rutting resistance, because of the presence of stiff binder and fibrous materials, and cracking resistance, because of the fibers.

Increasing the Use of Recycled Concrete as Aggregate

According to the CMRA, 143 million tons of concrete are recycled each year in the United States. A 2004 FHWA study on the use of recycled concrete aaggregate (RCA) reported that 38 States recycle concrete as an aggregate base and 11 recycle it into new portland cement concrete. The States that do use RCA in new concrete report that concrete with RCA performs equal to concrete with natural aggregates.

Reuse of Industrial Materials in Highway Applications

Byproduct materials differ vastly in their types and properties and, as a result, in the highway applications for which they may be suited. Experience and knowledge regarding the use of these materials vary from material to material as well as from State to State. To recover these materials for potential use, engineers, researchers, generators, and regulators need to be aware of the properties of the materials, how they can be used, and what limitations may be associated with their use. FHWA has partnered with the Recycled Materials Resource Center to maintain an online reference for the use of byproducts and secondary use materials in highway applications. This online reference can be found at: http://www.rmrc.unh.edu/tools/uguidelines/index.asp.

Warm-Mix Asphalt

FHWA, in cooperation with the HMA industry, researchers, and academia, is continually exploring technological improvements that will enhance the performance, construction efficiency, resource conservation, and environmental stewardship of asphalt mixtures. One approach to achieving all these goals is to reduce HMA production temperatures—sometimes by as much as 100° Fahrenheit (38° Celsius)—and to this end engineers are exploring the concept of warm-mix asphalt (WMA). WMA processes and products use mechanical and chemical means to reduce binder viscosity at lower temperatures or reduce the shear resistance of the mixture at construction temperatures while maintaining or improving pavement performance.

Compared with HMA, the immediate benefit of WMA is its lower energy consumption. HMA requires high heat to enable the asphalt binder to become fluid enough to coat the aggregate completely, have workability during laying and compaction, and retain durability during traffic exposure. With WMA's lower production temperatures comes the additional benefit of reduced emissions from burning fossil fuels, and decreased fumes and odors, at the plant and paving sites.

To deploy this new technology FHWA and the National Asphalt Pavement Association formed the Warm Mix Asphalt Technical Working Group to provide national guidance in investigating and implementing WMA technologies. The group included multiple sectors of the asphalt pavement industry, such as State transportation departments, academia, and contractors. The group's longstanding goal is to provide technical WMA guidance that will lead to a product with quality, cost-effectiveness, and performance at least equal to conventional HMA.

AASHTO also has been active in implementation of WMA. Since 2006, AASHTO has approved five research needs statements and funded them through three NCHRP projects:

- Project 09-43 *Mix Design Practices for Warm Mix Asphalt*;

- Project 09-47 *Engineering Properties, Emissions, and Field Performance of Warm Mix Asphalt Technologies*; and
- Project 09-49 *Performance of WMA Technologies*.

In addition to continuing to develop research needs statements for future funding, the technical working group is focused on gathering detailed information on State WMA pavement projects and specification changes made to accommodate WMA.

WMA technology serves as a compaction aid, thus allowing improved construction density and potentially longer performing pavements. Crews use the technologies at traditional HMA temperatures to improve field compaction, provide more consistent pavement density across an entire pavement, or increase the final in-place density of the pavement. A less variable, better compacted asphalt pavement should have improved performance overall. As documented in *Volumetric Requirements for Superpave Mix Design* (NCHRP Report 567), better compacted asphalt pavements often have superior fatigue and rutting performance. Greater pavement density also can decrease the permeability of asphalt mixtures, which would decrease the amount of field aging in the mixture and susceptibility cracking and moisture.

The deployment of WMA is occurring at a very fast pace in the United States. Over the past 3 years demonstration projects have occurred in 40 States—with a goal of 25 States adopting WMA as a standard for highway use. The performance to date on completed projects has been promising, with pavements exhibiting equal or improved performance compared with conventional HMA.

Potential Impacts of Climate Change to Highway Infrastructure

Research efforts regarding climate change's potential impacts to highway infrastructure are ongoing. In 2002, the U.S. Department of Transportation's (USDOT) Center for Climate Change convened a workshop focusing on the issue of global climate change (GCC) impacts to the transportation system. It brought together top transportation and climate change experts to discuss the issue. The Transportation Research Board's 2008 *Special Report 290 (Potential Impacts of Climate Change on U.S. Transportation*) and the USDOT *Gulf Coast Study, Phase I, also 2008,* are two examples outlining the wide range of forecasted impacts on highways. *Gulf Coast Study* includes a comprehensive review of the literature on the numerous, potential impacts of GCC on transportation. More recently, FHWA released a report on projected changes in climate over the century. USDOT has also used geographic information system to map areas and transportation infrastructure along the Atlantic coast potentially vulnerable to sea-level rise. According to these sources, GCC impacts—both those that gradually manifest and those that are catastrophic—are expected to be geographically widespread and modally diverse, and will stress transportation systemsbeyond the limits of their designs.

Highway infrastructure is already planned, designed, and maintained in the context of weather-related effects. For example, when designing highway infrastructure, engineers consider the likelihood of an extreme weather event, such as a 100-year storm (1 percent chance of occurring in any given year), and incorporate the effects of that event into project designs. However, in many areas of the United States, such storms are occurring more frequently, and precipitation patterns will likely continue to alter due to climate change. The vulnerability of transportation infrastructure to climate change impacts varies based on location and the environmental context in which they occur. An understanding of how an area may be impacted in the future should be informed by both potential changes in climate and ongoing environmental processes, such as land subsidence/uplift or erosion.

Sea-level rise, coastal erosion, tropical storms/hurricanes, and storm surge are major concerns in coastal areas. Impacts on coastal infrastructure include increased risk of bridge scour and bridge failure during storms, periodic or permanent inundation of coastal roads, increased frequency of infrastructure repair after events, and more frequent and/or intense emergency evacuations on a more fragile and less resilient network. *Gulf Coast Study, Phase I* found that an increase of 2-feet in sea level could affect 64 percent of the region's port facilities, while a 4-foot rise would impact nearly three-quarters of facilities; similarly, approximately "a quarter of the region's arterials and interstates, nearly half of the region's intermodal connector miles, and 10 percent of its rail lines would be affected by a four foot rise in sea level."

A University of South Alabama study estimated that roughly 60,000 road miles in the United States are occasionally exposed to coastal waves and surges. After Hurricane Katrina in 2005, FHWA conducted an assessment of coastal bridges potentially vulnerable to failure from coastal storm events. Using very broad criteria, the assessment found an estimated 36,000 bridges within 15 nautical miles of coasts. Of these, over 1,000 bridges may be vulnerable to the same failure modes as those associated with recent coastal storms.

Other GCC effects are not confined to coastal or near-lake areas and might be experienced more broadly across the nation. These effects includeincreased variability in temperature extremes, more severe precipitation events, changes in the melting rate of snow pack and permafrost, and increased mudslides, fires, and avalanches. In some cases, the effects might be compounded. Multiple GCC effects, such as storm surge *and* sea level rise or temperature increase *and* more severe precipitation, can join to create even more severe and damaging impacts. Potential impacts include increased pavement deterioration, an inability to implement or maintain environmental mitigation commitments, such as wetlands or forests, short-term flooding and/or compromised safety, among many others. Further, catastrophic events run the risk of destroying vulnerable facilities and straining emergency response abilities.

Adaptation Strategies for Highway Infrastructure

Adaptation strategies differ in direct cost as well as economic, social, and environmental implications. None of these strategies fits all situations or scenarios. Instead, an appropriate adaptation strategy is based on the specific context of the transportation project being considered as well as the risk transportation agencies and stakeholders are willing to accept. Adaptation strategies can be categorized as: repair and maintenance, reconstruction/strengthening, relocation, or abandonment/disinvestment.

Repair and Maintenance

The repair and maintenance adaptation strategy does not requirechanges to the base transportation facility. Transportation agencies respond to interruptions without necessarily addressing the underlying factors contributing to the damage. While the incremental cost of repair after each event is likely low, the cost can grow over time. Examples include closures and rerouting; simple damage repairs, such as resurfacing; water and debris clearance; cleaning of storm-drain basins; snow or sand removal; and, establishing weight limitations to manage asphalt deficiencies caused by increased temperatures.

Reconstruction/Strengthening

Reconstruction/strengthening focuses on applying higher design standards to effectively protect or reinforce a structure. It is a particularly suitable strategywhen a facility has reached the end of its service life, is structurally deficient, or has been destroyed.

Costs associated with reconstruction or strengthening can be high. Such measures include building bridges to greater heights; increasing the size of culverts; considering higher design-year storms (e.g., 50-year storms versus 100-year storms) and changing the associated design assumptions; and construction of revetments, embankments, jetties, or other structural fortifications. One example of reconstruction/strengthening is the application of FHWA floodplain regulations to coastal bridge design (such as the U.S. 90 and I-10 bridges, which were destroyed during Hurricanes Ivan in 2004 and Katrina), which allow engineers to consider the "greatest flood" event instead of the "50-year event" considered under most State design standards. In practice, reconstructed bridges could be better protected.

Relocation

Relocation is characterized by moving a transportation facility away from the threat. Accomplishing this strategy, the results of which likely have long-term implications, might necessitate environmental review, right-of-way acquisition, new construction, and other related activities. This option has a potential for high cost, and it could take many years to complete the process. However, relocation is potentially the most effective adaptation strategy since repeated repair, maintenance, or strengthening actions might not be necessary. An example of relocation is the proposed realignment of 2.8 miles of State Highway 1 near Piedras Blancas Lighthouse, California. The goal of the project is to protect the highway from bluff erosion for the next 100 years.

Abandonment/Disinvestment

The abandonment/disinvestment adaptation strategy involves a decision to discontinue service on a particular roadway or to make a roadway ineligible for funding based on its condition, and implies moving populations that rely on the facility as well. The primary consideration in deciding to abandon or disinvest in a facility is whether continuing to invest in a facility given the current or potential future threats it faces makes financial sense. Although cost savings might be possible, the resulting loss in service could lead to economic detriment, political or public opposition, and/or loss of access. For example, Texas Highway 87 was closed in the early 1990s due to storm events and erosion.

FHWA Activities

Climate change effects and impacts on highway infrastructure raise new questions for transportation decision-makers . Traditional planning, design, and operational methods and assumptions may no longer be adequate in areas affected by GCC effects, particularly in high-risk areas. Due to the wide-ranging potential implications of GCC on transportation infrastructure, as well as uncertainties in predicting the future from GCC models, an approach to the transportation development process is needed that is dynamic, multidisciplinary, and risk-based. In addition, a new level of coordination between different levels of government and across specialties is needed to meet the challenges that GCC poses.

The approach must be designed to address the incremental changes in weather resulting from GCC and potential catastrophic events. To ensure the continued integrity and durability of the nation's highway system, highway infrastructure decisions must adequately consider projected climate change effects and resulting transportation impacts. FHWA recognizes that climate change effects, impacts, and adaptation considerations should be integrated throughout the transportation decision-making process, from transportation planning, design, and construction through operations, maintenance, and emergency management.

Example Applications

States that have begun some level of adaptation planning or related activities include: Alaska, Washington, California, Maryland, Connecticut, New Hampshire, Maine, Virginia, and Florida. Cities including New York and Boston have made similar efforts.

Alaska has probably faced the greatest level of climate impacts. The Alaska Department of Transportation and Public Facilities (DOT&PF) is a multi-modal agency with ownership of public roads and bridges as well as 257 rural airports, 28 harbors, and 720 buildings. In 2007, the State established the Alaska Climate Change Sub-Cabinet to focus on adaptation, mitigation and research needs. In addition, the Governor appointed an Adaptation Advisory Group, which includes a Public Infrastructure Technical Working Group.

Documented climate change impacts in Alaska include melting permafrost, increased storm frequency and intensity, coastal erosion due to lack of sea-ice, river erosion, sea level rise, increasing temperatures, and loss of the subsistence way of life for native populations.

The infrastructure in many of Alaska's regions is underlain by ice-rich permafrost, an active layer that is permanently frozen. Increasingly, the soil layers are experiencing melting cycles causing severe structural damage to infrastructure. The DOT&PF spends about $10 million per year to mitigate melting permafrost yet this is only a fraction of the need and costs are expected to increase as warming trends continue.

Storm frequency is another phenomenon i that is causing avalanches, floods, erosion, and debris flows that all significantly increase maintenance and operations costs. The loss of shore-fast sea ice is also causing coastal erosion that poses serious threats to infrastructure and is causing entire communities to be displaced.

Alaska is adapting to these extreme impacts with shoreline protection programs, planned evacuation routes, relocation of infrastructure and communities at risk, drainage improvements, and permafrost protection. Increased collection and density of data is needed, including stream flow, precipitation, and hydraulic data and to investigate alternative design, construction, and maintenance techniques to address the changing environment. The Alaska DOT&PF will also need to continue to collaborate with others to address future impacts of climate change.