Research Report
KTC-10-20/TA26-06-1F

KENTUCKY TRANSPORTATION CENTER

SUSTAINABLE PRACTICES AND RELATED PERFORMANCES AT STATE HIGHWAY AGENCIES

UNIVERSITY OF KENTUCKY
College of Engineering

OUR MISSION

We provide services to the transportation community through research, technology transfer and education. We create and participate in partnerships to promote safe and effective transportation systems.

OUR VALUES

Teamwork
Listening and communicating along with courtesy and respect for others.

Honesty and Ethical Behavior
Delivering the highest quality products and services.

Continuous Improvement
In all that we do.

1. Report No. KTC-10-20/TA26-06-1F	2. Government Accession No.	3. Recipients catalog no
4. Title and Subtitle **Sustainable Practices and Related Performance Measures at State Highway Agencies**		**5. Report Date** DEC. 2010 **6. Performing Organization Code** KTC
7. Author(s) **Lenahan O'Connell, PhD**		**8. Performing Organization Report No.** TA-26 **10. Work Unit No. (TRAIS)**
12. Sponsoring Agency Code Kentucky Transportation Center College of Engineering University of Kentucky Lexington, Kentucky 40506-0281		**13. Type of Report and Period Covered** Final **14. Sponsoring Agency Code**
15. Supplementary Notes		

16. Abstract

This report identifies seven ways in which an SHA can harm the environment: (1) excessive consumption of virgin materials; (2) unnecessary levels or amounts of storm water runoff; (3) release of environmental contaminants by SHA employees and contractors; (4) inadequate environmental training of employees and contractors; (5) wasteful use of energy by SHA employees and contractors; (6) the promotion of excessive driving by the public and concomitant release of green house gases; and (7) inadequate oversight mechanisms and procedures to prevent unsustainable practices. The report then identifies the sustainable practices and related performance measures SHAs can use to prevent or minimize each type of environmental harm and reduce its overall use of resources. SHAs are adopting many of these practices. Given the diversity of ways that the activities of a SHA can harm the environment, it is imperative that SHAs respond along a comprehensive front. A comprehensive program for sustainability will contain a number of specific policies and reforms. It will also incorporate specific mission mandates and possibly create a new organizational unit tasked with responsibility for training and oversight.

17. Key Words	**18. Distribution Statement**
State highway agencies, Sustainability, Sustainable practices, Performance measures for sustainability	Unlimited, with the approval of the Kentucky Transportation Center

19. Security Class. (of this report)	**20. Security Class. (of this page)**	**21. No. of Pages**	**22. Price**
		53	

Table of Contents

List of Tables

Executive Summary

Sustainable development, as defined by the Brundtland Commission report, is development that meets the needs "of the present generation without compromising the ability of future generations to meet their own needs." Manufacturing companies in the private sector are embracing the concept of sustainability. In their quest to be more sustainable, companies in the private sector tend to focus on using fewer resources and taking less waste to a landfill.

State highway agencies (SHAs) are beginning to adopt a similar approach to their tasks in the pursuit of a more sustainable approach to transportation. Like private sector firms, SHAs produce a product—a state highway system. To do so they use materials to build and maintain the system. Given the manifold tasks for which they are responsible as well as FHWA's sustainability goal of reducing the number of miles driven per capita in each state, the turn toward sustainability by SHAs has many facets: including at the very least the design of facilities; the efficient regulation of traffic; the maintenance of facilities, the recycling of construction materials, methods to encourage less driving; and the reduction of environmental impacts on air, water, and other resources.

This report identifies seven ways in which an SHA can harm the environment: (1) excessive consumption of virgin materials; (2) unnecessary levels or amounts of storm water runoff; (3) release of environmental contaminants by SHA employees and contractors; (4) inadequate environmental training of employees and contractors; (5) wasteful use of energy by SHA employees and contractors; (6) promoting excessive driving by the public and concomitant release of green house gases; and (7) inadequate oversight mechanisms and procedures to prevent unsustainable practices.

The report then identifies the sustainable practices SHAs can use to prevent or minimize each type of environmental harm and reduce its overall use of resources. SHAs are adopting many of these practices.

Given the diversity of ways that the activities of a SHA can harm the environment, it is imperative that SHAs respond along a comprehensive front. A comprehensive program for sustainability will contain a number of specific policies and reforms. And to be truly comprehensive it will do more than fulfill the requirements of the various environmental laws. In this sense a sustainability program must be proactive.

Thus, a comprehensive sustainability program requires a detailed effort to reduce the likelihood of environmental harm from *any and all* of the SHAs myriad activities from adding lane miles to clearing brush to storing herbicides to cleaning trucks and more. Addressing such a wide range of issues rarely occurs during the NEPA process, although doing so is in line with the manifest goals of the environmental protection laws and clearly contributes to the overall sustainability of SHA practices.

One of the primary goals of sustainability is a reduction in the total vehicle miles driven by the public and a related reduction in the number of lane miles of highway built. This requires a deliberate effort to "right size" roads with practical design and it requires SHA planning officials

to work with local governments, MPOs, and other organizations to integrate transportation planning with land use planning. It will also call for a deliberate effort to use the various devices of Intelligent Transportation Systems (ITS) to improve traffic flow so as to avert the need to build more lane miles of highways. Thus, planning officials, like their counterparts in maintenance, operations and construction, will need training in the various ways to improve the sustainability effects of the policies they devise and implement.

To embrace sustainability in a comprehensive fashion, a SHA will need to incorporate additional mission mandates and possibly create a new organizational unit tasked with responsibility for training and oversight. Building such training and oversight into the organizational structure appears to be the key to reducing the adverse impact of SHAs on the environment. In addition to environmental benefits, there may be financial advantages from more use of lifecycle cost analysis and reduced reliance on the construction of more lane miles of facilities. Financial sustainability may become an enduring issue, as most SHAs are likely to confront revenue shortfalls from their fuel taxes, due to vehicles becoming more fuel efficient.

At this time, the extent to which each state has adopted a comprehensive sustainability program is not known. Only future research can tell us the best combination of training, SHA practices and oversight mechanisms to ensure sustainable outcomes. Appendix A contains a short survey designed to obtain information from environmental coordinators on their training programs and the presence of management personnel tasked with oversight of sustainability programs and practices.

Chapter 1: The Rising Concern for Sustainability

Manufacturing companies in the private sector are embracing the concept of sustainability. Applied to manufacturing, sustainability can be described as an industrial process guided by adherence to the 6Rs: Reduce, Re-use, Recycle, Recover, Re-design and Re-manufacture. The overarching principle is to minimize the use of natural resources by re-using material either through the re-use of specific parts or through more traditional techniques of recycling basic materials. Re-use calls for designing parts so they can be disassembled, recovered, and re-used again as originally produced. Product designers are asked to think in terms of the product life-cycle from design through manufacturing to consumer use and then post-use or re-use (dispersion versus reclamation).

In their quest to be more sustainable companies tend to focus on using fewer resources and taking less waste to a landfill. Thus, DOW chemical reports that, between 1996 and 2005, it trimmed its solid waste by 1.6 billion pounds, reduced its waste water by 183 billion pounds, and saved 900 trillion BTUs of energy. This success was facilitated by DOW's creation of a position of chief sustainability officer and its committing to a set of sustainability goals for the year 2015.

State highway agencies (SHAs) are beginning to adopt a similar approach to their tasks in the pursuit of a more sustainable approach to transportation. Like private sector firms, SHAs produce a product—a state highway system. To do so they use materials and energy to build and maintain the system. Given the manifold tasks for which they are responsible as well as the FHWA's sustainability goal of reducing the number of miles driven per capita in each state, the turn toward sustainability by SHAs has many facets: including at the very least the design of facilities; the efficient operation of traffic; the maintenance of facilities, the recycling of construction materials, methods to encourage less driving; and the reduction of environmental impacts on air, water, and other resources. System planners and project design engineers are beginning to think in terms of practical solutions that appropriately limit the roadway footprint, thus fitting the community and regional context, social as well as environmental.

Any practice that reduces the amount of material or land used or the impact of that material on the environment increases sustainability. The same is true of recycling materials, as recycling reduces the amount used and the quantity that ends up in a landfill. Highways tend to impact the immediate environment. Sustainable practices would include building fewer roads and designing them in such a way that the adverse effects of storm water run-off and construction are reduced. This could include practices to diminish impacts on wetlands and endangered species.

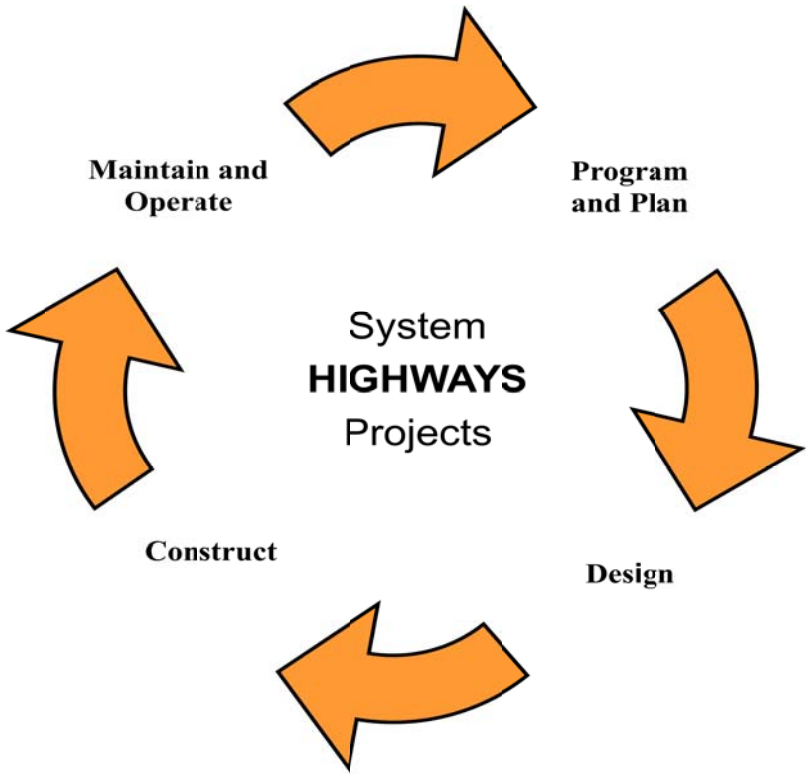
The use of new technologies and designs can be viewed as improving sustainability when they improve traffic flow, reduce the amount of construction needed, or reduce driving. For instance, when Intelligent Transportation System (ITS) devices improve traffic flow, thereby decreasing congestion, they tend to reduce auto emissions. Policies that encourage more transit use or less driving, such as transit oriented development or High Occupancy Vehicle (HOV) lanes, also contribute to sustainability. The same is true of SHA policies that encourage more facilities for walking and biking. (In the long run, these can also contribute to financial sustainability in that they will lead to less wear and tear on the highway system.)

Most sustainable practices can generate quantitative performance measures (e.g., the amount of material recycled or number of people in car pools and high occupancy vehicles.) Along with identifying the sustainable practices adopted by SHAs, this study will identify performance measures associated with each practice.

1.1 Sustainability in the SHA Field of Operation

Sustainable development, as defined by the Brundtland Commission report, is development that meets the needs "of the present generation without compromising the ability of future generations to meet their own needs." Speaking broadly, this can be accomplished by minimizing a SHAs use of resources, including the natural environment as a resource, in the course of building and maintaining an effective transportation system.

The construction and maintenance of state highways unfolds over a long span of time or lifecycle, sometimes as long as 30 years from initial planning to substantial rehabilitation. Thus, a highway department must plan for the future as well as the current transportation needs of its state. Clearly, attention to environmental impacts and sustainability must inform each phase of a highway department's activities from initial planning through design, construction, operations, and maintenance. Planning alone can consume five or more years. Once a road project is listed on a state's six year plan, a highway department often devotes years to project scoping including legally mandated environmental studies.



The Multi-Year Highway Development and Life-Cycle Process

A preliminary design is followed by a final design. But before construction can commence, the SHA must acquire right of way, negotiate with utility providers, obtain a variety of permits, and assemble a number of estimates. Construction, itself, may be fairly rapid, but planning and preparing for construction rarely is. A productive focus on sustainability during planning takes ample time and effort, as it calls for the development of designs that minimize the impact on the landscape. Moreover, the expected impact on the environment from construction activities must also be minimized.

Construction is followed by operations and maintenance. Here too steps can be taken to reduce the impact on the environment from mowing, snow removal, storm water runoff, pavement repair and other routine activities. In short, a commitment to sustainable practices will impact all aspects of the project development process before and after construction.

Given the diversity of ways that the activities of a SHA can harm the environment, it is imperative that SHAs respond along a comprehensive front. AASHTO has set forth five broad objectives, each of which a SHA should address as part of a successful program for sustainability. Perhaps, the most controversial concerns SHA involvement in land use; but the reason for this is clear. Transportation and land use decisions influence mode choice, vehicle miles travelled (VMT), and traffic congestion. Land use patterns that promote auto use are not sustainable in that they increase VMT and fuel use and road or lane construction along with the associated environmental impacts. (Jeon and Amekudzi 2010).

1.2 AASHTO's Five Objectives

1. **Reduce energy consumption.** This includes options and project solutions that reduce energy consumption, support energy efficient movement of people and goods, and use resources with lower operations and maintenance requirements. Examples include: traffic signal coordination, low energy lighting, dedicated transit lanes, bike lanes, transit signal priority, more fuel efficient fleets, transit expansion, use of wind and solar power at SHA facilities, policies to change driver behavior e.g., speed limits, and restrictions on idling at work sites.

2. **Reduce Consumption of material resources.** This includes design solutions that reduce the consumption of virgin material resources, use recycled materials in construction, require less infrastructure in the solution, or increase durability and life of the design. Examples include: recycled aggregates, narrow traffic lanes, fewer luminaire poles/catenary lighting systems; higher strength concrete pavements, and precast or modular construction elements.

3. **Reduce Impacts to Environmental Resources.** This includes solutions that minimize impacts on surrounding ecosystems, encourage and support biodiversity, and reflect historical and cultural context. Examples include: Rain gardens for storm water infiltration; diverse plant/tree selections, storm water infiltration basins in planter strips, porous pavement; spill prevention programs, and wildlife crossings.

4. **Support vibrant urban communities**. This entails solutions that incorporate features that support community livability; public services and adjacent land uses; and enhance public health, safety, and security for all people. Examples include bike and pedestrian facilities, traffic calming, public art, pedestrian refuges in medians, and transit oriented development.

5. **Support sustainability during implementation.** Here the goal is to reduce impacts during construction of a capital project, or during operations and maintenance of physical transportation projects. Examples include: reclamation of demolition materials; use of renewable fuels for construction equipment; use of locally obtained materials; and minimizing the construction footprint.

1.3 Plan of Report

Current research and writing on sustainable transportation tends to focus on fuel efficient vehicles, pollution reduction, the design of cities, and related themes. This research will take a more focused approach by looking at the transportation-related activities under the control of state highway agencies. There are a wide variety of ways to improve the sustainability of SHA practice. And, SHAs can be expected to vary in their use of sustainable practices and their related performance measures. Therefore it is useful to cast a wide net by looking at the sustainable practices of a number of SHAs. At this time very little is known about the current effort to make the practices of the SHAs more sustainable. This study will serve as a preliminary reconnaissance that can inform the design of subsequent studies.

The research will begin by identifying the various ways that a state highway agency can impact the environment. This discussion will provide an organizing scheme or categorization of those impacts. In the following chapters, the study will then identify a variety of policies within each category of impacts that are likely to promote sustainability. This will be accomplished by canvassing the literature on sustainability.

The study will also identify the various organizational structures that SHAs use to coordinate the effort to reduce their impact on the environment. Given the manifold activities of SHAs and the many ways they can harm the environment, it seems likely that the sustainability effort within each SHA will require that some form of organizational entity be assigned responsibility for institutionalizing sustainable practices across the SHA.

In the course of the review of state practices, data was gathered, whenever available, on the activities of the various states. This data was used to evaluate the effectiveness of two different types of organizational structures assigned responsibility for increasing sustainability.

The study concludes with a lists of sustainable practices at each stage of the highway lifecycle—planning, construction, operations, and maintenance..

Chapter 2: State Highway Agencies (SHAs) and Their Potential for Harm to the Environment

More so than any other agency of state government, state highway agencies can have numerous adverse effects on the natural environment. The reason for this is easily discerned. SHAs are responsible for nearly 780,000 miles of state owned highways, virtually all of which are paved (Yusuf et al 2010). These highways and their adjacent right-of-way cover tens of thousands of square miles across the country and introduce polluting chemicals from their constituent materials, such as asphalt. They alter or disrupt the natural ecology in ways that can harm plant and wildlife, especially aquatic life. State owned highways, moreover, carry ever-increasing volumes of pollution-emitting traffic and must be maintained with periodic resurfacings of asphalt and concrete, but mostly asphalt.

In this section of the report, we discuss seven ways in which SHAs can harm the environment. In subsequent chapters, we discuss the various techniques and methods in current use to avoid or minimize the deleterious practices.

1. Excessive Consumption of Virgin Materials

Each year the United States produces millions of tons of asphalt, much of it from virgin materials of gravel and oil-based binder. Some 94 percent of roads are paved with asphalt. The production of asphalt consumes energy and emits large amounts of green house gases. Over time asphalt breaks down and must be removed. Much of the asphalt taken up can be recycled, but some along with other waste products is carried to construction and demolition landfills.

2. Unnecessary Storm Water Runoff

Almost all asphalt and concrete is impervious, which leads to large concentrations of storm water and the possibility of erosion from storm water runoff. Moreover, oil and other chemicals leaking from vehicles build up on the highway. Rain washes these chemicals and residues from the road surface onto adjacent lands and plants. The runoff from storms can then pollute streams and rivers, having destructive effects on aquatic life. Fortunately, some of these chemicals are broken down and absorbed as nutrients by plants along the highway. But construction and maintenance often strip the land of the trees and plant life that absorb rainfall and chemicals, thereby fostering erosion, an increase in the volume of water entering streams, and the intensity of chemical pollution in the water course.

3. SHA Release of Contaminants

State SHAs are large organizations that in 2007 employed 236,758 people in highway related activities—many of them in tasks that can harm the environment (Yusuf et al 2010). Road crews, for instance, spread salt, repair potholes, patch cracks and perform sundry activities that use tools and chemicals that can in various ways contaminate the environment. SHA employees also operate vehicles and heavy equipment, which burn gasoline and diesel and leak contaminants. At their regional facilities, SHAs store pesticides, deicing chemicals, and various herbicides. These must be stored properly and used wisely to prevent spills and other accidents, especially those that pollute streams and rivers.

4. Inadequate Training of Employees and Contractors

To keep spills, accidents, and other polluting incidents to a minimum and properly respond to them when they occur, SHAs must effectively train and monitor their employees and contractors. This requires the creation of training programs and protocols for the wide variety of situations in which employees can impact the environment. Training is also required for the contractors that the SHA hires for its construction and maintenance projects. Even when a project is perfectly designed and built, the contractor can damage the environment by, for example, using more land than necessary to store materials and construction equipment, stripping the land of more vegetation than necessary, allowing chemicals to enter the water course or failing to replant the areas that lost vegetation.

5. Excessive Use of Energy and Release of Green House Gases

Sustainability has another dimension, namely, reduction in the amount of vehicle miles driven and the amount of green house gases emitted. This can be done in ways large and small- small by reducing idling at construction sites and reducing energy use at SHA facilities and large by reducing the volume of traffic or by alleviating congestion by improving traffic flow.

6. Excessive Land Use and Lack of Coordination with Public Transportation Facilities

This is perhaps the most difficult reform of SHA activities to accomplish as it requires cooperation from governments at all levels, as well as changes in residential and commercial development practices and transportation modes. Rather than build more lane miles of roads, SHAs are now expected in the interest of sustainability to build facilities for biking and walking, and promote more use of transit along with the related encouragement of transit oriented development.

7. Inadequate Oversight Structures

Sustainability is a recent concern that has been added to the long-standing responsibilities of SHAs. Like other organizational objectives, sustainability requires constant and predictable attention from management. This will require the creation of new positions and organizational units with new responsibilities including ways of measuring organizational performance.

2.1 The Need for Comprehensive Sustainability Planning

In sum, for SHAs, the goal of sustainability is multifaceted and demanding. Some sustainable practices are a response to the requirements of environmental laws that protect air and water quality, historic and archeological resources, and endangered species. Some are a response to economic factors such as the cost of virgin asphalt. But many sustainable practices are not the product of a specific legal mandate or financial incentive. They reflect better management and an enlightened commitment to environmental protection. This can take the form of comprehensive planning for sustainability.

Oregon has a comprehensive sustainability plan (Oregon DOT 2008) that includes steps to avoid the seven obstacles to sustainability discussed in this chapter. It starts with this definition of sustainability that echoes the Brundtland Commission Report: "using, developing and protecting resources in a manner that enables people to meet current needs and provides that future generations can also meet future needs, from the joint perspective of environmental, economic and community objectives (Oregon DOT 2008:7)." Among Oregon's main goals are: minimizing environmental impacts, integrating transportation and land use, reducing fossil fuel use, reducing greenhouse gas emissions, and reducing waste of transportation materials through recycling and reuse.

To reach the goals, Oregon emphasizes managerial oversight. Thus, Oregon has created management structures to coordinate the many facets of sustainable practice. For instance, Oregon has a Sustainability Program Manager who reports to ODOT's chief of staff. It also has the Oregon Sustainability Board, which has 11 members. Last, Oregon has created an Environmental Management System (EMS).

To minimize its impact on the environment from its maintenance and construction activities, Oregon SHA has environmental performance standards and sustainability goals for site landscaping, storm water, streams, wetlands, wildlife and fish habitat, noise, air quality, and historical and cultural resources.

Oregon's EMS provides oversight of ODOT's maintenance yards. This oversight guides staff in managing the storage, use and disposal of different kinds of potentially damaging materials, such as pesticides, herbicides, cleaning fluids, gasoline and diesel.

Its sustainability plan also calls for integrating life-cycle cost analysis into purchasing decisions for vehicles and infrastructure as well as the purchase of green products such as bio-diesel and compost erosion control Thus, it has sustainability goals and practices for such varied activities as site landscaping, chemicals used in major facilities, and purchasing practices.

To reduce energy consumption by the driving public, ODOT has instituted programs for transportation demand management. These include programs for carpooling and telecommuting, as well as campaigns designed to reduce driving and increase the use of alternative transportation modes, specifically transit, walking and biking. The plan also calls for more construction of facilities for walking and biking.

Various ITS technologies are also used for transportation demand management with such services and methods as: traveler information, incident management, commercial vehicle electronic clearance, traffic signal communication, and tolling and congestion pricing. These techniques can reduce the need for new lane miles of roadway.

ODOT is committed to recycling materials and waste minimization and has specifications for the use of alternative fuels, along with programs to reduce fleet fuel use and building energy use.

ODOT works with other entities to integrate transportation and land use planning. On a regular basis OSHA works with the Land Conservation and Development Commission (LCDC).

In short, ODOT has a multifaceted sustainability program designed to reduce over several years: the total number vehicle miles travelled; the number of additional lane miles built; the use of virgin materials used; and the number and extent of adverse impacts on the environment from construction, storm water runoff, and maintenance activities.

Chapter 3: Sustainability through Recycling and Reduced Consumption of Virgin Materials

3.1 Pavement Practices for Sustainability

Of the 2.6 million miles of paved roads in the U.S., over 94 percent are surfaced with asphalt. Approximately 85 percent of the nation's airfields are surfaced with asphalt and 85 percent of the parking lots. Given its ubiquity, the fact that asphalt is oil-based and uses large amounts of resources, consumes a great deal of energy in its preparation, and gives off green house gases, SHAs need to adopt a number of different policies to minimize the impact of asphalt on the environment.

There are two main types of asphalt preparation: the more common and more energy intensive is hot mix asphalt (HMA), which is prepared at very high temperatures. Recently a second type—warm mix asphalt, prepared at significantly lower temperatures—has emerged and is growing in popularity. According to the National Asphalt Paving Association (NAPA), "Running warm mix can reduce energy consumption during the manufacturing of the asphalt pavement mixture by an average of 20 percent, which decreases total life-cycle greenhouse gas emissions by 5 percent….Warm mix with 25 percent reclaimed asphalt pavement could potentially offset asphalt pavement life-cycle greenhouse gas emissions by 15 to 20 percent. The potential for total savings in green house gas emissions using both warm mix and recycling is about 3 million tons per year." (National Asphalt Paving Association (NAPA) 2010).

3.2 Recycling Asphalt

Recycling entails reusing materials rather than sending them to a landfill as waste. It therefore has many advantages: among them, less use of primary raw material; less air and water pollution; less use of energy in the preparation and transport of construction materials: and a reduced need for landfill. In addition to protecting air and water from pollutants, recycling saves money and resources.

Currently there are many thousands of miles of roads, many of which are near, at or past their design life. The need for roadway maintenance and roadway deconstruction has afforded a material that can be readily used for the repairs, reclaimed asphalt pavement (RAP).

Reclaimed asphalt pavement (RAP) is the term given to removed and/or reprocessed pavement materials containing asphalt and aggregates. These materials are generated when asphalt pavements are removed for reconstruction, resurfacing, or to obtain access to buried utilities. When properly crushed and screened, RAP consists of high-quality, well-graded aggregates coated by asphalt cement. Asphalt pavement is generally removed either by milling or full-depth removal. Milling is typically done in rehabilitation projects where the upper level of pavement is removed and then replaced to increase the pavement's service life. RAP that is produced from milling is ready to be recycled with little to no processing, depending on the amount being used in the mixture. If the percentages of the mixture exceed 15 to 25 percent then additional screening, crushing and fractioning may be necessary. In full-depth removal bulldozers or front end loaders break the entire pavement structure into manageable slabs and then load them into trucks, which transport the pavement to a reprocessing site. This use of trucks uses energy, of course.

RAP can be used in several ways: as an addition to regular HMA; as an aggregate in cold-mix asphalt; as a granular base course when pulverized; and as fill or embankment material. HMA is one of the most recycled products in the U.S. As much as 100 million tons of HMA are milled off roads during resurfacing and widening projects each year. Due to the variety of uses more than 90 percent of all asphalt taken up is recycled.

The amount of RAP allowed in surface course mixes varies from 10 to 25 percent depending on a number of variables including winter temperatures and traffic volume. Robinette and Epps write: "Utilization of RAP in HMA is the most efficient use of this material as it provides a reduction in virgin asphalt binder and aggregate demand. Currently, around 75-percent of all State Standard Specifications allow at least 10 percent RAP in HMA surface course mixes and allow for greater than or equal percentages in lower pavement lifts (NAPA 2010)."

3.21 In-Place Recycling

Although the majority of old asphalt pavements are recycled at central processing plants, asphalt pavements may be pulverized in place and incorporated into granular or stabilized base courses using a self-propelled pulverizing machine. In-place recycling techniques can be used to resurface an existing pavement or pulverize an existing pavement for use as base material. There are two types: cold in-place recycling, which can be either partial depth or full depth; and hot in-place recycling, which is used for surface recycling.

Hot in-place and cold in-place recycling processes have evolved into continuous train operations that include partial depth removal of the pavement surface, mixing the reclaimed material with beneficiating additives (such as virgin aggregate, binder, and/or softening or rejuvenating agents to improve binder properties), and placing and compacting the resultant mix in a single pass.

A principal advantage of in-place recycling is that the recycling occurs at the roadway being rehabilitated, thus reducing the amount of material that must be hauled to the job-site. Asphalt binder and aggregate are conserved, as is the energy used in hauling. But, a 2003 study by the Colas Group documented another advantage: CIR and HIR used, respectively, only 83 and 20 percent of the energy required in the production of conventional HMA, respectively.

According to the FHWA (2010), CIR costs less, conserves material, and returns the road to use sooner. The driving public is more satisfied due to more roads being improved for the money as well as less down time for the roads. According to New York State, CIR (4") with 1.5 inch overlay can last 10-15 years with little maintenance compared to a 5-8 years service life for a 1.5 inch traditional overlay.

Robinette and Epps (2010) concluded their study of hot in-place and cold in-place recycling with these words: “In most instances these activities can reduce energy consumption, emissions generation and conserve natural resources (aggregate and asphalt binder).” For that reason in-place recycling is becoming more common. FHWA reports that Nationwide, cold in-place recycling (partial depth) has been employed on four or more projects in 18 states with 12 states having standard specifications or special provisions for CIPR.

3.22 Implications for Sustainable Road Building and Maintenance Policies

Taken as a whole, the research suggests three broad principles for SHAs seeking to institute a sustainable approach to the use of asphalt.

1. Recycle as much asphalt as possible.
2. Use warm-mix asphalt as often as possible instead of hot mix asphalt.
3. Use in-place recycling as often as possible.

In addition to these, SHAs need to engage in life cycle cost analysis. Long-lasting pavements properly maintained can reduce the use of asphalt, as pavements need less rehabilitation over the long term. This requires a system for pavement performance monitoring. The use of cool pavements to reduce heat island effects is also recommended.

3.23 Data Demonstrating the Widespread Use of Asphalt Recycling

About 100 million tons of old pavement are reclaimed every year, much of it is used for resurfacing, but about 60 million is used in other pavement-related applications, such as aggregate road base (NAPA 2010).

The National Asphalt Pavement Association (NAPA) conducted a survey of the states and reported in 2007 that only 7 percent of reclaimed asphalt pavement (RAP) is discarded in landfills. A full 93 percent is recycled--with 72 percent recycled in hot mix asphalt. In a telephone interview, David Newcomb, the research director for NAPA, said that the percent going to landfills in 2010 is lower than in 2007. (Source David Newcomb, research director NAPA, interview on June 22, 2010.)

According to Dr. Newcomb, warm mix asphalt has become increasingly popular. He believes 10 to 15 million tons of warm mix asphalt were produced last year. He stated that 26 states have increased their use of RAP since 2007. Only 4 states do not permit the use of more than 25 percent RAP in one or more HMA layers—surface, base or intermediate. He provided research results showing that the average percent of RAP in asphalt allowed by the states is 18 percent RAP in the surface mixes; 27 percent in the base mixes; and 26 percent in the shoulder mixes.

3.3 Other Waste Recycling and Reuse

Construction and demolition (C&D) waste is solid waste such as asphalt shingles, gypsum, wood, floor tile, siding, and clean rubble. The latter is concrete, asphalt pavement, reinforcing steel, brick, soil, or rock. All these materials can and should be recycled whenever feasible. And some materials can be reused (e.g., guard rails). Many bridge components can also be reused.

C& D recycling, Warren, Chong, and Kim (2007) report, is more likely when there are comprehensive recycling facilities available, and supply chain networks. Also, knowledge on the part of developers is lacking in regard to the use of recycled materials. Codes and standards are needed for materials that require structural strength. This does not apply to asphalt.

Due to an absence of C&D landfills on the coasts, the use of recycled materials is more common on the coasts than in the middle of the country.

3.31 Recycling Base and Sub-base Materials

RAP often goes into the sub-base. However, other materials can also be recycled in the sub-base. Lee et al (2010) studied the use of fly ash and foundry sand. Their study found that using recycled materials in the base and sub-base layers of pavement can result in reductions in global warming potential (20%), energy consumption (16%), water consumption (11%), and hazardous waste generation (6%). Overall, use of recycled materials in the base and sub-base has a potential life cycle cost savings of 21% while providing a longer service life.

3.4 Concrete is Preferable to Asphalt

At this time, most highway and road construction (94%) uses asphalt for the road surface. Concrete surfaces are relatively more expensive; but they have some advantages that suggest the utility of more use of concrete in the pursuit of sustainability. According to the American Concrete Pavement Association (ACPA), concrete pavement has the advantages compared to asphalt listed in table 3.1.

TABLE 3.1 Advantages of Concrete over Asphalt in Highway Construction and Maintenance

1. It lasts longer than asphalt—as much as 50 plus years. It does not require rehabilitation or reconstruction as often and therefore does not consume as much raw material over the long run.

2. Reduced pavement deflection, which results in reduced vehicle fuel consumption from 1 to 6% less fuel for heavy trucks.

3. Concrete pavements consume less fuel during materials construction, transportation, and placement than the construction of asphalt pavements. This results in CO2 savings. The amount of fuel per lane mile of concrete roadway constructed is less than one-fifth of the fuel used to construct the same length of asphalt.

4. Concrete pavement incorporates industrial byproducts (i.e., fly ash and slag cement), which lowers the disposal needs, reduces the demand on virgin materials, and conserves natural resources

5. It is renewable and 100% recyclable.

6. It requires less sub-base aggregate materials for structural support.

7. Its lighter color and increased reflectivity improve nighttime visibility and reduce the amount of power needed to illuminate roads and help mitigate urban heat island and smog generation. Asphalt roads are estimated to require 24% more light poles.

8. It has a lower energy footprint over time in regard to production, delivery and maintenance.

9. It reduces the heat island effect

10. Concrete pavements designed with pervious concrete shoulders minimize surface water discharge and help replenish groundwater aquifers.

11. Optimized concrete pavement surface textures produce quieter pavements over longer periods of time, reducing noise pollution.

3.5 Summary

In almost all circumstances, the use of recycled materials contributes to sustainability. The recycling of asphalt appears to be nearing 100 percent, which probably reflects the coincidence of economic and environmental incentives. Recycling saves money. On new highways, the use of concrete may be preferable to asphalt. In preparing asphalt, warm mix methods are more sustainable than hot mix.

Chapter 4: Sustainability through Improved Storm Water Management Programs

Almost all state owned roads have impervious surfaces that generate large amounts of storm water runoff. As discussed previously, this runoff, besides leading to floods, can cause erosion and pollute streams, rivers, lakes and ponds. Federal and state law call for continuing improvement in the amount and condition of the water that enters the nations water courses. The National Pollutant Discharge Elimination System (NPDES) permitting program is authorized under the Clean Water Act to control the discharge of pollutants from industrial and municipal point sources to waters of the United States. Progress in the control of runoff is expected and the NPDES discharge permits are issued on a five year cycle to owners of storm drain (sewer) systems.

To be in compliance with the Clean Water Act (CWA), state SHAs must follow federal regulations that state that receiving waters be "fishable and swimmable." Federal regulations require that storm water shall not cause or contribute to a violation of water quality standards. However, this is to be done to "the maximum extent practicable (MEP)". The CWA does not explicitly define MEP, so the law is flexible. But, SHAs should follow the best management practices (BMP) to minimize the discharge of pollutants into receiving waters.

Table 4.1 contains a list of the more commonly recommended management practices designed to reduce the volume of storm water runoff and the amount of pollution in the runoff that reaches streams and various bodies of water. Several of these practices rely on vegetation to absorb water and remove pollutants (e.g., storing topsoil for revegetation, bio-retention basins, replanting native species). Most storm water pollution prevention plans will contain these and other features. The goal of such plans is often referred to as Low Impact Development (LID), which emphasizes vegetated controls and the objective of maintaining pre-development hydrologic conditions on a site. These will mitigate an upsurge in runoff as a result of construction.

During construction steps can be taken to control erosion and written contracts should specify the steps to be taken to that end in an erosion control plan. In addition to the techniques already mentioned, a plan can contain such features as silt and sedimentation basins and storm water harvesting.

Table 4.1 contains some other methods for controlling the effects of runoff including more use of pervious pavement and grass shoulders. Water quality can also be maintained by fencing off wetland areas, the creation of bio-engineered stream banks, and the installation of water quality inlet structures.

In regard to oversight and control, the best approach combines specifying the desired practice in the construction contract or work order followed by inspection to ensure compliance. It is recommended that state highway agencies keep records detailing the practices followed on each project. Wherever possible, these records should contain quantitative measures, for example, square feet of pervious pavement or miles of grass shoulders, acreage of revegetation and the like.

New practices and techniques for managing storm water are emerging. Many SHAs (e.g., New York, DC, Maryland, North Carolina, Texas, and Florida) are working with their state universities to develop best practices. Among those being developed according to Tayler and McGowen (2010) are: polyacrylamide application, which is used to reduce turbidity in storm water discharging from construction sites and new ways to remove pollutants with bio-retention. Regarding the latter, UT Austin has developed a low cost retrofit application for wet or dry detention basins—batch detention— that significantly improves removal efficiency for particulate constituents. An active pond outlet detains storm water runoff in quiescent conditions, improving removal compared to conventional basins with passive outlets.

To sum up, the list of techniques in table 4.1 is very general and not by any means exhaustive, as new techniques are under development and the search for sustainable practices gathers momentum. One recent development is the permeable friction course overlay— an open graded friction course applied over a conventional pavement section to improve the water quality of highway runoff.

TABLE 4.1 Management Practices to Reduce Storm Water Runoff and Storm water Pollution

Management Practice	Oversight Technique or Measure
Stormwater pollution prevention plan	Inspection of construction site for adherence to plan
Stockpiling topsoil for revegetation	Specifying in contract with inspection for compliance
Storm water harvesting for landscape Irrigation	Specifying in contract with inspection for compliance
Low impact development (LID)	Inspection of construction site
Bio-retention basins	Specifying in contract with inspection for compliance
Re-planting native species and/or low water vegetation	Specifying in contract with inspection for compliance
Plans for habitat connectivity	Specifying in contract with inspection for compliance
Erosion control plan	Inspection of construction site for adequate erosion and sedimentation control measures
Use of pervious pavement	Percent of new parking surfaces and break down lanes with pervious pavement
Grass shoulders	Miles of lanes with grass shoulders
Bio-engineered stream banks	Specifying in contract with inspection for compliance
Water quality inlet structures	Specifying in contract with inspection for compliance
Delineate and fence wetland areas	Specifying in contract with inspection for compliance

.

Chapter 5: Sustainability through Reduced Release of Contaminants from SHA Activities

State SHAs are large organizations that carry out many tasks that involve the application or use of substances that can harm the environment. As previously noted road crews spread salt, repair potholes, patch cracks and perform sundry activities that use tools and chemicals. Much of their work requires the operation of vehicles and heavy equipment. These run on gasoline and diesel and can leak contaminants. At their regional facilities, SHAs store pesticides, deicing chemicals, and various herbicides. These must be stored properly and used wisely to prevent spills and other accidents, especially those that pollute streams and rivers.

The harmful effects of highway agency activities can be reduced through careful attention to the proper use and storage of potential contaminants. Table 5.1 lists some of the methods used to protect the environment from exposure to contaminants.

Many problems arise from the inadvertent spilling of harmful substances. The occurrence of these can be reduced with the adoption of a spill prevention program. All employees who handle these materials need instruction on best practices for preventing spills and best practices for limiting their effects through quick and thorough clean-ups.

Environmental damage can also be curtailed by covering stockpiles at construction sites and at regional facilities. These stockpiles, along with all toxic materials, need to be clearly separated from the water course. In that spills can occur during refueling of vehicles, it is important to require that refueling occur a safe distance from the water course. The washing and servicing of vehicles should also be kept away from the water course.

Refueling areas should be small. In fact, all construction and staging areas should be confined to the smallest areas possible. In general, it is better to use bio-friendly hydraulic fluids whenever possible on as many pieces of equipment as possible.

State highway agencies are tasked with the removal of snow and ice in the winter and excess vegetation in the summer. In the cold months, the agencies use salt, sand and deicers to render the roads safe and passable. In the warm months they mow, trim trees and use herbicides. In pursuit of sustainability, the use of salt, sand, deicers and herbicides should be kept to a minimum.

Table 5.1 Practices to Reduce Release of Contaminants

Management Practice	Oversight Technique or Measure
Spill prevention program	Number of employees trained
Covering stockpiles at construction site	Inspection of sites
Refueling away from water course	Inspection of sites
Washing and servicing vehicles away from water course	Inspection of sites
Store toxic materials away from water course	Inspection of sites
Use of bio-friendly hydraulic fluids in vehicles	Percent of vehicles with bio-friendly fluids
Reduced use of salt and deicers	Percent reduction in use
Reduced use of herbicides	Percent reduction in use
Reduced use of pesticides	Percent reduction in use
Reduced use of sand	Percent reduction in use
Confine construction and staging areas to smallest area necessary	Inspection of sites
Plan for fossil fuel use reduction at construction site	Reduction in amount used

Chapter 6: Sustainability through Reduced Release of Greenhouse Gases

State highway agencies contribute to green house gas emissions in several ways. (1) Their vehicles and equipment as well as those of their contractors emit exhaust fumes from the burning of gasoline and diesel fuel; (2) the building of highways consumes large amounts of energy in the production and transport of asphalt and concrete; and (3) the addition of lane miles of highway induces more miles of driving by the public. Clearly, the effort to reduce green house gas emissions must address all three factors contributing to the problem of air pollution if it is to put as large a dent as possible in the release of green house gases. Fortunately there are many ways to reduce emissions. See table 6.1.

Among the steps available to reduce emissions by vehicles driven by employees and contractors are programs that require the reduction of engine idling at work sites. Another is mandatory use of cleaner fuels and/or the use of vehicles with improved emission control devices. Such requirements and mandates can become a standard feature of SHA practice and SHA contracts.

In a previous chapter, it was noted that the growing use of warm mix asphalt will effectively decrease the emission of green house gases by significantly lowering the temperature needed to prepare the asphalt. The emergence of in-place asphalt recycling technologies will also curtail emissions—by reducing the need to transport by truck as much material to the site. In the interest of sustainability, state highway agencies are likely to increase the use of these emerging technologies.

Perhaps the best way to reduce green house gas emissions is to reduce the number of miles driven on the roads. One obvious method is to build fewer lane miles of arterials, which is discussed in the next chapter. Another is to improve the management of traffic on the current system of highways. In recent years a number of techniques for managing traffic have emerged. These techniques are usually referred to as intelligent transportation systems or ITS. They regulate traffic flow so as to maximize the number of vehicles efficiently travelling along a specific length of highway. Ramp metering, for instance, prevents an excess of vehicles from entering a limited access highway. This can prevent the emergence of stop and go traffic on the highway. Corridor management techniques can use such devices as adjustable speed limit signs to keep traffic flowing at a steady rate. A slower but steady rate can improve traffic flow by preventing back-ups.

When accidents occur and traffic comes to a standstill, state highway agencies are able to use systems for traffic incident monitoring to quickly remove disabled vehicles from the highway. These systems are often run from a traffic management center staffed by SHA officials.

Many states have created high occupancy vehicle (HOV) lanes to encourage more ride-sharing. These lanes can be coordinated with park and ride facilities. The net effect is a reduction in the number of vehicles and a smoother flow of traffic, both of which lower emissions.

ITS devices are also used to reverse the flow of traffic on designated lanes during the morning and afternoon rush hours. Thus an inbound lane in the morning for those heading to work can be turned into an outbound lane for the same drivers going home in the afternoon. This can eliminate the need to build a new lane of roadway along with improving traffic flow during rush hours.

For some time now, cities have been adjusting the timing on traffic signals in response to differences in traffic flow. This can speed up passage along a highway. These adjustments are often coordinated from traffic control centers.

Traffic flow is also improved with the emergence of electronic toll collection. Emissions also decline, providing there is no increase in traffic volume (Bekir et al 2007). Drivers place a transponder or identification strip on their vehicle which eliminates the need to stop at a toll booth to pay an attendant. The driver pays a fee by mail or computer.

Electronic tolling will facilitate the adoption of congestion pricing by some cities. Under such systems of pricing, drivers pay more for driving on a specific roadway at its peak usage and less during off-peak times. This spreads traffic out over the day, reduces the amount of time spent stuck in traffic, and reduces emissions.

A last point, state highway agencies can reduce their own use of energy for heating and cooling office and other buildings. This would entail the installation of better insulation and more use of LED lighting. It might also involve the use of wind and solar power at their facilities.

SHAs should seek LEED certification for their buildings. LEED is an acronym for Leadership in Energy and Environmental Design. The program is run by U.S. Green Building Council. In the LEED system, points are given to a building project based on performance in specific areas including sustainable sites, water use, energy use, indoor environmental quality, stewardship of resources, innovation in design and regional priorities. SHAs can have a set of employees trained in the LEED evaluation system to ensure that all buildings are LEED certifiable.

Table 1 lists an associated performance measure or oversight technique related to each specific reform or practice. But the most important measure—improved air quality—would be the result of the entire package of techniques the state adopts. These could be assessed by the level of daily CO_2 and other emissions per mile of roadway

TABLE 6.1 Practices to Reduce Release of Green House Gases

Management Practice	**Oversight Technique or Measure**
Idling reduction programs	Reduction in state highway agency fuel consumption
Use of clean fuels	Clean fuels as percent of all fuels
Require contractors to use emission control devices	Inspection at sites for compliance
Coordinating park and ride with transit or ride-sharing	Frequency of use
Ramp metering	Improved traffic flow at peak hour
HOV lanes	Reduction in percent of single occupancy vehicles
Congestion pricing	Improved traffic flow at peak hour
Electronic toll collection	Increase in use by drivers
Adjustable speed limit signs	Improved traffic flow at peak hour
Traffic incident monitoring and rapid response	Decrease in traffic delay per incident
Signal timing to encourage smoother traffic flow	Improved traffic flow at peak hour
A traffic management center	Improved traffic flow at peak hour across system
Road weather information system	Improved traffic flow/ fewer crashes during storms
Integrated corridor management	Improved traffic flow at peak hour
Energy efficient insulation and lighting, wind and solar power at DOT facilities	Reduction in utility bills, LEED certification of buildings

Chapter 7: Sustainability through Improved Land Use and Public Transportation

Attention to land use along with a concerted effort to relate land use to public transportation can lead to significant reductions in driving. But, these are not easily done as they require cooperation from governments at all levels, as well as changes in residential and commercial development practices and transportation modes. Nevertheless, the pursuit of sustainability will necessitate a downshift in the production of new lane miles of roads and conversely a rise in the production of facilities for transit, biking and walking in conjunction with a SHA commitment to work with the agencies and developers promoting transit oriented development.

State highway agencies are paying more attention to land use and transit use. A measure of this is cooperative involvement in planning with city and county governments and such intergovernmental bodies as Metropolitan Planning Organizations (MPOs). As a result of such cooperation, many cities are now adopting policies for more infill development and more transit oriented development. The former contributes to higher population density in cities. The latter policy coordinates residential and commercial construction with bus routes or light rail. Several cities have regional growth plans that incorporate transportation facilities and transit oriented development (TOD), among the leaders Denver, Portland, and Minneapolis.

A recent study estimates that by 2002, more than 46 percent of cities with populations of 50,000 or greater had adopted a policy for transit oriented development (Yusuf, O'Connell, & Abutabenjeh 2010). Moreover, many of the larger cities are creating light rail systems. At this time, there are 34 light rail or street car systems in the United States. Remarkably, 20 of these have been built since 1990.

Some states are actively promoting transit oriented development. California and North Carolina have adopted legislation that promotes TOD. New Jersey goes so far as to subsidize it with grants for transit villages. These are administered by NJDOT's Division of Local Aid and Economic Development. By 2005, New Jersey had 16 transit villages. Pennsylvania has passed the Transit Revitalization Investment District Act (TRIDS) that authorizes state public transportation agencies to work with counties, local governments, transportation authorities, the private sector and Amtrak to create and designate TRIDs. In addition to New Jersey, federal and state financial and technical assistance has been used to support transit villages, downtown revitalization and sustainable development in Vermont, and Texas.

Porter (2006) reports that SHAs are increasingly linking corridor planning to land use issues. This requires training. For instance, Wisconsin SHA now provides training for headquarters and district staff on how to work with communities on land use issues. In Kentucky, The Newtown Pike extension was designed with subsequent land use in mind. Porter states that "In NJ and Wisconsin, State SHAs have realized that the short-term costs of investing in land use planning for transportation corridors are small compared to long-term savings in transportation investment needs. NJ is spending approximately $500,000 per study to address transportation and land use in major corridors, a small amount compared to project construction costs that can range in the tens to hundreds of millions of dollars." He concludes that a comprehensive regional transportation plan addressing land use issues can serve as a broad framework for more specific transportation decisions.

TABLE 7.1 Practices to Improve Land Use and Public Transportation

Management Practice	**Oversight technique or Measure**
Participation in transit oriented development	Number and/or size of TOD projects
Participation in local comprehensive planning	Changes in proposed Land Use and Highway Construction/ Number of consultations with MPOs and Local Governments
Construction of bike and pedestrian facilities	Miles of Facilities Built or Improved
Funding of transit	Money Spent on Transit Facilities and Operations
Building of fewer new roads and lane miles	Decrease in Construction of New Lane miles

Federal policy since ISTEA in the 1990's has called for more investment in facilities for alternative forms of transportation—bike riding, walking, and transit. These investments can reduce the number of vehicles on the road. They also reduce the need for new additions to state highway system. Since ISTEA, there has been a steep decline in the number of miles of new state owned roads built. As the table below shows, between 1999 and 2007, the miles of state owned roads increased from 772,552 miles to 779,131 miles, an increase in length of less than 1 percent. Conversely, local governments have been adding roads. In 1999, local governments owned 3,028,289 miles of roadway. By 2007, localities owned 3,122,058 miles of roadway, an increase of 93,769 miles or 3 percent. See table 7.2.

TABLE 7.2. Comparison of State-owned and Locally-owned Roads, 1999-2007

	State-owned Roads		Locally-owned Roads	
Year	Miles	% Change from Previous Year	Miles	% Change from Previous Year
1999	772,552		3,028,289	
2000	771,993	-0.07%	3,046,066	0.59%
2001	772,270	0.04%	3,054,561	0.28%
2002	773,289	0.13%	3,042,635	-0.39%
2003	772,555	-0.09%	3,077,780	1.16%
2004	774,687	0.28%	3,085,533	0.25%
2005	777,252	0.33%	3,091,196	0.18%
2006	779,074	0.23%	3,109,311	0.59%
2007	779,131	0.01%	3,122,058	0.41%

Source: Table HM-10 from multiple years of the Federal Highway Administration's *Highway Statistics*.

There is a related decline in the addition of lane miles of arterials. Between 1987 and 1997, the nation added 61,646 lane miles of arterials, significantly more than the 39,671 added in the following decade from 1997 to 2007. Arterials are known to foster sprawling development. Presumably, the reluctance to add lane miles will result in fewer homes being built in outer suburbs and rural areas.

Chapter 8: Sustainability through Training and Certification Programs for SHA Employees and Contractors

SHAs must effectively train and monitor their employees and contractors in order to keep spills, excessive runoff, and other polluting incidents to a minimum and properly respond to them when they do occur. The same is true for other activities from context sensitive design to the installation of ITS devices. Sustainability thus requires the creation of a wide array of training programs and protocols across the spectrum of situations in which employees can impact the environment. And as previously noted, training is also required for the contractors that the SHA hires for its various construction and maintenance projects. As we have seen, even when a project is well designed, the contractor can damage the environment by, for example, using more land than necessary to store materials and construction equipment, failing to replant vegetation, or allowing chemicals to enter the water course during construction activities.

Table 8.1 lists many of the useful training programs being adopted by state highway agencies. Some of these programs are more relevant for contractors and some for employees. However, both contractors and trainees can increase the sustainability of their activities by acquiring more information about the best practices from training programs in their area of expertise.

As indicated in the table most of these programs focus primarily on SHA employees. They are expected to subsequently instruct contractors in the field on the best practices to protect the environment. Still contractors, as well, can profit from training in all the areas mentioned in the table, especially the more complex programs like context sensitive solutions and erosion control.

TABLE 8.1 Training Topic and Oversight Technique or Measurement

Training Topic	Oversight Technique or Measure
Context sensitive solutions/design	Percent of SHA personnel and contractors trained
Water pollution controls for construction	Percent of SHA personnel and contractors trained
Erosion and sediment control	Percent of SHA personnel and Contractors Trained
Storm water best management practices	Percent of SHA Personnel and contractors trained
Environmental law and NEPA process	Percent of SHA personnel and contractors trained
Hazardous materials handling	Percent of SHA personnel and contractors trained
Energy efficient equipment practices	Percent of SHA personnel and contractors trained
Spill prevention	Percent of SHA personnel and contractors trained
Wetlands issues	Percent of SHA personnel and contractors trained
Salt and deicing issues	Percent of SHA personnel and contractors trained
Vegetation management	Percent of SHA personnel and contractors trained
Endangered species issues	Percent of SHA personnel and contractors trained
Cultural and archeological Resources	Percent of SHA personnel and contractors trained
Inspection training	Percent of SHA personnel and contractors trained
Contractor certification in erosion and sediment control	Percent of SHA personnel and contractors trained

Chapter 9: Sustainability through Improved Oversight and Management Structures

As remarked throughout, SHAs can harm the environment in multiple ways. Today, all SHAs have environmental divisions or sections that prepare environmental impact statements for proposed highway and related projects. These sections tend to be compliance oriented and work in cooperation with such agencies as FHWA, the EPA, state and federal fish and wildlife agencies and other resource agencies. Compliance with federal and state law contributes to sustainability. But sustainability has additional dimensions, not related directly to compliance (e.g., using ITS to manage traffic and reduce the need for new highway lanes.) To increase sustainability many states are creating new oversight structures, two of which are discussed below.

9.1 Environmental Management Systems (EMS)

According to AASHTO, "An EMS may be considered as the organizational structure and associated responsibilities and procedures to integrate environmental considerations and objectives into the ongoing management decision-making processes and operations of an organization. " (Soltis 2003) AASHTO adds the following: "This system consists of planning, operational, and review procedures, processes and tools that incorporate various features and benefits. EMS features include: needs identification, solution identification, consistency, repeatability, adaptability and flexibility to accommodate various situations, integration of existing initiatives, and measurable performance.

In 2006, AASHTO conducted a survey of state DOT to ascertain the status of EMS development. Table 9.1 lists the states that had implemented a full EMS, had an ongoing pilot, or said they had implemented one selectively, informally, or partially.

Table 9.1: States with Full EMS, with Ongoing Pilot, or with Selective, Informal or Partial Implementation of an EMS

Full Implementation	Pilots Ongoing	Selective, Informal, or Partial Implementation
Alabama, Florida, Kentucky, Maine, Maryland, Massachusetts, New Hampshire, New York, Pennsylvania, Washington	Rhode Island, South Carolina, Tennessee, Virginia, West Virginia	California, Indiana, Louisiana, Minnesota, Montana, Nebraska, New Jersey, North Carolina, Ohio,

The use of an EMS by state SHAs is encouraged by presidential Executive Order 13148, the FHWA, and AASHTO. An EMS has an EMS manager and an EMS team, authorized to oversee environmental compliance. In practice, an EMS can connect the various departments with environmental responsibilities. An EMS can identify gaps in policy and high-risk areas, establish responsibilities, audit, and measure overall environmental performance. (AASHTO's 11 steps for creating and operating an EMS are in table 9.2.)

TABLE 9.2: AASHTO's Steps in the Creation and Operation of an EMS (from Venner 2004)

1. Identify environmental issues and/or opportunities to be addressed by the EMS
2. Identify desired environmental and business results and benefits
3. Establish objectives, quantifiable measures and targets, and associated milestones.
4. Obtain management commitment to EMS, characterize EMS resource needs, and identify EMS leaders
5. Identify existing initiatives, programs, procedures, processes, and tools relevant to the EMS.
6. Identify improvements to achieve EMS objectives
7. Assign responsibility for developing enhanced or new procedures, processes and tools.
8. Identify personnel (by title) affected by EMS, define responsibilities, and communicate responsibilities
9. Identify EMS-related training needs, responsibilities, and schedule. Conduct the training.
10. Project review. Assess EMS performance.
11. Managers/senior management. Review progress, identify adjustments, and confirm commitments.

9.1.1 The Possible Strengths of an EMS

An EMS is said to improve environmental oversight, because as Venner explains (2007:4), "An EMS is a process that gives rise to better communication and understanding of roles and responsibilities, and it ensures that workers whose jobs affect the environment have the know-how they need to reduce the likelihood of adverse impacts or increase the likelihood of environmental performance improvement." That is (Venner 2007:3): "An EMS provides a structure and process to identify needs and opportunities, ensure consistency in approach, and improve results."

An EMS is expected to take a comprehensive approach to the environment that goes well beyond compliance with the NEPA process and environmental law. And, as Venner (2007) has concluded: "As existing EMSs mature, they tend to move beyond a compliance focus…and tend to strengthen the connections among the system components."

Thus, an EMS can serve as a tool for strategic planning to implement an organization's environmental priorities. The prime emphasis of this sort of strategic planning is quality improvement and assurance; accomplished through planning, well-documented action, re-evaluation, and implementation of improvements through revisions of plans and procedures. An EMS can help integrate environmental considerations into an organization's day-to-day operations and management culture.

9.1.2 ISO 14001 Certification for an EMS

Some EMSs are seeking certification by the International Standardization Organization. ISO 14001 certification is an effective and widely recognized method for demonstrating an organization's commitment to environmental performance and quality management. ISO 14001 compliant EMSs have six key elements.

1. Environmental policy with goals
2. Planning to meet goals of policy
3. Implementation and operation with defined roles for all staff
4. Checking and corrective action with auditing, monitoring, and measurement of environmental indicators
5. Management review by top officials
6. Continual improvement

Some general measures for a SHA's larger monitoring and measurement effort related to environmental performance are established by ISO 14001, section 4.5.1

9.2 Environmental Advisory Teams

Another common device for improving environmental performance is the creation of environmental advisory teams. According to Marie Venner (TRB 2003 Annual Meeting CD-ROM) half the U.S. states have created environmental advisory teams comprised of a combination of partners and stakeholders at federal and state agencies and even consulting firms. These teams identify opportunities for streamlining and process improvement.

In contrast to an EMS, their focus is on communication with external stakeholders rather than the generation of internal performance standards for environmental stewardship. It is an open question as to which is more likely to bring about state highway agency commitment to sustainable practices.

9.3 Comparing the Effectiveness of Environmental Management Systems to Environmental Advisory Teams

Table 9.2 presents a correlation matrix with the two oversight structures and three sustainability techniques on which data was available from a study by Marie Venner (2004). The presence of an Environmental Management system is significantly correlated with two of the three techniques while the presence of an Environmental Advisory Team is not significantly correlated with any of the three. Specifically, a state with an EMS is significantly more likely to have a policy to reduce the use of deicers and to have a best management practices manual for storm water management.

TABLE 9.2 Correlation of Two Oversight Methods with Three Sustainability Techniques

	EMS	EAT	Deicers	Vegetated Erosion Control	BMP Stormwater Manual
Environmental Management System	1				
Env. Advisory Team	.170	1			
Minimize Deicers	.314*	.081	1		
Vegetated Erosion Control	.191	.259	.091	1	
BMP Manual for Stormwater	.506**	.176	.400**	.217	1

Chapter 10: Sustainable Practices for Bridge Building and Repair

Much of the previous analysis applies to the construction and repair of bridges. Bridges are close to the water course and can impact it directly when piers are placed in the water or runoff from the bridge enters the water course. During construction and maintenance, improperly handled chemicals, paint, and other debris can impact the environment. Bridge building uses asphalt, concrete and steel, all of which should be used in ways that minimize environmental impacts. When bridges are replaced, they generate construction waste, which should be recycled or reused in various ways.

There are, however, some issues unique to bridges and some steps that states can take to mitigate adverse impacts. Oregon's bridge repair and replacement program has pioneered a number of sustainable practices. Thus, to limit harmful impacts, Oregon replaced many of its worn-out bridges with precast, prestressed concrete beams. These enabled Oregon to build single span structures that eliminated footings in streams, preventing adverse effects on the aquatic environment. Whenever possible, to maximize sustainability, bridge designers should avoid placing piers in the water course.

When replacing a bridge, ODOT takes steps to minimize the transfer of construction waste to landfills. It is estimated that on one bridge project a total of 25,000 tons of materials from a demolished bridge was recycled, saving an estimated $200,000 as well as space in a landfill.

Sustainability is built into the Oregon approach in multiple ways with policies for a wide range of impacts from watershed health to habitat connectivity. On several bridges Oregon has installed crossing benches that help wildlife cross underneath the bridges.

Along with the challenge of preserving the physical environment, bridges often require sensitivity to the mandate to preserve the historic built environment. This can require that bridges maintain many of their historic design features, such as unique materials, arches, truss designs and the like. Of course, the bridge must be able to carry safely its traffic load.

Bridge maintenance requires periodic repainting (overcoating) of bridges to prevent rusting and other problems. This may require the removal of paint, some with lead or other pollutants, from the bridge. Both the process of paint removal and that of painting can introduce harmful contaminants into the environment. Fortunately, new methods to contain the release of pollutants and even recycle them have been developed.

Painting can release volatile organic compounds (VOCs) into the atmosphere, which creates low-lying ozone. The release of VOCs can be minimized with the use of the activated carbon absorption method. During painting, contractors place a containment enclosure around the section of the bridge being painted. With ducting and blowers, the containment enclosure is attached to an activated carbon absorption system. VOC-contaminated air is filtered through the system, the VOCs are captured, and clean air then released into the atmosphere.

Prior to painting, bridges are pressure washed with water. This water can contain lead paint debris and must be filtered prior to release. Much of the lead can be removed by passing the waste water through a sand filter before releasing it.

Table 10.1 Sustainable Practices for Bridges

Management Practice	Oversight Technique or Measure
Avoidance of placing piers in water	Frequency of use
Use of precast prestressed concrete beams	Frequency of use
Recycling bridge parts	Quantity recycled
Reuse of bridge parts	Quantity reused
Historic preservation rather than demolition	Number of bridges preserved
Filtering to capture lead from paint	Amount filtered
Use of activated carbon absorption system to remove VOCs	Amount removed

Chapter 11: Working with the Private Sector to Adopt New Ideas and Technologies

Many firms in the private sector are creating sustainable products and practices, some of which can be usefully adopted by SHAs. As previously discussed, sustainability in the private sector can be described as a process guided by adherence to the 6Rs: Reduce, Re-use, Recycle, Recover, Re-design and Re-manufacture. Whenever economically feasible, corporations seeking to adopt more sustainable practices try to conserve natural resources by re-using material either through the re-use of specific parts or through more traditional techniques of recycling basic materials. Sustainability also calls for adopting production techniques that use less energy and materials during the manufacturing process as well as methods that release fewer pollutants into the air and water.

For the most part, SHAs do not possess the resources or the mandate to invent more sustainable products and processes. But, they can work with research organizations and associations and the private sector firms that do and actively look for improvements by systematically scanning the environment for new and better products and practices. To do so, they will probably need to assign the task of identifying new products to an individual or department. In chapter one, we noted DOW chemical's remarkable reduction in the use of energy, water and materials. Between 1996 and 2005, DOW trimmed its solid waste by 1.6 billion pounds, reduced its waste water by 183 billion pounds, and saved 900 trillion BTUs of energy. This success was facilitated by DOW's creating a position of chief sustainability officer and its commitment to a set of sustainability goals for the year 2015. SHAs should follow DOW's lead by hiring people charged with locating suppliers and contractors who have developed cutting edge techniques for enhancing the sustainability of their manufacturing systems or created new products or techniques that a SHA can use to reduce its impact on the environment.

Products and techniques for sustainable practices are emerging. For example, a German firm, F.C. Nudling Betonelemente has developed paving stones that remove toxic nitrogen oxide from the air. The paving stones are coated with titanium dioxide (TiO2), which converts nitrogen oxide and other harmful substances into safe nitrates. Titanium dioxide, a photocatalyst, uses sunlight to accelerate a natural occurring chemical reaction. Tests have shown improvements in air quality in areas with the stones. Currently, the German city of Fulda is using the stones to lower the levels of nitrogen oxide.

At this time, most highways are paved with asphalt. However, depending on conditions, concrete may be a more sustainable material in that it lasts longer and may impose lower costs across the pavement lifecycle. However, net present value analyses tend to show similar costs for asphalt and concrete pavement. Moreover, asphalt tends to be easier to apply and mistakes in application less costly to correct. Thus, before deciding on the type of pavement to install on a particular road, SHAs need to take a number of factors into account such as subsoil conditions and load-carrying capacity, weather, necessary pavement thickness, construction considerations, cost comparisons, and likely traffic volume, especially commercial traffic (AASHTO 1993).

Clearly, these decisions should be based on state-of-the art information as new and more environmentally sustainable ways to produce pavement materials are emerging. For instance, according to the Concrete Joint Sustainability Initiative, compared to 1972, it now takes 37% less energy to produce a ton of concrete. Moreover, by the end of 2008, 54 percent of U.S. Portland cement plants had an environmental management system (EMS). Of course, as previously discussed, asphalt production too is becoming more environmentally sustainable.

As standard practice, SHAs should adopt up-to-date methods for decisions about selection of pavement type and continue to scan the research literature on improvements in concrete and asphalt use and technology. The calculation of tradeoffs should always involve a net present value analysis based on the latest pavement type selection guidelines.

The broad principle here applies to all industries serving the transportation sector. Namely, by working with industries committed to sustainable practices, SHAs can not only reduce their direct impact on the environment, they can also reduce the impacts of the firms that supply them with materials and other resources.

Chapter 12: The Components of an Effective Sustainability Program across the Highway and Bridge Lifecycle

This study began with the observation that SHAs can damage the environment in many ways. The report was organized around seven categories pertaining to state highway agencies and the possibility of environmental harm: (1) excessive consumption of virgin materials; (2) unnecessary levels or amounts of storm water runoff; (3) release of environmental contaminants by SHA employees and contractors; (4) inadequate training of employees and contractors; (5) wasteful use of energy by SHA employees and contractors; (6) excessive driving by the public and release of green house gases; and (7) inadequate oversight structures to prevent or reduce unsustainable practices.

A chapter was devoted to each of these and a number of the more sustainable practices and reforms were identified. At this time many SHAs already have many of these practices in place. . But the extent to which each state has adopted a comprehensive sustainability program is not known. Only future research can tell us the best combination of practices and oversight structures to ensure sustainable outcomes. (Appendix A contains a short survey designed to obtain information from environmental coordinators on their training programs and oversight structures with management personnel tasked with oversight of sustainability practices.)

This chapter offers a comprehensive sustainability program for SHAs. Each state will develop its own program, of course, but most of the components identified in this chapter appear to be needed for an effective and comprehensive program to minimize environmental harm and maximize sustainability.

12.1 The Need for a Comprehensive Program with Management Oversight

Certainly, an effective program will contain a large number of specific policies and reforms. And to be truly comprehensive it will do more than fulfill the requirements of the various environmental laws. In this sense a sustainable program must be proactive. SHA managers must do more than go through the NEPA process and comply with the various environmental laws. These tend to produce very specific conditions to minimize harm from a particular highway project. A comprehensive sustainability program, in contrast, requires a detailed effort to reduce the likelihood of environmental harm from *any and all* of the SHAs myriad activities throughout the highway lifecycle from planning through maintenance and operations. For example, a comprehensive program would require state employees to work with contractors to ensure that top soil is stored and reused to maximize the effectiveness of the revegetation aspect of its storm water program. Another example, it would train employees and contractors in the best practices for preventing spills. Such issues are rarely addressed during the NEPA process, although they are obviously in line with the manifest goals of the environmental protection laws and clearly contribute to the overall sustainability of SHA practices. To be sure, all this will require more training for SHA employees in the various ways to increase sustainability. Thus, sustainability requires a change in practice across many areas from planning through routine maintenance.

The planning process, itself, must become more comprehensive. One of the primary goals of sustainability is a reduction in the total vehicle miles driven by the public and a related reduction in the number of lane miles of highway built. This requires SHA planning officials to work with local governments, MPOs, and other organizations to integrate transportation planning with land use planning. It will also require a deliberate effort to use ITS to improve traffic flow so as to avert, whenever feasible, the need to build more lane miles of roads. Thus, planning officials, like their counterparts in maintenance, operations and construction, will need training in the various ways to improve the sustainability of the policies they devise and implement.

FHWA in concert with EPA has created a comprehensive program which it calls the Green Highway Partnership (GHP). Seven states are in the program. SEE appendix B for a description of the GHP. The GHP is a good base from which to erect a comprehensive sustainability program.

It is a truism in the field of organizational reform and development that management gets what it measures. But it is also true that reform only leads to success when an organization effectively trains and supervises its employees. Thus to embrace sustainability in a comprehensive fashion most SHAs will need to create a new organizational unit tasked with responsibility for sustainability training and oversight. As this study found, SHAs with environmental management systems (an EMS) appear to have more of the components of an effective sustainability program. The extent of training for sustainability and the assignment of oversight for sustainability no doubt vary across SHAs. But systematic training and oversight built into the organizational structure are probably the keys to reducing the impact of SHAs on the environment.

12.2 Sustainable Practices for Planning, Construction, and Maintenance and Operations on Highways and Bridges

Given the wide array of ways in which a SHA can harm the environment, it is necessary for SHAs to respond along a comprehensive front at each stage of the lifecycle of a highway from planning, through construction, to operations and maintenance. As previously noted, a productive focus on sustainability during planning requires attention to many potential impacts, as it calls for the development of designs that minimize the impact on the landscape and other environmental resources such as air quality during and after construction. A sustainable approach will contain many of the following. It will also contain an EMS or its functional equivalent responsible for measurement and oversight to ensure compliance with the plans and policies.

Table 12.1 Sustainability Practices and Oversight Technique or Accountability Measure for Planning

Sustainability Practice	Oversight Technique or Accountability Measure
Plan for storm water pollution prevention	Inspection of construction site for adherence to plan
Plan for low Impact development	Inspection of construction site for adherence to plan
Plan for more use of bio-retention basins, rain gardens and swales	Specifying number in design and contract
Plan for erosion control	Inspection of construction site for adequate erosion and sedimentation control measures
Plan for use of bio-engineered stream banks	Specifying number in contract
Plan for more use of grass shoulders	Miles of grass shoulders constructed
Plan for more use of pervious pavement	Percent of new parking surfaces and breakdown lanes with pervious pavement
Plan to encourage more use of concrete pavement	Lane miles of concrete pavement
Plan for habitat connectivity	Number of sites with connectivity
Plan to coordinate park and ride with transit or ride-sharing	Number of commuters using facility
Use of ramp-metering	Number of locations/improvement in traffic flow
High occupancy vehicle lanes (HOV)	Number of locations/improvement in traffic flow
Use of congestion pricing	Area of cities involved in plan and air quality

Electronic toll collection	Number of vehicles/improvement in traffic flow
Use of adjustable speed limit signs	Improvement in traffic flow
Traffic incident monitoring with rapid response plan	Improvement in traffic flow
Coordinated signal timing to promote traffic flow	Improvement in traffic flow and air quality
State traffic management center	Improvement in traffic flow
Road weather information system	Improvement in traffic flow and reduction in accidents
Integrated corridor management with ITS	Improvement in traffic flow and air quality
Plan for reduced energy use at state DOT facilities	Measured reduction from previous usage
Participation in local comprehensive planning	Changes in proposed land use and highway construction
Participation in local planning to encourage transit oriented development	Number and/or size of TOD projects
Increased funding for transit	New services and increased ridership
Construction of new or improved pedestrian facilities	Miles of facilities built or improved
Construction of new or improved bike facilities and lanes	Miles of facilities built or improved
Use of reversible lanes to handle rush hour traffic	Improved traffic flow

12.3 Construction

Many of the environmental impacts during construction come from the use and preparation of asphalt. Another set of impacts is associated with the activities of the construction company, especially its effects on vegetation and water resources. Sustainable policies call for construction companies and their employees to do the following and for SHAs to provide appropriate training.

Table 12.2 Sustainability Practices and Oversight Technique or Accountability Measure for Construction

Sustainability Practice	Oversight Technique or Accountability Measure
Recycle asphalt	Percent of asphalt not recycled and taken to landfill
Use warm-mix asphalt	Number of lane miles built or resurfaced with warm-mix
Use In-place recycling	Number of lane miles built or resurfaced
Stock-pile topsoil for revegetation	Specifying in contract with inspection for compliance
Replant native vegetation/low water species	Specifying in contract with inspection for compliance
Delineate and fence wetland areas	Specifying in contract with inspection for compliance
Cover stockpiles at construction sites	Inspection of sites
Refuel vehicles away from water course	Inspection of sites
Store toxic materials away from water course	Inspection of sites
Plan for fossil fuel reduction at the construction site	Specifying in contract and inspection at site
Confine construction and staging areas to smallest area possible	Specifying in contract and inspection at site
Require contractors to use emission control devices	Specifying in contract and Inspection at Site
Training programs for contractors in sustainable construction practices	Number of contractors trained
Training programs for SHA employees in sustainable construction practices	Number of employees trained

12.4 Maintenance and Operations

Construction is followed by operations and maintenance. Here too steps can be taken to reduce the impact on the environment from mowing, snow removal, storm water runoff, pavement repair and other routine activities. In short, a commitment to sustainable practices will impact all SHA activities after construction.

Table 12.3 Sustainability Practices and Oversight Technique or Accountability Measure for Maintenance and Operations

Sustainability Practice	Oversight Technique or Accountability Measure
Spill prevention program	Number of employees trained
Use of bio-friendly hydraulic fluids in vehicles	Percent of vehicles with bio-friendly fluids
Plan for reduced use of Herbicides	Percent reduction in use
Plan for reduced use of salt, sand, and deicers	Percent reduction in use
Requirement to wash and service vehicles way from water course	Specify in contract and inspection of site
Plan to reduce use of fossil fuels by maintenance and operations crews	Percent reduction in use
Plan to reduce idling at facilities and construction sites	Reduction in fuel use
Plan for more use of clean fuels	Increase in use of clean fuels
Training programs in sustainable practices for maintenance and operations employees	Number of employees trained
Training programs in sustainable practices for maintenance and operations contractors	Number of contractors trained

Bridges present an additional set of issues and opportunities. Table 12 lists some sustainability practices that apply to bridges. Bridges tend to contain metal parts that can be reused. In addition, bridges need periodic repainting, which calls for the use of techniques to prevent contamination of the adjacent environment.

Table 12.4 Sustainability Practices and Oversight Technique or Accountability Measure for Bridges

Management Practice	Oversight Technique or Measure
Avoidance of placing piers in water	Frequency of use
Use of precast prestressed concrete beams	Frequency of use
Recycling bridge parts	Quantity recycled
Reuse of bridge parts	Quantity reused
Historic preservation rather than demolition	Number of bridges preserved
Filtering to capture lead from paint	Amount filtered
Use of activated carbon absorption system to remove VOCs	Amount removed

12.5 Summary

A concern for sustainability, like that for efficiency, should be built into the management structure and policies of every SHA. All should have an environmental management system or functional equivalent, staffed by personnel who train employees and contractors in sustainable practices and keep records or inspect work sites to guarantee compliance with environmental plans and policies. Sustainability requires attention to the environmental impact during all phases of the highway and bridge lifecycle from initial planning to operations and management. Therefore, plans with specific policies, should be written for each stage of the lifecycle.

References

Amirkhanian, S.N., A Laboratory and Field Evaluation of the Use of Waste Materials in Highway Construction. FHWA-SC-99-01, Final Report, Washington DC (1999) 372pp.

AASHTO. 1993 "AASHTO Guide for Design of Pavement Structures." (American Association of State Highway and Transportation Officials: Washington, DC).

Bekir, Bartin, Sandeep Mudigonda, and Kaan Ozbay. "Electronic Toll Collection Impact of Electronic Toll Collection on Air Pollution Levels." TRR 2011: 68-77.

Brundtland G. (ed.) Our Common Future: The World Commission on Environment and Development. Oxford University Press. Oxford, UK 1987

FHWA. 2010. Cold In-Place Recycling. Retrieved April 17, 2010 from www.fhwa.SHAgove/pavement/recycling/cir/map.cfm.

Jeon, Christy M. and Adjo A. Amekudzi. 2010. "Understanding of Relationship among Sustainability Measures in Transportation: Using Influence Diagrams. TRB 2010 Annual Meeting CD-ROM

Lee, Jin Cheol Lee, Tuncer B. Edil, James M. Tinjum, and Craig H. Benson. "Quantitative Assessment of Environmental and Economic Benefits of Using Recycled Construction Materials in Highway Construction" TRB 2010 Annual Meeting CD-ROM

Muench, Stephen T., Jeralee Anderson, and Tim Beven. "Greenroads: A Sustainability Performance Metric for Roadways." TRB CD-ROM 2010

National Asphalt Pavement Association. Black and Green: Sustainable Asphalt: Now and Tomorrow. http://www.hotmix.org/images/stories/sustainability_report_2009.pdf, Accessed April 7, 2010

Oregon DOT. 2008. Sustainability Plan, Volume 1: Setting the Context. Accessed March 10, 2010 from www.oregon.gov/odot/sus/docs/sustain_plan_volume1.pdf

Peterson, James. Recycling and Use of Waste Materials and By-products in Highway Construction NCHRP Synthesis of Highway Practice 199, Transportation Research Board, National Research Council, Washington, DC (1994) pp84

Porter, Christopher D. 2006. "Coordinating Transportation and Land Use" ITE Journal/June 2006:28-32.

Robinette, Christopher and Jon Epps. 2010. "Energy, emissions, material conservation and prices associated with construction, rehabilitation and Materials alternatives for flexible pavement." presented at TRB 2010 and on the CD-ROM.

Soltis, David. 2003. Using an Environmental Management System to Meet Transportation Challenges and Opportunities: An Implementation Guide. AASHTO Center for Environmental Excellence.

Taylor, Scott M, and Scott McGowan "NCHRP 20-68A, Scan 08-03 Domestic Scan Program: Best Practices in Addressing NPDES and Other Water Quality Issues in Highway System Management." TRB 2010 Annual Meeting CD-ROM

Venner Consulting and Parsons Brinkerhoff. 2004. Environmental Stewardship Practices, Procedures, and Policies for Highway Construction and Maintenance. NCHRP Project 25-25, Task 4, National Cooperative Highway Research Program, Transportation Research Board.

Venner,Marie, Michael DeWit, Will Gibson, Rodney Concienne, Sonal Sangavi, and Julie Hunkins. 2007 "Current department of transportation environmental management system development efforts" TRR 2011: 1-10

Warren, Josh D. Wai K. (Oswald) Chong, and Changwan Kim. 2007. "Recycling Construction and Demolition Waste for Construction in Kansas City Metropolitan Area, Kansas and Missouri." TRR No 2011: 193-200.

Yusuf, Juita-Elena (Wie), O'Connell, Lenahan, and Abutabenjeh, Sawsan. 2010. "Four emerging responses to the Crisis in local government highway finance." Kentucky Transportation Working Paper

Appendix A

Proposed Survey

State highway agencies are being asked to reduce their impact on the environment. This is often referred to as sustainability. This short survey (20 questions) concerns some of the possible steps your state highway agency (SHA) has taken to make its practices more sustainable. This requires new practices including changes in organizational roles and positions and changes in training for employees and contractors/consultants.

Does your State Highway Agency (SHA) have or do any of the following:

1. A spill prevention plan or program ______YES ______NO _____Don't Know

2. A low impact development plan to reduce storm water runoff through increased use of vegetation or swales or filtration methods ______YES ______NO _____Don't Know

3. Do you have a best management practices manual for storm water ______YES ______NO _____Don't Know

4. A plan to reduce waste disposal at landfills ______YES ______NO _____Don't Know

5. A plan to reuse metal parts, such as bridge trusses or guard rails ______YES ______NO _____Don't Know

6. A plan to reduce the emission of green house gases by SHA vehicles ______YES ______NO _____Don't Know

7. An environmental management system (EMS) with specific personnel assigned to it ______YES ______NO _____Don't Know
   If you do not have an EMS, go to question 9.

8. Does your EMS have ISO 14001 certification ______YES ______NO _____Don't Know
   If you have an EMS, go to question 10

9. If you don't have an EMS, do you have another management unit that provides oversight to insure sustainable practices ______YES ______NO _____Don't Know

10. A plan for life-cycle cost analysis for pavement projects ______YES ______NO _____Don't Know

11. Environmental training for all or most highway maintenance and construction SHA personnel ______YES ______NO _____Don't Know

12. Environmental training for all or most contractors/consultants ______YES ______NO
    _____Don't Know

13. Training in context sensitive design/solutions for employees ______YES ______NO
    _____Don't Know

14. Training in context sensitive design/solutions for contractors ______YES ______NO
    _____Don't Know

15. Please indicate the percent of asphalt taken up during resurfacing that goes to a landfill
    ________20% or more ________10% to 19% ________5% to 9%

    _______Less than 5% ______Don't Know

16. Please estimate the percent of asphalt that is warm mix rather than hot mix
    _______20% or more ________10% to 19% ________5% to 9% _______Less than 5%
    _______Don't know

17. A program to reduce the use of deicers or salt ______YES ______NO _____Don't Know

18. A program to reduce the use of herbicides ______YES ______NO _____Don't Know

19. Do you conduct a net present value life cycle cost analysis for pavement selection?
    ______YES ______NO _____Don't Know

20. Has your DOT worked on projects that involve transit oriented development?
    ______YES ______NO _____Don't Know

21. Please estimate the percent of lane miles of state highway that are paved with concrete and not asphalt _________%

22. Do you have a plan to increase the use of concrete for paving highways?
    _______Yes _______No _______Don't Know

Appendix B

The Federal Government's Green Highway Partnership

The Federal government is promoting sustainable practices by SHAs with its Green Highway Partnership (GHP), which is an alliance of Federal Highway Administration (FHWA), U.S. Environmental Protection Agency (EPA), other Federal agencies, State transportation and environmental agencies, industry, trade associations, members of academia, and contractors to encourage environmentally friendly road building.

The partnership is advancing a highly diverse program that addresses the many ways in which highways impact the environment. Currently, it is working with the following mid-Atlantic states: Delaware, Maryland, DC, New Jersey, New York, Pennsylvania, Virginia, and West Virginia. The program has three emphases, which they call Theme Teams: (1) storm water management to protect watersheds; (2) conservation and ecosystem protection, and (3) methods for reuse and recycling.

The program has required features that a state must accomplish and voluntary ones (Muench, Anderson, and Beven 2010). The project requirements are: NEPA compliance; Life cycle cost analysis (LCCA); life cycle inventory (LCI); quality control plan; noise mitigation plan; waste management plan to divert C&D waste from landfill; pollution prevention plan; low-impact development (LID) plan for stormwater; pavement maintenance plan for pavement preservation; site maintenance for roadside maintenance; and educational outreach to publicize sustainability information for a project.

The voluntary elements have six categories: environment and water; access and equity; construction activities; materials and resource; pavement technologies; and custom credits. The comprehensive nature of the plan is illustrated by the requirements it places on contractors as well as SHAs.

The environment and water include the following: ISO 14001 certification for general contractor; reduction of runoff quantity; stormwater treatment; conduct an LCCA for stormwater BMP/LID selection, use native low/no water vegetation; habitat restoration beyond required; ecological connectivity to connect habitat across roadways; efforts to discourage light pollution.

Access and equity include these desirable features in highway planning: a roadway safety audit; efforts to reduce SOV use; Context Sensitive Solutions; pedestrian and bicycle access; transit access, scenic views; cultural values.

Construction activities thought to promote sustainability include the following: ISO 9001 certification for general contractor; environmental training for contractors and employees, on-site recycling; fossil fuel use reduction; equipment emission reduction to meet EPA Tier 4 standards for non-road equipment; use of pavers that meet NIOSH requirements; water use monitoring during construction; and provision warrantee on constructed pavement.

Materials and resources policies to promote sustainability include: Full Life Cycle Assessment (LCA); pavement reuse; Use of Native Soil; Recycled materials for new pavement; use of regional materials to reduce transport to construction site; and methods to improve energy efficiency of operational system.

Pavement Technology planning for sustainability includes: Use of long-life pavement; Use of permeable pavement as a LID technique; use of Warm Mix Asphalt (WMA) in place of HMA; use of cool pavement to reduce the heat island effect; use quiet pavement; have a system for pavement performance monitoring.

Obviously the green highways program covers the gamut of sustainable practices. It seems unlikely that any SHA will embrace every one of the above desirable policies. But clearly a sustainability program must look at ways to reduce the use of materials and energy, increase the use of vegetation, protect the environment from harmful substances, reduce the impact of storm water runoff on plants and aquatic life, and limit the amount of area paved with impervious surface. SHAs that embrace the green highway approach to highway construction seem more likely to adopt designs with such sustainable elements as:

- Bioretention Swales
- Porous Pavements
- Environmentally Friendly concrete
- Forest Buffer
- Restored and Stormwater Wetlands
- Stream Restoration
- Wildlife crossings
- Stormwater Management with Pervious Concrete Pavement

For more information or a complete publication list, contact us at:

KENTUCKY TRANSPORTATION CENTER
176 Raymond Building
University of Kentucky
Lexington, Kentucky 40506-0281

859.257.4513
859.257.1815 (FAX)
1.800.432.0719
www.ktc.uky.edu
ktc@engr.uky.edu