



Developing Sustainable Transportation Infrastructure

**Exploring the Development and Implementation
of a Green Highway Rating System**

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Executive Summary

America's infrastructure is currently strained to a state of limited functionality. Increased ridership and depleting funds have caused many state and federal departments of transportation to become concerned with the future of America's roads. Much maintenance is required on highways, and their capacity is in desperate need of expansion. Infrastructure needs have been brought to the attention of Congress by GAO reports stating that, "The nation faces a host of serious infrastructure challenges. Demand has outpaced the capacity of our nation's surface transportation ...resulting in decreased performance and reliability¹." Along with the declining state of infrastructure is a growing concern for the need to recognize and mitigate mankind's impact on the natural environment.

A more sustainable solution to America's infrastructure problems must be assessed. Highways have a large negative impact on surrounding ecosystems and overall environmental quality. The next step in highway infrastructure's advancement needs to include practices that reduce the highways effect on the natural environment, increase capacity, and benefit society beyond the ability of current highways. This can be achieved by instituting a system of green highways.

Green highways are a system of roads that mitigate the negative impact on the environment to a level past minimum standards. Green highways include more sustainable practices than modern construction techniques, and consist of maximizing the lifetime of a highway. Green highway construction techniques include; the use of recycled materials, ecosystem management, energy reduction, increasing the water quality of storm water runoff, and maximizing overall societal benefits.

Green classifications should be developed in order to determine the future needs for research and implementations of green highways. These classifications should be developed by a forum of experts, and will include regional and national highway needs. The classifications will vary from region to region, as the same technologies may not be required in every part of the United States. In order to promote the importance of sustainable construction, the classifications should be developed on a national scale and sponsored by the Federal Highway Administration.

Currently there is no clearly defined role for the federal government in infrastructure issues, leading to a general lack of performance of federal programs. Federal programs need to take more charge in creating the initiative to build in a more sustainable and environmentally

friendly conscious. Incentives need to be garnered and distributed to projects that recognize the needs of both the current and future generations.

To meet the infrastructure needs of future generations, new goals must be set. State and federal best management practices will need to be revised, and federal programs will need to take more charge of infrastructure initiatives. Research will have to be given more attention, and a new generation of highway designs will have to be developed.

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1.0 Introduction: The Call for Green Highways

Many technologies exist to reduce the environmental impacts of highways. The use of advanced planning, intelligent construction, and efficient maintenance techniques are incorporated into every modern highway design. However, present practices look very closely to the initial investment required (first cost) and few projects account for the possibility of reduced lifecycle costs associated with sustainable highway construction. User costs, energy consumption, and long term environmental benefits need to be factored into state and federal highway best management practices if a sustainable solution for highway design is going to be assessed.

The need to be able to quantify sustainability for highways has been suggested by various agencies, as well as many individuals². In a June 24, 2008 hearing in front of the House Committee on Science and Technology, the expert witnesses were asked to give their opinions on the next logical steps in implementing green highways. A common answer was for the need of "...green performance measures"². These performance measures, or metrics, will form the basis of a green highway rating system. The metrics involved with evaluating green highways have not been refined, and will require further research. It is necessary throughout the design of a rating system to understand the importance of developing a dynamic system that can be changed to incorporate future technologies.

A green highway rating system can be used for developing and classifying an environmentally and economically sustainable highway. The green highway rating system will prove beneficial in the design and construction of new surface transportation systems, as well as the reformation of existing surface transportation systems. A rating system should be developed with cooperative roles from several agencies, and with required standards incorporated into the materials and testing of the transportation system. This paper will explore the implementation of a green highway rating system for use at the state and federal levels.

1.1 The concept of a Green Highway

Green highways are a relatively new concept; although, the implementation of a large number of technologies involved in green highway design has been encouraged for many years^{3, 4, 5, 6, 7, 8}. Each of these technologies can be used concurrently to develop a holistic design for a green highway. Each of these practices are not mutually exclusive, but can be included into multiple categories. Therefore, the evaluation of a green highway shall not be developed to look

at single practices, but should take into account improvement above a baseline reference. An evaluation should be made to understand what the impacts of the highway would be without any green technology implementations, and then a separate evaluation should take into account improvement to highway sustainability due to increased mitigation techniques.

The Green Highways Partnership (GHP) has developed three key areas to be focused on for the development of green highways; Watershed Driven Stormwater Management, Recycle & Reuse, and Conservation and Ecosystem Protection³. Each of the three key areas developed by the GHP is a focal point for specific research groups. In addition to the focus areas of the GHP, House Bill H.R. 5161 chartered another focus area, the lifecycle energy reduction of highways⁹. Each aforementioned topic addresses specific needs within a green highway, and combined with other topics can encompass the development of a green highway.

2.0 Background and Implementations

The United States Highway system is a vast network that is vital to our nation's economy¹⁰. The construction of the Eisenhower Interstate System helped to spur the trade of commerce from a regional level to a national level¹⁰. Unfortunately, the interstate system has had a negative effect on the natural environment¹¹. M.A. Aziz points out in the Handbook of Highway Engineering, "Highway development enhances mobility and is critical to the economic growth of a community and a country as a whole. Unfortunately, inappropriately planned, designed, and constructed highways can aggravate the conditions of the poor, and harm the natural and socio-economic environment¹¹."

Green highway development includes designing highways in such a manner that improves the quality of the nation's infrastructure. For instance, lifecycle energy reduction sets a standard that the highway will have a long-term life that will accommodate traffic flows with minimal congestion⁹. Designing a highway in such a manner not only reduces the cost of energy and maintenance, but also increases the capacity of the highway and reduces emissions caused by vehicles stuck in congestion¹².

A 2008 report to *Civil Engineering* pointed towards the report card released by the American Society of Civil Engineers (ASCE) on the state of the nation's infrastructure, in which highways scored a grade of a D¹³. The Article went on to quote a May 2007 report from the National Cooperative Highways Research Program, "The interstate system alone sees more than 700 billion vehicle miles traveled annually on a network little changed since its original conception over 50 years ago¹³". The report from Reid emphasizes the critical need for continued research towards developing new technologies to sustain America's infrastructure.

The age and condition of America's infrastructure has compelled much discussion about the reauthorization of the surface transportation act, SAFETEA-LU. SAFETEA-LU, or Safe Accountable Flexible Efficient Transportation Equity Act: A Legacy for Users, authorizes federal surface transportation programs for highways from 2005 until 2009¹⁴. The act will be a focus for the 111th congress. Surface transportation bills are an integral part in funding research for the advancement of highway systems. The research funded by SAFETEA-LU extends through the United States Department of Transportation (DOT), to the Federal Highway Administration (FHWA), and on to various partnerships and university research centers. These

research centers are responsible for developing and helping to implement new and beneficial technologies into the United States highway system.

2.1 Partnerships for Green Highways

Many partnerships exist to work with federal agencies on the development of sustainable infrastructure. These partnerships work to inform or educate federal agencies about technologies available to the construction and maintenance of public infrastructure. Two such partnerships that are integral to green highways are the Recycled Materials Resource Center, and the Green Highways Partnership, which are described in detail below.

2.1.1 The Recycled Materials Resource Center

The Recycled Materials Resource Center (RMRC) works hand in hand with federal highway programs in order to promote the use of recycled materials in highway projects⁶. In June of 1998, the Transportation Equity Act was passed in order to better fund federal highway projects. The funding allocated to the FHWA by the Transportation Equity Act was used for the conception of the RMRC. The RMRC has grown in the past ten years to include campuses at the University of New Hampshire and the University of Wisconsin, both of which research the beneficial use of recycled materials in highway construction⁶. The ultimate objective of the RMRC is to increase the wise use of recycled materials in roadway construction and maintenance⁶. This objective will decrease the amount of materials going to landfills or stockpiles, and will reduce the cost and environmental impact of DOT projects¹⁵.

2.1.2 The Green Highway Partnership

The Green Highway Partnership (GHP) is a partnership comprised of many state and federal agencies that work together towards the development of green surface transportation systems³. The GHP is working towards developing technologies through research and related activities. According to their goal statement, “The GHP is a voluntary, public/private initiative that is revolutionizing our nation's transportation infrastructure. Through concepts such as integrated planning, regulatory flexibility, and market-based rewards, GHP seeks to incorporate environmental streamlining and stewardship into all aspects of the highway lifecycle³.”

2.2 *The Definition of Sustainability as it applies to Green Highways*

Key to the development of green highways is the need to clearly define sustainability. Sustainability is defined as utilizing a resource in such a manner that the resource is not depleted or permanently damaged¹⁶. The definition of sustainability can then be narrowed in focus to encompass sustainable development.

Many definitions for sustainable development exist. Each definition of sustainable development is catered in such a manner as to fit the type of development that is occurring. One widely used definition of sustainable development is the one presented by the World Commission on Environment and Development (WCED); “...*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*¹⁷.”

Applying the WCED definition of sustainable development to highway projects will yield a similar, yet more focused definition. This paper will refer to sustainable development as the merging of economic, societal, and environmental benefits with highway projects to an optimal level. Economic benefits include an increased roadway life, decreased maintenance costs, and the incitement of commerce to communities. Societal benefits include the use of highways to increase the welfare of communities, as well as aesthetics and accessibility. Environmental benefits include reducing a highways adverse effects on the natural and man made environments. Incumbent in all aspects of sustainable construction is the need to also be cost effective and maintain feasible constructability.

Sustainable development is a holistic practice that includes efforts to mitigate negative effects on every part of the infrastructure system, not just the highway. Examples of such practices include the reduction of energy absorption into a highway, consequently reducing the urban heat island effect (the increase in temperature found in metropolitan areas due to urban development) and lowering local energy bills. Therefore, an important theme to understand throughout this paper is that some technologies may seem minuscule to the impact of highways, but may be integral in an overall healthy infrastructure.

2.3 Sustainable Highways in a Global View

Sustainability has not only been a topic of concern for the United States, many countries around the world have taken action in sustainable construction. In 1999 the FHWA sponsored a team of researchers to travel to four countries in Europe to explore international practices in highway sustainability⁴. Sweden, Germany, the Netherlands, and the United Kingdom were all countries that were visited because they “were identified as nations that have been actively addressing sustainable transportation issues for several years”⁴. Each of the countries visited have implemented programs to increase the number of sustainable construction projects, as well as raise public awareness on the overall need for sustainability. Important motivations for these countries move to sustainability are the increase in land use and the reduction in availability of landfill space⁴. Each government decided to implement extensive research towards increasing recycling while still maintaining a strong infrastructure, leading to more recycled materials being used in highway projects⁴.

In October of 2000, members of the FHWA’s International Technology Exchange Program traveled to Europe to meet with officials from Sweden, Denmark, Germany, the Netherlands, and France⁵. The purpose of the meeting was to discuss the use of recycled materials in European highway projects, and then make recommendations to reduce barriers to the use of recycled materials in the United States. It was found that “The European countries visited all had recycling policies promoting sustainability as well as a pervasive public culture about recycling⁵”. Many of the countries visited by the International Technology Exchange Program impose taxes on the use of virgin materials in road construction and supplied tax benefits to the use of recycled materials⁵. The tax proceeds were used to drive research on the applications of recycled materials so that less construction materials will end up in landfills. A report released identifying key information about the trip points out that there is still concern that many engineering test methods used for materials do not predict the true performance of recycled materials. Additional emphasis was placed on the continuing need for research of recycled materials use⁵.

In South Africa, cold mix asphalt has been used as a pavement for many years. Cold mix asphalt (CMA) is a mix of aggregates with a bituminous binder that can be placed as a highway material without heating the mix to high temperatures¹⁸. CMA was developed mainly for the purpose of reducing the energy costs associated with hot mix asphalt. Traditionally CMA has

been seen as a low performance roadway application. However, South Africa has continued to develop CMA for use in high performance applications and has successfully constructed high volume roads with the application¹⁸. In the past, CMA has been labeled as a temporary repair material for pavements in the United States. However, CMA applications have recently begun to be implemented in the United States further than as just a patch material¹⁸. Standards and construction techniques, such as ASTM standard D 7229 *Test Method for Preparation and Determination of the Bulk Specific Gravity of Dense-Graded Cold Mix Asphalt (CMA) Specimens by Means of the Superpave Gyratory Compactor*, have aided in the process of extending the use of CMA in the United States¹⁹.

2.4 Current Green Highway Rating Systems

Green Roads is a rating system that was developed by researchers in Washington State in 2007. It is based on assigning point values to a road much like the United States Green Building Council's (USGBC) LEED rating system. The Green Roads system was modeled closely after the LEED green building rating system²⁰. Table 1 shows the model for points from the Green Roads rating system.

Category	Description	Credits Available	Total Available Credits
Sustainable Design SD	SD-1: Alignment Selection	1	10
	SD-2: Context Sensitive Design	1	
	SD-3: Traffic Flow Improvement	1	
	SD-4: Safety Improvement	2	
	SD-5: Long-Life Pavement Design	3	
	SD-6: Public Input	2	
Materials & Resources MR	MR-1: Construction Waste Management	1	11
	MR-2: Reuse of Pavement	2	
	MR-3: Recycled Content	4	
	MR-4: Pavement Life Cycle Assessment	3	
	MR-5: Regionally Provided Material	1	
Stormwater Management SM	SM-1: Stormwater Management	2	8
	SM-2: Runoff Treatment	1	
	SM-3: Permeable Area	3	
	SM-4: Innovative Stormwater Technology	2	
Energy & Environment EE	EE-1: Cool Pavement	1	12
	EE-2: Quiet Pavement	3	
	EE-3: Light Pollution	1	
	EE-4: Lighting Efficiency	1	
	EE-5: Eco-Connectivity	1	
	EE-6: Visual Quality	1	
	EE-7: Pedestrian Access	1	
	EE-8: Bicycle Access	1	
	EE-9: Environmental Management System	2	
Construction Activities CA	CA-1: Reduce Diesel Emissions	1	9
	CA-2: Reduce Fossil Fuel Dependency	1	
	CA-3: Temporary Stormwater Control	1	
	CA-4: Noise Mitigation Planning	1	
	CA-5: Paving Emissions	1	
	CA-6: Construction Quality	2	
	CA-7: Quality Process	2	
Innovation (IN)	IN-1: Innovation	4	4

Total Credits = 54; Certified = 19; Silver = 26; Gold = 32; Evergreen = 38+

Table 1 – Green Roads Rating System Points Model²⁰

Preliminary research on the Green Roads system has shown that the system can be implemented in Washington State with promising outcomes²⁰. However, the Green Roads system needs extensive research in order to be implemented for areas outside the Northwest. In addition, much concern has been expressed by professionals in the Federal Highway Administration (FHWA), the Environmental Protection Agency (EPA), as well as many other agencies that any rating system will need to be flexible to change^{21, 22}.

Many technologies either are not relevant to every region of the United States, or cannot be transferred to different regions without extensive retrofitting. A rating system must be designed such that officials from each region of the United States can evaluate regional needs, then assign a point scale accordingly. It is important to address the need for separate rating scales for multiple regions, because a single scale rating system will not cater to every region of the United States.

2.5 Legislation Related to Green Highway Development

Many pieces of legislation have been introduced before both the House of Representatives and the Senate outlining the needs for America's infrastructure. The 110th congress has seen a number of these bills in committee review; however, many bills important to researching the state of our nation's infrastructure have been slowed in the committee review process. Outlined below are a few bills that have been introduced, each bill emphasizes the research needed in sustainable infrastructure.

2.5.1 House Bill H.R. 5161

House bill H.R. 5161 was presented to the House of Representatives on January 29, 2008 with 23 co-sponsors. The bill is titled, Green Infrastructure Research and Technology Transfer Act. The objective of the bill is to provide for the establishment of green transportation infrastructure research and technology transfer centers⁹.

The importance of H.R. 5161 is evident within the title; to not only research the technologies for use in green infrastructure, but also to ensure that technology is communicated throughout the industry. A common concern voiced at the June 24, 2008 House hearing on sustainable, energy efficient transportation infrastructure was the weak lines of communication between research centers and state and federal officials².

Currently, house bill H.R. 5161 is in committee review, and was last updated April 10, 2008. The bill defines green transportation infrastructure as infrastructure that:

- (1) preserves and restores natural processes, landforms (such as floodplains), natural vegetated stream side buffers, wetlands, or other topographical features that can slow, filter, and naturally store storm water runoff and floodwaters for future water supply and recharge of natural aquifers⁹;
- (2) uses natural design techniques to manage stormwater⁹; and
- (3) minimizes lifecycle energy consumption and air pollution⁹.

H.R. 5161 outlined research areas needed in the field of green highways. The findings of the bill are as follows;

- (1) Transportation infrastructure contributes to the pollution of surface and ground water because it is comprised of impervious surfaces that concentrate contaminants which are introduced into the water supply during storms⁹.
- (2) Scientists and engineers have developed numerous technologies that can be incorporated into transportation infrastructure which control storm water and mitigate nonpoint source water pollution⁹.
- (3) There has not been widespread implementation of green transportation infrastructure by governments or private industry because of technical, regulatory, and social barriers, such as restrictive designs and lack of training and awareness for builders⁹.
- (4) The Federal Highway Administration, in partnership with the Environmental Protection Agency, has the technical expertise and capacity to promote the use of green transportation infrastructure technologies by State and local governments and private industry through education and outreach and technical assistance programs⁹.

2.5.2 S. 775

S. 775 is also known as the National Infrastructure Improvement Act of 2007. This bill was introduced March 6, 2007. According to a Congressional Research Service (CRS) report, S. 775 “Establishes the National Commission on the Infrastructure of the United States to ensure that U.S. infrastructure meets current and future demand, facilitates economic growth, is maintained in a manner that ensures public safety, and is developed or modified in a sustainable manner²³.”

If signed into law, S. 775 would enact a study that would develop recommendations to the next session of congress relating to infrastructure needs. These recommendations would come after two years of in depth study, analysis, and inventory of the current infrastructure state. The commission would also analyze the impact of local development patterns on demand for federal funding for infrastructure, and ensure sustainable practices can be implemented.

2.6 Differing Views on a Green Highways Rating System

There is much support for the development of a green highway rating system. The Recycled Materials Resource Center believes that the development of a rating system may help extend current needs for research²⁴. Leif Wathne, Director for Highways at the American Concrete Pavement Association, expressed the need to increase the awareness of highway sustainability across many disciplines by defining highway sustainability²¹. However, many agencies have differing views on the development of rating systems. Some believe that a rating system would prove counterproductive, while some believe that a rating system is premature.

Before any new technology can be introduced into society, it must be verified by a consistent history and accepted as safe for use. Most techniques that will lead towards the creation and implementation of a Green Highway System are very young. This was described by Gloria M. Shepherd, Associate Administrator, Office of Planning, Environment, and Realty, Federal Highway Administration,

“Because of a lack of monitoring information, scientific analysis, and third-party evaluations, it may be difficult for new and innovative technologies to demonstrate significant water quality treatment to satisfy regulatory agencies. ... While these programs are beginning to test and approve innovative technologies in their region, many technologies are still being tested, thus the level of acceptance by the regulatory agency for meeting permitting requirements may be limited, even if the technology theoretically demonstrates the necessary ability to meet the requirements²⁵.”

Some opposition to a green highway rating system can be found within agencies that are not in support of higher levels of regulations throughout the federal system. One example is the Federal Highway Administration (FHWA). John Bukowski, Deputy Director and Senior Pavement Engineer with FHWA explained that the FHWA can not currently support the development of a rating system²⁶ (Appendix A).

Mr. Bukowski did make it very clear that FHWA does support and encourage the use of recycled materials in the design and construction of highways. “Currently there is a sort of ceiling reached when asphalt is comprised of twenty-five percent recycled asphalt. FHWA is working with other research facilities on technology to increase that number up to forty percent²².” He also explained that FHWA is encouraging the use of warm mix asphalt, instead of

traditional hot mix asphalt, as well as encouraging the use of recycled materials in highway construction.

In spite of the views of the FHWA on the development of a rating system, many benefits can be cited in support of a green highway rating system. A rating system will help guide research towards beneficial applications, and state DOT's will have goals to strive for to expand sustainable practices. As well, communities will be able to more clearly recognize benefits associated with certain highway designs.

The differing views on a green highway rating system each validate future needs for the development of green highways. Research and implementations must be studied on a much larger scale. Each concern expressed against the development of a rating system can be addressed with extensive evaluations, and extensive dissemination of knowledge, which will be discussed in the next section.

3.0 Recommendations

This section includes recommendations for green highway classification development, important aspects of green highways that should be supported, and potential changes in existing policy that would encourage green highway development. Recommendations are based on the facts collected in this research, as well as the concerns expressed by public officials on the issues. The recommendations are below, followed by descriptions of each.

1. A single database containing all research pertinent to green highways needs to be developed and maintained by a mandated agency.
2. More extensive lifecycle analysis research needs to be sponsored for green highways.
3. The FHWA will need to have a stronger role in creating new best management practices to be adopted by individual states, as well as better supporting research.
4. Incentives for sustainable construction and green highway design should be created.
5. An outline for a rating system needs to be created in a particular way so that research can populate the systems framework. An example of important key areas to focus on is presented in the section on developing a system.

3.1 Combining Research in a Single Database

The development of green highways will require continued research and extensive dissemination of information. Research is being conducted around the country on many technologies and the information extends to design work. However, it is all too often that important research information is difficult to find or difficult to interpret. The success of a green highway program will hinge on the ability to gather and disperse information. An extensive database for research pertaining to green highways be developed and maintained by a federal program.

Many institutions currently maintain large databases of information on subjects. The GHP and the RMRC both maintain databases of past research related to green highways, as well as information for the development of green highways. Unfortunately, many databases have yet to be integrated and information is lost by keeping small databases separate from major project sites. Important research information related to particular subject areas can be difficult to find and equally as difficult to acquire.

3.2 *Lifecycle Analysis Should be Further Evaluated*

In order to better understand long term benefits of green highways, extensive lifecycle analyses should be evaluated. The lifecycle analysis research will be vital in determining which technologies will most benefit a green highway. The DOT should approach the task of lifecycle analysis, and create partnerships with outside agencies on the subject. Although many lifecycle analyses have been evaluated for various green highway components, the lifecycle behaviors of many technologies still need to be analyzed.

The RMRC has sponsored many research projects on the topic of lifecycle analysis of the use of recycled materials. Other lifecycle analysis tools have been developed to evaluate the environmental and economic effects of sustainable construction. One powerful lifecycle analysis tool is the BEES program, developed by the National Institute of Standards and Technology. The BEES program evaluates material selection and acquisition, as well as an overall economic impact.

Lifecycle analysis standards also have been developed by standards development companies. ASTM sponsored the development of standard ASTM E1991 – 05, *Standard Guide for Environmental Life Cycle Assessment (LCA) of Building Materials/Products*. Economic performance can be measured using the ASTM standard life-cycle cost method, which covers the costs of initial investment, replacement, operation, maintenance and repair, and disposal of materials²⁷.

3.3 *A More Involved Role for the FHWA*

Currently there is no clearly defined role for the federal government in infrastructure issues, leading to a general lack of involvement by federal programs²⁸. FHWA should assert more authority in the development of sustainable infrastructure, particularly in supporting the states departments of transportation in decision making. Sentiments at the FHWA are to stay clear of influencing the states to particular decisions²². However, the move to sustainability must also change current practices. The FHWA has the ability to disperse information as well as educate states in adapting new best management practices⁹. The spread of knowledge aligns with the role of the FHWA to being leaders in national mobility, stewards for national highway programs, and innovators for a better future²⁹.

Research should be funded at a higher rate, as well as advocated more extensively by the FHWA. In addition to developing beneficial technologies, research funds the higher education of many science and technology students to become future experts in their fields. Information gathered from research projects benefit society, and research results have important roles in decision making. In a recent Transportation Research Board magazine article, the results from an Indiana DOT research project produced costs savings of over \$150,000 in one month³⁰.

Research is the catalyst to technology development, and has been recognized as important for the continued growth of the United States. The ability of the United States to remain competitive in the global economy relies on the United States' research and development of innovative technologies³¹. However, the authorization of SAFETEA-LU directed that less than two percent of funds be spent on title V research¹⁴. Many more modes for funding research should be developed and distributed.

3.4 Incentives for Green Highway Development

Constructing sustainable infrastructure is completely voluntary. In some cases the benefits of sustainable construction outweigh the costs, immediately justifying the use of sustainable products. However, in the cases where the benefits do not outweigh the cost, the contractor has no financial incentive to use sustainable methods in the highway construction. In such cases, tax benefits should be offered. Tax incentives will help offset the contractors cost as well as help in making constructing a more sustainable infrastructure become more appealing.

In order to encourage sustainable development, green highway designs should be given first priority for federally and state funded projects instead of basing the decision mainly on cost. Unfortunately, many highway projects only have the capability to be evaluated on an initial cost basis, meaning that even if the future benefits can outweigh the initial cost, the project with the lowest initial cost is still typically selected. If a green highway's cost cannot be justified by a lifecycle analysis, benefits to society due to sustainable practices need to be figured into the cost calculation.

3.5 *Recommendations for Defining and Developing a Rating System*

3.5.1 *Definition of a Green Highway for Green Highway Development*

The focus areas presented by the Green Highways Partnership and H.R. 5161 are the foundation for the areas needed to develop green highways^{3,9}. An additional key area to consider is the overall societal affects of a highway. Every highway has a social impact. Combining the five focus areas will begin to bring the concept of a green highway to fruition.

Combining the aforementioned key areas, a set of topics can begin to be assessed in the development of green highways. Each topic addresses a broad subject, as well as overlaps with other topics minimally. A green highway can be defined by these five broad topics (Figure 1).

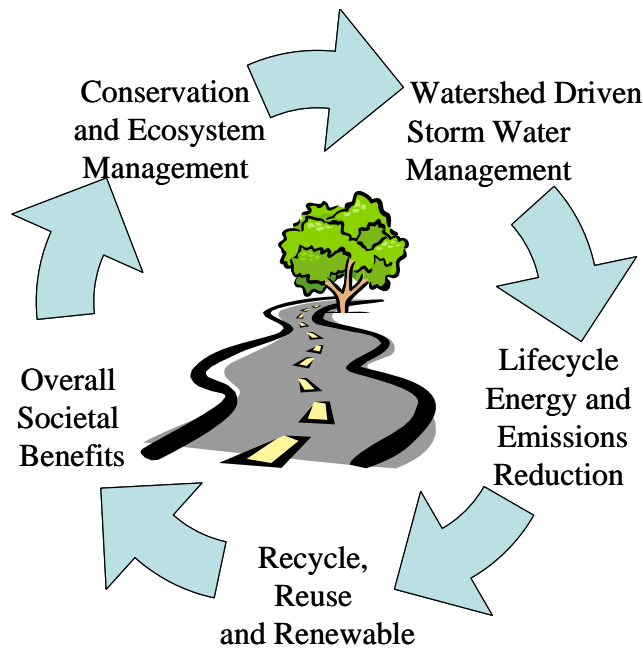


Figure 1 – Five Key Areas for Green Highways

3.5.2 *Key Areas to Green Highways*

Each key area of the highway defines the specific subjects that relate to the development of green highways. The key areas are defined below, and brief examples are given that relate them to green highways.

3.5.2a Key 1 – Watershed Driven Storm Water Management

Watershed driven storm water management is significant in reducing the storm water runoff from a highway, as well as treating the runoff³. Storm water management consists of various techniques for containing and treating the runoff produced by a highway, as well as diverting the storm water runoff to areas where it can infiltrate through to the groundwater table³². In a book titled Porous Pavements, Bruce Ferguson explains effects of surface runoff due to impervious pavements.

“... impervious pavements produce two-thirds of the excess runoff...are responsible for essentially all of the hydrocarbon pollutants...produce two-thirds of the groundwater decline and resulting local water shortages³².”

In a testimony given before Congress, the Assistant Administrator for Water at the United States Environmental Protection Agency (USEPA), Benjamin H. Grumbles, explained ways that green highways could improve water quality.

“Green infrastructure practices protect water quality primarily in two ways. First, they reduce the amount of pollutants that run off a site and ultimately are discharged into adjacent water bodies. Secondly, they reduce or eliminate the water that runs off the site²⁵.”

In his testimony Mr. Grumble also spoke of how diverting flow of water into the medians could allow for much of the water to be infiltrated into the groundwater table or evapo-transpired, which decreases the flow of runoff into local streams and rivers. Infiltration and evapo-transpiration of water are two natural methods of water treatment²⁵.

Storm water management practices are incorporated into many highway designs. Water treatment technologies such as bio-swales (landscape elements designed to remove silt and pollution from surface water runoff) are being implemented along neighborhood roads and along impervious parking lots to slow and treat storm water runoff in Portland Oregon. Many highway projects incorporate wetlands along the side of the highway, which also act as natural water treatment mechanisms.

Many tools exist to aid in the design and analysis of storm water treatment along highways. The USEPA has a Storm Water Management Model (SWMM) that is used extensively to predict the surface flow due to rainfall events. SWMM can be used to design a

routing system for storm water management purposes. The US Army Corps of Engineers also has many programs available for runoff prediction and mitigation.

3.5.2b Key 2 – Lifecycle Energy and Emissions Reduction

Energy is an important economic concern, and the construction a highway requires a large amount of energy. A significant amount of energy is used to produce both asphalt and cement for use in pavements and excavating materials for use in the road base³³. Energy is required during maintenance of a road, and energy is consumed by vehicles traveling in congestion on a poorly designed highway.

Practices exist to reduce the lifecycle energy consumption of a highway. Many of these practices also work to reduce emissions, leading to better air quality. For instance, the US Department of Transportation's (DOT) research center, RITA (Research and Innovative Technology Administration), is developing a method of using warm mix asphalt in place of hot mix asphalt². The warm mix asphalt will consume considerably less energy than hot mix asphalt due to the lower production temperatures that the warm mix asphalt requires. Cement is also a very energy intensive material to produce that is used extensively in highway projects. In order to counteract the amount of energy required to produce cement, the USEPA has researched materials to replace a large portion of cement⁷. These materials are known as pozzolans, and consist mainly of by-products from steel plants and coal combustion facilities (Table 2). The use of one ton of fly ash as substitute for one ton of cement in concrete can have a total primary energy reduction of 4.5 million BTU's (4,695 mega joules), or the equivalent of the energy used in burning 39 gallons (147 liters) of gasoline. Given that cement production is estimated to reach 202 million tons (183 million metric tons) in the year 2020, substituting 50% fly ash for cement could save the equivalent energy of 6.4 billion gallons (24 billion liters) of gas annually.^{8, 34, 35}

Energy consumption and emissions can also be avoided by the design of the highway. Certain highway features that lessen freeway congestion also reduce the amount of time vehicles idle in traffic, consequently reducing the energy consumed and emissions released by vehicles traveling on the highway¹². According to an article in *Civil Engineering*, over 2.9 billion (11 billion liters) gallons of gas were wasted by vehicles sitting in congestion in 2007¹³. Highway congestion can be mitigated in many ways. Wider shoulders to allow vehicles to pull further away from the road during light emergencies can reduce traffic flow interruption¹². Designing

traffic signals for maximum vehicular flow and periodically monitoring their effectiveness will also reduce the amount of fuel wasted by vehicles sitting in congestion. Technologies are also being researched to integrate traffic flow data with the infrastructure for route optimization and congestion mitigation, consequently reducing energy consumption and emissions². Overall, transportation practices account for more than 25 percent of total green house gas emissions³⁶.

Energy and emissions can both be reduced during highway construction. Many companies have policies that prohibit a truck on a jobsite to be left idling. The construction equipment should also be regularly maintained to ensure optimal performance. Many of these techniques will also result in reduced fuel costs for the contractor, as well as longer life for construction equipment.

3.5.2c Key 3 – Recycle, Reuse and Renewable

Recycle, Reuse and Renewable involves incorporating recycled materials or renewable materials in every aspect of highway construction. Using recycled materials in the design of highways can significantly reduce the amount of materials going into area landfills, as well as reduce the amount of virgin material pits required in the construction of the highway.

Renewable materials can also be used in place of some non-renewable highway materials. For example, the Missouri Department of Transportation has studied the use of renewable soy based pavement markings to replace some petroleum based pavement markings³⁷.

Recycled materials have long been used as aggregates in embankment fill, sub-base, and pavements⁶. The materials can be taken from local facilities as well as stockpiled for future highway projects. Recycled materials can be classified into several subcategories based on their production. Recycled Materials Components (RMCs) are a type of recycled material that is derived from industrial byproducts and were recently researched by the USEPA (Table 2)⁸. It was found that the use of RMCs can notably reduce energy consumed by a highway, reduce green house gas emissions, and reduce the overall cost of the roadway⁸. The USEPA estimated the effects due to RMCs being incorporated into construction projects in 2004 and 2005. Some results from the 2004 through 2005 study are;

1. A reduced energy use of 30 trillion BTU's (31.5 billion mega joules)⁸
2. Avoided CO₂ equivalent air emissions of 4.2 million tons (3.8 million metric tons)⁸
3. Water savings of over 55 million gallons (2.1 billion liters)⁸

RMC	Description	Uses/Applications
RMCs Named by Congress		
Ground granulated blast-furnace slag (GGBFS)	A ferrous slag produced during the production of iron as a result of removing impurities from iron ore. Quick quenching (chilling) of molten slag yields glassy, granular product which can be ground to a fine, powdered hydraulic cement.	GGBFS can be used as partial replacement for portland cement, or, if not finely ground, as concrete aggregate.
Coal combustion fly ash	A finely-divided mineral residue from the combustion of ground or powdered coal in coal-fired power plants.	Partial replacement for portland cement in concrete applications. Can be used as a raw material in the production of portland cement clinker or as an inter-ground or blended supplementary cementitious material (SCM) in the production of blended cements.
Blast furnace slag aggregate (BFSA)	Produced by allowing molten slag to cool and solidify slowly. Also commonly referred to as: air cooled blast-furnace slag (ACBF slag).	After crushing and screening, used as aggregate in applications, such as concrete, asphalt, rail ballast, and roofing. It is also used in shingle coating, and glass making.
Silica fume	A very fine, dust-like material generated during alloyed metal production.	Concrete additive used to increase strength and durability.
Other RMCs Identified by EPA		
Foundry sand	Silica sand that is a byproduct of both ferrous and nonferrous metal castings.	Can be used in the manufacture of cement clinker and as an ingredient in concrete.
Cenospheres	Small, inert, lightweight, hollow, "glass" spheres composed of silica and alumina and filled with air or other gases. They occur naturally in coal fly ash.	Used in concrete production to increase concrete's strength and decreasing shrinkage and weight. [Cenospheres may also be used in a wide variety of materials, from paints and finishes to plastics and caulking.]
Flue gas desulfurization (FGD) gypsum	FGD by-products are generated by air pollution control devices used at some coal-fired electric power plants. Forced oxidation wet FGD systems create gypsum as a by-product.	Replacement for natural gypsum in wallboard production and grinding with clinker to produce finished cement.
Flue gas desulfurization (FGD) dry scrubber material	Dry FGD systems remove sulfur dioxide (SO ₂) from coal-fired power plant flue gas. Main constituents of resulting byproduct include calcium sulfite, fly ash, portlandite, calcite, calcium sulfate.	Dry FGD material is used in concrete mixes and products as a substitute aggregate material. Dry FGD material may also be used for embankments and roadbase compositions.
Power plant bottom ash	A coarse, solid mineral residue that results from the burning of coal in utility boilers.	Used as aggregate in concrete, or for other aggregate uses such as compacted base course. Also used as raw material in cement clinker manufacture as alternative source of silica, alumina, iron, and calcium.
Power Plant Boiler slag	A coarse, hard, black, angular, glassy material, produced from slag in wet-bottom boilers.	Owing to its abrasive properties, boiler slag is used almost exclusively in the manufacture of blasting grit; can also be used as raw feed component to make cement clinker.
Steel furnace slag	A by-product from the conversion of iron to steel in a basic oxygen furnace or the melting of scrap to make steel in an electric arc furnace.	Used as raw material substitute in cement clinker manufacturing.
Cement kiln dust (CKD)	The fine-grained, solid, highly alkaline material removed from cement kiln exhaust gas by air pollution control devices.	Material is primarily recycled through closed loop processes in the cement kiln. Small amounts used as supplementary cementitious material (SCM) for blended and/or masonry cements. Material can be used as a soil liming agent.
Note: Congress specifically excluded lead slag from this Report.		

Table 2 – Recycled Material Components and Applications Researched by the USEPA⁸

Organizations such as the USEPA and the RMRC have many past and present research projects on the subject of beneficial material reuse^{3, 6, 7, 8}. Recycled highway components can also be reused in the maintenance of existing roadways. Techniques exist that allow 100 percent of asphalt pavements to be collected and used in specific quantities in the resurfacing of a highway²². As well, concrete pavements can be crushed onsite and used as an aggregate in particular highway applications. In a hearing before Congress, the president of the American Concrete Paving Association (ACPA) testified that the technology exists for one hundred percent of the concrete pavements to be reused in some part of highway construction such as an embankment fill or base aggregate². The RMRC and the American Concrete Institute are continuing research on extending the use of crushed concrete as aggregate in new construction.

A few concerns for the use of recycled materials are cost effectiveness and availability. Some recycled materials are widely available and cost little money or energy to obtain^{6, 7}. However, other recycled aggregates can cost more to refine and transport than the cost of digging a virgin aggregate pit. Research is currently being conducted to develop methods for reducing cost and energy consumption of recycled highway aggregates³⁸.

3.5.2d Key 4 – Conservation and Ecosystem Management

Conservation and ecosystem management has an important role in lessening the effect that a highway system has on its surrounding ecology. Many aspects of the ecosystem are affected by the highway system. The most obvious effect highways have on the natural ecosystem is the displacement and division of natural habitats.

Other adverse wildlife effects can be seen when natural flows increase in streams and rivers near a highway. The excess flow is caused by surface runoff from the highways and can cause scouring of the river bed, resulting in the widening of the stream channel²⁵. The widening of the channel, along with the lowering of the natural ground water table due to more impervious areas created by highways, can cause times of very low-flow and even no-flow in streams. Times of no flow in streams are often detrimental to local habitats.

Ecosystem management can include the use of wildlife crossings, and wildlife buffer zones. According to a study presented to the Transportation Research Board, providing animal crossing structures and underpasses reduced the vehicle-wildlife collisions as much as ninety-seven percent³⁹.

Many of the mitigation techniques that exist for ecological system management that can also be used for watershed driven storm water management. Porous highways will reduce surface runoff, help to feed the natural groundwater table, and help to filter pollutant deposited on the road surface³². Wetlands and bio-swales are both water treatment techniques that will also help decrease the peak flows from highways, work to reduce stream scouring, and provide a natural water treatment process.

3.5.2e Key 5 – Overall Societal Benefits

For many years sustainability has been defined as a tool that focused on the natural environment, while effects on the man made environment have sometimes been overlooked. However, in a more holistic approach to sustainable construction, overall societal benefits should be taken into account. Highways have an important impact on local economies. An aesthetically appealing highway design can draw business into a community and supply local jobs and tax income; whereas a poorly designed highway diverts traffic from a business and causes the business to eventually seek a better location¹⁰.

Other societal benefits are inherent in the previous four key areas. As mentioned, an increase in use of recycled materials will decrease the amount of materials in landfills. A decrease in the use of landfill space will result in decreased user costs for communities around the landfills. Reduction in noise and light pollution from highways can increase the quality of life in an area. Many more societal benefits can be achieved just by practices included above, such as:

- Decreased water use in drought areas by increasing use of recycled mineral components⁸
- Decreases animal to vehicle crashes resulting from animal crossing structures can lead to decreased insurance rates³⁹
- Decreased amount of pollutants contained in surface runoff and increases in stream and recreational water quality³²

The five key areas present an outline for research to focus on. Data can begin to populate the frame work, and sub-topics can be developed to focus each topic area. In the next section this paper will discuss the development of a rating system in further detail.

3.5.3 *Developing a Rating System*

Applying an umbrella credit system to all highway projects would prove counter-productive. Each highway project is unique to the extent that the environmental impacts of projects can vary vastly from one side of the country to another. Additionally, new technologies are continuously being researched at various research facilities around the country. Developing one base rating system may impede future technology development, encouraging highway departments to become overly concerned with gaining certification based on sometimes minute details. For these reasons, it is recommended that a set of metrics be created based on the evaluation of individual projects, and the incorporation of new technologies into the highway construction. The system should be based on the foresight that new innovations will continually surface, and particular criteria shall outweigh other criteria if deemed more pertinent by the state department of transportation.

The basis for the recommended rating system is founded in the need for continued research on sustainable highways. The system should require professionals to understand current practices as well as keep up to date with current research. The rating system should be designed to determine what level of mitigation would prove most beneficial to the key areas of sustainability by using a system of pre and post analysis. When the highest level of improvement is determined, sustainable techniques that are incorporated into the project will be accounted for. Only after the full analysis is complete can a highway be rated as “Green” or not (Figure 2).

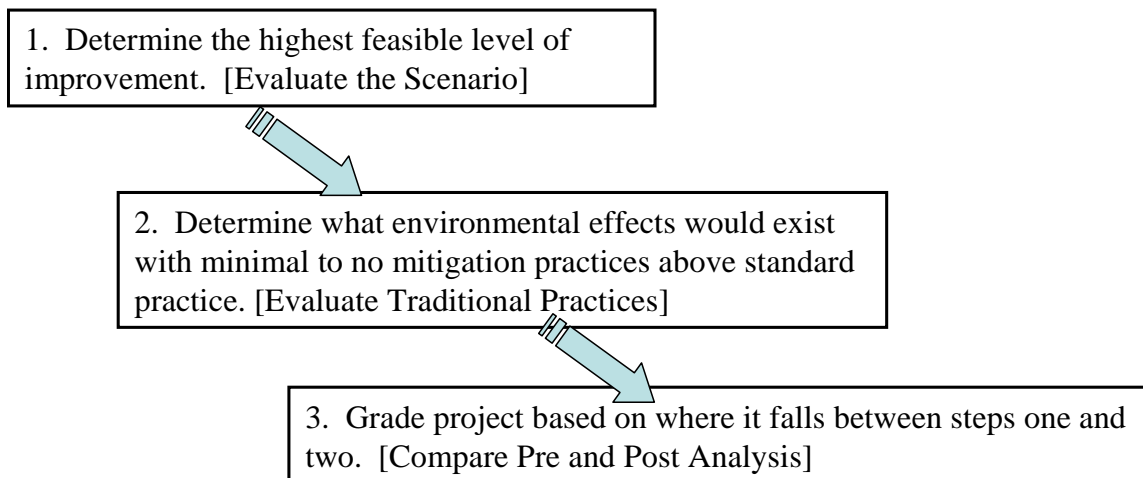


Figure 2 – Steps for Evaluating a Green Highway

Not every technology will change relative to the region of the United States, but every technology will change based on future research. For instance, treatment of runoff is an important topic that is independent of location. Every highway produces pollutant runoff during a precipitation event, and every highway will benefit from some type of runoff treatment¹¹. However, the level of treatment achievable will increase as technology advances. Therefore, it is important to continue to look at relative scales instead of a fixed rating system. The recommended steps for evaluation seen in Figure 2 are discussed below.

3.5.3a Step 1 – Evaluate the Scenario

Each highway design is different and should be treated as such. Highway projects should not be considered less sustainable because they are not incorporating technologies that may not be necessary. The needs of the individual project and the capabilities of the region should be considered, and a green highway rating should be weighted accordingly. For instance, many large cities do not have a need to control wildlife using wildlife crossings. However, rainfall runoff mitigation and decreasing the urban heat island effect may be important issues in most large cities. Therefore a small weight should be given to any sort of mitigation techniques for wildlife to vehicle crashes, and high priority should be given to the use of porous pavements for runoff control and better heat transfer.

Some questions that need to be asked during the pre-evaluation process include;

- What is the regional availability of recycled materials, and will the energy used to transport the recycled materials to the site justify their use?
- Is the urban heat island effect a concern? If so what mitigation technique would prove most beneficial?
- Is the highway in an urban area and if so how could the local economy somehow benefit from the highway design?

Although this list is far from complete, a general outline for questions can be developed based on regional and local needs.

Another important issue in the pre-evaluation process is the availability of new technologies. Universities are reporting new beneficial technologies at a high rate. Every highway design needs to be inclusive of new technologies, instead of focusing on traditional practices.

The pre analysis will be based extensively on research. Practices must be evaluated for their projected benefits. For instance, mitigation techniques for runoff treatment will need to be based on treatability reports developed by environmental water quality specialists. The amount of pollutants removed based on statistical rainfall events will be analyzed, and the worst case scenario will be calculated.

3.5.3b Step 2 – Evaluate Traditional Practices

Traditional practices will demonstrate the minimal acceptable levels of sustainability. The proposed highway design should be evaluated based on practices that are used in traditional highway design. An environmental impact statement should be prepared by the designer as required by the USEPA. The evaluation of traditional practices is important, because it will take into account practices in current highway design for use in comparison to what is being considered. As design begins to incorporate more sustainable practices, the traditional practices evaluation will change to include these practices. For instance, most current highway designs incorporate at least 20% recycled pozzolanic materials into concrete to replace cement²². Therefore; projects that use more than 20% pozzolans in the design should be given higher credit than projects that only meet current practice standards.

3.5.3c Step 3 – Grading; A Comparison of the Pre and Post Analysis

The comparison of the pre and post analysis is where a true green rating can be assessed. The analyses of traditional practices provide a baseline to normalize all practices, and the pre analysis will provide the level of maximum benefit. A level of sustainability can be calculated by measuring the level of treatment relative to the maximum level of treatment. By providing both a maximum possible level of green practices and the level of minimum practices, a relative scale can be evaluated based on a case by case basis

3.5.4 Developing Standards for use in a Green Highway Rating System

A green highway rating system will foster the development of technologies based on the many criteria used for evaluating highways. Standards will be an integral role in defining sustainability as well as developing sustainable technologies. The use of standards assures identical practices can be reproduced with similar results, so that classifications can be made with as little bias as possible. Many standards have been developed on the subject of sustainability. For example, ASTM International currently has over 500 sustainable standards.

Many practices compose the development of green highways, but the construction of the highway is usually done by a limited group of people. Standards will assure that technologies are implemented as effectively as possible. As green highways mature, codes will need to be developed for their construction. Standards are essential to technology and code development. Federal and state agencies incorporate standards into building codes, many of which are developed by voluntary agencies.

The inclusion of voluntary agencies in the development of green highway standards will prove valuable to federal agencies. In 1996 the National Technology Transfer and Advancement Act (NTTAA) was signed into law. The NTTAA helped assure that time and money was not expended reproducing existing standards. The NTTAA directed that, "...all Federal agencies and departments shall use technical standards that are developed or adopted by voluntary consensus standards bodies, using such technical standards as a means to carry out policy objectives or activities determined by the agencies and departments⁴⁰." Standards developed by voluntary agencies prove advantageous to federal agencies since the cost is most often carried by the group developing the standard.

Many existing standards can be applied to the design, cost analysis, and risk analysis involved with the construction of green highways. ASTM standard E 1804, *Practice for Performing and Reporting Cost Analysis During the Design Phase of a Project* has been used by transportation professionals in order to set up a frame work for project estimation. ASTM standard E 2013, *Practice for Constructing FAST Diagrams and performing Function Analysis During Value Analysis Study*, helps to increase the cost benefit ratio during the design phase of the project. The continual growth and development of standards will be an important part of green highways.

4.0 Conclusions

The development of green highways will play an important role in the effort to mitigate man made impacts on the natural environment. The market for green construction is expanding, and many disciplines have realized the benefits of sustainability. Green construction has taken place in the structures market, and has had positive results with the development of the United States Green Building Council and the LEED green building rating system. However, success in the private markets does not automatically translate into success in the public sector. Highways are publicly owned and funded. New innovative techniques must be developed for sustainable highways.

Green highway classifications will help transportation planning officials have a more clear understanding of techniques and incentives for maximizing sustainable efforts. An outline for a green highway rating system should be accepted by industry; however, green highways must mature before a rating system can be completely developed. Defining sustainability as it pertains to highway construction is fundamental to the future of the green highways research.

When a green highway rating system is developed, it is critical that experts from every field of highway construction and standards development be involved. Equally important is the need for the involvement of regional state highway officials from around the country. Highway development varies through different regions of the United States, and the development of a rating system will also vary with regional needs.

The United States has consistently been at the forefront of technological advancement. Emphasis has traditionally been placed on the need for integrated infrastructure and efficient, low cost construction. However, with the increasing concern of mankind's negative impact on the environment, new infrastructure goals need to be recognized.

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Appendix A
Federal Highway Administrations View on a Rating System

The FHWA does not endorse any type of rating system in regards to highway projects. FHWA, along with EPA and the states as represented through AASHTO (The American Association of State Highway Transportation Officials) are currently not in favor of the concept of a rating system applied to highway projects.

We cannot support any such rating system because at this time our office maintains that this concept is not only unproductive to developing and enhancing environmentally friendly technologies but will foster an unconstructive reaction that we would engender among the majority of the states that would ultimately and irreparably set back the Green Highway (GH) movement and concepts.

We do want to have an environmentally sensitive spirit, not just projects that are labeled as “green” and miss the spirit of the GH initiative; or alternatively be criticized for all other non-green projects.

Therefore the FHWA will not help advance any notion of a project rating system. We have no position on a specific state transportation agency wanting to advance such a rating system, but the FHWA will have no part in facilitating that concept among the states or as a national effort²⁶.