GREENROADS: A SUSTAINABILITY PERFORMANCE METRIC FOR ROADWAYS

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ABSTRACT

Greenroads (www.greenroads.us) is a performance metric for sustainable practices associated with the design and construction of roads. It assigns points for approved sustainable choices/practices and can be used to assess roadway project sustainability measures based on total points. Such a metric can (1) provide a quantitative means of sustainability assessment, (2) allow informed sustainability decisions, (3) provide baseline sustainability standards, and (4) stimulate improvement and innovation in integrated roadway sustainability. This paper describes Greenroads version 1.0, which consists of 11 requirements and 37 voluntary practices that can be used as a project-level sustainability performance metric. Development efforts and a Washington State Department of Transportation (WSDOT) case study suggest (1) existing project data can serve as the data source for performance assessment, (2) some requirements and voluntary actions need refinement, (3) projects need to treat sustainability in a holistic manner to meet a reasonable sustainability performance standard, (4), the financial impact of Greenroads use must be studied, and (5) several pilot projects are needed. The Greenroads sustainability performance metric can be a viable means of project-level sustainability performance assessment and decision support.

KEYWORDS

performance metric, sustainable construction, roadway, sustainability, rating system

INTRODUCTION

The use of sustainable practices in civil infrastructure can often be difficult because (1) decision makers do not have adequate information to make informed decisions on these aspects, and (2) there is no quantitative means of assessment in this area. This paper describes a performance metric, broadly termed "Greenroads", for quantifying sustainable practices associated with the design and construction of roadways. This project-based system awards points for approved sustainable choices/practices and can be used to assess projects based on total point value.

This performance metric could:

1. Encourage more sustainable practices in roadway design and construction
2. Provide a standard quantitative means of roadway sustainability assessment
3. Allow informed decisions and trade-offs regarding roadway sustainability
4. Enable owner organizations to confer benefits on sustainable road projects
5. Establish an implementable baseline requirement for roadway sustainability

Greenroads (www.greenroads.us) could be used in a number of ways by agencies, design consultants and contractors. Its use could have direct implications for the design and construction of new, rehabilitated, expanded or otherwise redesigned roadways.

This paper presents version 1.0 of the Greenroads performance metric. This metric can be

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freely used and modified by anyone, however the official version resides online (www.greenroads.us) and is maintained by its developers, the University of Washington and CH2M HILL, for general use. Options concerning its ultimate use and ownership remain open. This paper includes a discussion of the perceived need for such a system and the underlying principles and ideas used in development. Two examples are discussed as a means of familiarization with the metric. Potential avenues to implementation and envisioned uses are discussed followed by a case study where it was retroactively applied to a Washington State Department of Transportation (WSDOT) freeway rehabilitation project.

SUSTAINABILITY DEFINITION

Greenroads defines "sustainability" as *a system characteristic that reflects the system's capacity to support natural laws and human values*. "Natural laws" refers to three basic principles that must be upheld to maintain earth's ecosystem as discussed by Robèrt (2000). These are summarized:

1. Do not extract substances from the earth at a faster pace than their slow redeposit and reintegration into the earth.
2. Do not produce substances at a faster pace than they can be broken down and integrated into nature near its current equilibrium.
3. Do not degrade ecosystems because our health and prosperity depend on their proper functioning.

"Human values" refers to equity and economy. Equity, which is essentially Robèrt's (2000) fourth principle, is interpreted as a primarily human concept of meeting their nine fundamental human needs: subsistence, protection, affection, understanding, participation, leisure, creation, identity and freedom (Max-Neef et al. 1991). Economy is broadly interpreted as management of human, manufactured, natural and financial capital (Hawken et al. 1999). Thus, by this definition economy refers to project finance but it also refers to items such as forest resources management and carbon cap-and-trade schemes.

In total, this definition contains the key elements of *ecology*, *equity* and *economy* and is essentially consistent but more actionable on a project scale than the often quoted United Nations 1987 Brundtland Commission report excerpt: "...development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (A/RES/42/187). It is also compatible with the Millennium Ecosystem Assessment (2005) and other local definitions, often drawn from Brundtland Commission language, such as the Oregon Sustainability Act of 2001 (ORS 184.421).

Beyond *ecology*, *equity* and *economy* we believe there are four other essential components to a sustainability definition. First, sustainability is context sensitive. Hence, for a particular project, the project's *extent* in space and time (i.e., its scope, physical dimensions and lifecycle) and performance *expectations* (i.e., design criteria, metrics of performance, and assessment of risks) must be part of the definition. Second, what transforms "sustainability" from concept to reality are *experience* (in the form of technical expertise and historical information that drive current decisions) and *exposure* (in the form of education and training) of the profession and general public to the idea of sustainability and its importance. In total, our sustainability definition has seven components: ecology, equity, economy, extent, expectations, experience and exposure.

To date, roadways typically approach sustainability in a piecemeal manner. Typical means have been through regulation (describing minimum acceptable standards); political or mandated processes for ensuring environmental justice, cultural and aesthetic considerations; project evaluative procedures (e.g., benefit-cost), external budgetary constraints and political or economic pressures. Although there are processes that attempt to integrate these efforts on a project level (e.g., the National Environmental Policy Act – NEPA and state equivalents, cost/benefit analyses, etc.) and Context Sensitive Solutions/Design (CSS/CSD) (Neuman et al. 2002) none yet are purposefully organized around the definition of sustainability presented here.

This paper assumes that improved sustainability is a roadway goal or, at a minimum, the sustainability of a roadway is something worth evaluating. Evidence in other fields suggests that this assumption will hold true. In the building industry, which is generally more advanced in sustainable applications, the U.S. Green Building Council (USGBC) lists 353 government and school agencies that have adopted formal policies defining building sustainability goals or requirements (USGBC 2010).

THE NEED FOR A PERFORMANCE METRIC

Greenroads is a straightforward means of translating sustainability ideas into definable design and construction practices that are likely to result in a more sustainable roadway. The need for such a metric arises for four basic reasons. First, roadways can be more sustainable than they currently are. This is at least partly because current metrics, standards and decision tools do not fully address sustainability. For instance, while pavements are heavy users of recycled material (Bloomquist et al. 1993) their design and construction do not explicitly account for life-cycle emissions or energy use, and ecological considerations can be limited to regulatory compliance. Second, most roadway sustainability efforts to date have not applied a consistent metric by which the relative importance of sustainability-related efforts are judged. Therefore, comparisons between projects or assessments of improvement over time are difficult. Third, the science and engineering underlying roadway sustainability can be complex. Decisions by non-experts that often drive project direction or funding can therefore be problematic. Finally, different aspects of roadway sustainability are difficult to compare because they are not normalized to a common value set. Consequently, it is difficult to get a holistic sense of a roadway's relative sustainability or weigh design and construction trade-offs. A commonly accepted sustainability performance metric could help with all these issues. Such a metric should be straightforward in order for it to appeal to a broad audience. It should also be consistent with existing laws, regulations and programs such as the Clean Water Act, the Clean Air Act, the National Environmental Policy Act, the Federal Highway Administration's (FHWA) *Environmental Review Toolkit* (2008), the Green Highways Partnership (2008) and the Millennium Ecosystem Assessment (MA 2005) to name a few. Finally, it should push the industry to improve on current practices and do more than the required minimum.

STAKEHOLDERS

There are a number of stakeholders who may have interest in a sustainability performance metric for roads. Each stakeholder is likely to have opinions on how Greenroads should work. Stakeholders include:

- Road owners: federal, state, county and city agencies as well as the general public.
- Funding agencies: federal, state, county, city and other regional authorities
- Design consultants: those involved with corridor, road or even pavement design
- Contractors: heavy construction, road and paving contractors
- Regulatory agencies: U.S. Environmental Protection Agency, ecology departments, etc.
- Sustainability organizations: U.S. Green Building Council (USGBC), Green Highways Partnership, Sierra Club, etc.
- Research organizations: universities and other research organizations that participate in investigating sustainable technologies.

GREENROADS PERFORMANCE METRIC

This section first discusses the performance metric in detail including philosophy, boundaries, examples certification. The version described in this paper, version 1.0, is intended to serve as a baseline to be refined, calibrated and evaluated by potential stakeholders. As such, it is expected that it will change based on stakeholder input and evolve as technology and sustainability savvy evolve.

General Philosophy

Greenroads is designed to assess more sustainable solutions within and beyond existing federal, state and local regulations. Specifically, Greenroads is designed to assess decisions regarding sustainability options where they are not precluded by regulation or where regulation allows a choice between options that could have sustainability impacts. Importantly, Greenroads is not meant to dictate design or trade-off decisions. Rather it provides a tool to help evaluate such decisions. Finally, Greenroads is meant to evolve as sustainable thought and technology evolve.

System Boundaries

Greenroads is applicable to the design and construction of new or rehabilitated roadways including expansion or redesign. Specifically, it applies to (1) the design process and (2) construction activities within the workzone as well as material hauling activities, production of portland cement concrete (PCC) and hot mix asphalt (HMA). The planning or operation phases of a roadway are only addressed by evaluating decisions made within the context of project design and construction. This means that some typical items associated with roadways and sustainability are considered in specific ways that merit explanation:

- **Supply-chain processes.** Items such as cement and asphalt manufacturing/refining are only considered in lifecycle inventories (LCI) or assessments (LCA). This means that specific improvements in these upstream processes may not be captured by Greenroads depending upon the data source(s) used for the required pavement LCI or voluntary roadway LCA.
- **Structures.** Bridges, tunnels, walls and other structures are considered in Greenroads, but no credits explicitly recognize sustainable design and construction choices for these structures in the current version. These structures are treated very generally, most often as a collection of materials or as a means to achieve a connectivity goal. Points can thus be awarded for material-based choices made, or, for the end purpose of the structure itself. However the structural design, aesthetics, special methods or technologies, and other non-material qualities are not covered in the current version of Greenroads. Clearly, these roadway elements offer another potential outlet for additional sustainability improvements to the roadway system and may be easily incorporated in a future version of Greenroads.
- **Paths and trails.** If directly associated with the roadway (e.g., adjoining foot/bicycle path or sidewalk), they are considered. Independent paths and trails (e.g., a conversion of a rail right-of-way to a bicycle path) are excluded but could be addressed within something like the Sustainable Sites Initiative (2008).
- **Future maintenance and preservation.** Long-term maintenance and preservation actions have a large impact on overall roadway sustainability. Greenroads considers them in LCA, and awards points for having formal procedures in place to ensure their execution. However, since they necessarily occur after certification, they are not judged at the time they are actually performed. Such an idea could be incorporated into a future Greenroads version. However, preservation and rehabilitation activities as individual projects can and should be considered from Greenroads evaluation.
- **Roadway use.** Traffic has a profound impact on sustainability. Design decisions that affect how a facility is used by traffic are given credit but judgments on direct use issues such as fleet composition, emissions ratings and vehicle fuel sources are not considered since they cannot be adequately predicted or verified at substantial project completion. These issues may be best left to planning level efforts as they are more universal in nature and not specific to one particular project.

Greenroads Description

Greenroads is essentially a collection of sustainability best practices that apply to roadways (Table 1). These best practices are divided into two types: required and voluntary. Required best practices are those that must be done as a minimum in order for a roadway to be considered a Greenroad. These are called "Project Requirements," of which there are 11. Voluntary best practices are those that may optionally be included in a roadway project. These are called "Voluntary Credits". Each Voluntary Credit is assigned a point value (1–5 points) depending upon its impact on sustainability. Currently, there are 37 Voluntary Credits totaling 108 points. Greenroads also allows a project or organization to create and use its own Voluntary Credits (called "Custom Credits"), subject to approval of Greenroads, for a total of 10 more points, which brings the total available points to 118.

Project teams apply for points by submitting specific documentation in support of the Project Requirement or Voluntary Credit they are pursuing. These documents, which can range from project specifications to field documentation, are verified

TABLE 1. Greenroads Listing by Category.

No.	Title	Pts.	Description
Project Requirements (PR)			
PR-1	Environmental Review Process	Req	Complete an environmental review process
PR-2	Lifecycle Cost Analysis	Req	Perform LCCA for pavement section
PR-3	Lifecycle Inventory	Req	Perform LCI of pavement section with software tool
PR-4	Quality Control Plan	Req	Have a formal contractor quality control plan
PR-5	Noise Mitigation Plan	Req	Have a construction noise mitigation plan
PR-6	Waste Management Plan	Req	Have a plan to divert C&D waste from landfill
PR-7	Pollution Prevention Plan	Req	Have a stormwater pollution prevention plan
PR-8	Low-Impact Development	Req	Study feasibility of LID techniques for stormwater
PR-9	Pavement Management System	Req	Have a pavement preservation system
PR-10	Site Maintenance Plan	Req	Have a maintenance plan for environment, utilities
PR-11	Educational Outreach	Req	Publicize sustainability information for project
Voluntary Credits			
Environment & Water (EW)			
EW-1	Environmental Management System	2	Have ISO 14001 certification for general contractor
EW-2	Runoff Flow Control	3	Reduce runoff quantity
EW-3	Runoff Quality	3	Treat stormwater on-site
EW-4	Stormwater Cost Analysis	1	Conduct a LCCA for stormwater BMP/LID selection
EW-5	Site Vegetation	3	Use native low/no water vegetation
EW-6	Habitat Restoration	3	Create new habitat beyond what is required
EW-7	Ecological Connectivity	3	Connect habitat across roadways
EW-8	Light Pollution	3	Discourage light pollution
	EW Subtotal:	**21**	
Access & Equity (AE)			
AE-1	Safety Audit	2	Perform roadway safety audit
AE-2	Intelligent Transportation Systems	5	Implement ITS solutions
AE-3	Context Sensitive Solutions	5	Plan for context sensitive solutions
AE-4	Traffic Emissions Reduction	5	Reduce air emissions systematically
AE-5	Pedestrian Access	2	Provide/improve pedestrian accessibility
AE-6	Bicycle Access	2	Provide/improve bicycle accessibility
AE-7	Transit & HOV Access	5	Provide/improve transit/HOV accessibility
AE-8	Scenic Views	2	Provide views of scenery or vistas
AE-9	Cultural Outreach	2	Promote art/culture/community values on roadway
	AE Subtotal:	**30**	

(continued on next page)

TABLE 1. *(Continued).*

No.	Title	Pts.	Description
Construction Activities (CA)			
CA-1	Quality Management System	2	Have ISO 9001 certification for general contractor
CA-2	Environmental Training	1	Provide environmental training
CA-3	Site Recycling Plan	1	Provide plan for on-site recycling and trash
CA-4	Fossil Fuel Reduction	2	Use alternative fuels in construction equipment
CA-5	Equipment Emission Reduction	2	Meet EPA Tier 4 standards for non-road equip.
CA-6	Paving Emission Reduction	1	Use pavers that meet NIOSH requirements
CA-7	Water Use Tracking	2	Develop data on water use in construction
CA-8	Contractor Warranty	3	Offer an extended warranty on pavement
	CA Subtotal:	**14**	
Materials & Resources (MR)			
MR-1	Lifecycle Assessment	2	Conduct a detailed LCA of the entire project
MR-2	Pavement Reuse	5	Reuse existing pavement sections
MR-3	Earthwork Balance	1	Balance cut/fill quantities
MR-4	Recycled Materials	5	Use recycled materials for new pavement
MR-5	Regional Materials	5	Use regional materials to reduce emissions
MR-6	Energy Efficiency	5	Improve energy efficiency of operational systems
	MR Subtotal:	**23**	
Pavement Technologies (PT)			
PT-1	Long-Life Pavement	5	Design pavements for long-life
PT-2	Permeable Pavement	3	Use permeable pavement as a LID technique
PT-3	Warm Mix Asphalt	3	Use WMA in place of HMA
PT-4	Cool Pavement	5	Use a surface that retains less heat
PT-5	Quiet Pavement	3	Use a quiet pavement to reduce noise
PT-6	Pavement Performance Tracking	1	Relate construction to performance data
	PT Subtotal:	20	
	Voluntary Credit Total:	**108**	
Custom Credits (CC)			
CC-1	Custom Credits	10	Design your own credit
	CC Subtotal:	**10**	
	Greenroads Total:	**118**	

by an independent review team. Once a project is complete the Greenroads team verifies the application and assigns a Greenroads score based on achieving all the Project Requirements and the number of points earned from the Voluntary Credits. This score may then be used at the owner's discretion and may also be translated to a standard achievement level if so desired: the more points earned, the higher the recognition. If a project reaches an achievement level it will be able to display the Greenroads logo and appropriate certification graphic. Greenroads achievement levels are detailed on page 121.

All Project Requirements and Voluntary Credits are directly traceable to at least one, if not several, of the seven components of sustainability. Components of sustainability may, at times, be at odds with one another, which we believe reinforces the idea that sustainability decisions are often thoughtful compromises between competing values. All Project Requirements and Voluntary Credits are also are also tied to at least one (and in most cases, several) of a predefined list of 16 "benefits":

1. Ecological benefits
   a. Reduce emissions
      i. Reduce air emissions
      ii. Reduce wastewater emissions
      iii. Reduce soil/solid waste emissions
   b. Reduce consumption
      i. Reduce water use
      ii. Reduce fossil energy use
      iii. Reduce raw materials use
      iv. Create renewable energy
      v. Optimize habitat and land use
2. Human-centric benefits
   a. User improvement
      i. Improve human health and safety
      ii. Improve access and mobility
   b. Performance improvement
      i. Improve business practice
      ii. Increase lifecycle savings
      iii. Increase lifecycle service
   c. Interaction improvement
      i. Increase awareness
      ii. Improve aesthetics
      iii. Create new information

Greenroads Voluntary Credits are weighted in accordance with a framework that attempts to relate the relative impact to sustainability of each one. This valuation set, which will be fully described in a subsequent article in this journal, includes general lifecycle assessment (LCA) conclusions, a quantifiable yet somewhat controversial ecosystem services valuation (Costanza et al. 1997), CSS/CSD, an incentive scheme, and an attempt to value roadway noise (Hofstetter and Müller-Wenk 2005) amongst other things. Further, Voluntary Credit values are limited to the range of one to five points to limit the influence of poor or controversial valuation. We acknowledge that any weighting scheme is bound to be controversial but believe that such a scheme is needed in order to quantify a performance metric and make it implementable.

Finally, Greenroads is meant to be applicable to both large (e.g., development of a major urban corridor) and small (e.g., a HMA preservation overlay) projects. Thus, not every Voluntary Credit is applicable to every project but most projects should be able to achieve some achievement level without drastically changing their scope. The following briefly discusses an example of a Project Requirement and a Voluntary Credit in order to provide a general feel for how they are constructed. A complete discussion of all Project Requirements and Voluntary Credits can be found on the Greenroads website at: www.greenroads.us.

Project Requirement Example: PR-9 Pavement Maintenance

Goal. Make pavements last longer and perform better by preserving and maintaining them.

Requirement. Have a pavement management system in effect for the project pavement. Generally, this means the owner of the roadway should have a pavement management system in place. This typically involves the use of one or more decision support tools (often computer-based) to organize the five activities detailed below.

Details. A "pavement management system" is a formal systematic process of maintaining, upgrading and operating a particular pavement or network of pavements. This system must serve the roadway project and include, at minimum, these activities:

1. Measure pavement condition at least once every two years.
2. Possess documented decision criteria for timing preservation actions.
3. Record when preservation efforts occur.
4. Store information from #1–3 in a retrievable format.
5. Display information from #1–3 to the user.

Reasoning. Pavement management is "...the effective and efficient directing of the various activities involved in providing and sustaining pavements in a condition acceptable to the traveling public at the least lifecycle cost" (AASHTO 1985). Choosing the optimal timing of preservation efforts can lead to lower lifecycle costs. In turn, lower lifecycle costs should result in better use of financial capital.

Traced to sustainability components. Extent, expectations, experience.

Sustainability benefits: improves business practice, increases lifecycle savings, increases service, increases aesthetics.

Voluntary Credit Example: CA-5 Equipment Emission Reduction (1–2 points)

Goal. Reduce air emissions from nonroad construction equipment by encouraging early achievement of the EPA Tier 4 emission standard.

Requirement. 1 point: at least 50% of the nonroad construction equipment fleet operating hours for the project are accomplished on equipment with installed emission reduction exhaust retrofits and add-on fuel efficiency technologies that achieve the EPA Tier 4 emission standard. 2 points: increase the fraction to 75%.

Details. For this credit to be implemented successful, workers may require additional training on how to keep track operating hours of equipment accurately. See also CA-2 Environmental Training.

Reasoning. Diesel engines are a major source of air pollution including nitrogen oxides (NO_x), particulate matter (PM) and sulfur oxide gases (SO_x), which contribute to adverse health and environmental effects (ICF Consulting 2005, EPA 1995). In order to combat these health effects, the EPA is implementing its Tier 4 emission standard, which is estimated to reduce emissions by more than 90% by 2030 (EPA 2004).

Traced to sustainability components. Ecology, equity.

Sustainability benefits: Reduces air emissions, improves human health and safety.

Achievement Levels

Greenroads contains 118 possible points (108 points for Voluntary Credits and up to 10 more points for Custom Credits). With "achievement levels," Greenroads offer basic guidance on what we believe are reasonable total point goals. The four levels listed here are meant to (1) suggest a minimum point level that represents a holistic approach to roadway sustainability, and (2) provide several gradations beyond this minimum level to give incentive to improve, innovate and lead in sustainable practices. These four levels are:

- Certified. 32–42 points (30–40% of the total Voluntary Credit points).
- Silver: 43–53 points (40–50% of the total Voluntary Credit points).
- Gold: 54–63 points (50–60% of the total Voluntary Credit points).
- Evergreen: 64+ points (>60% of the total Voluntary Credit points).

These achievement levels have yet to undergo extensive calibration, the goal of which would be to make them generally unattainable using current roadway design and construction practices but attainable without drastically changing the scope of work on typical projects. The WSDOT case study presented later on is, in part, a first attempt at calibration.

BENEFITS

The ultimate benefit of Greenroads is more sustainable roadways. This means impact in any or all of the seven sustainability components. Whether overtly stated or not, the implicit mission of most public road agencies is a sustainable transportation network. A survey of all 50 state department of transportation (DOT) and the USDOT mission statements (Muench 2007), a crude proxy for DOT missions, shows 10 DOT mission statements contain ideas directly relating at least three components of "sustainability" as defined in this paper (ecology, equity, economy) while 34 address at least one component. If ideas of safety and mobility are included this number increases to 47. Given this implicit goal of sustainable transportation, Greenroads can be of benefit to because it can:

1. Provide a credible performance metric for roadway project sustainability.
2. Define basic roadway sustainability attributes.
3. Provide means for sustainability assessment.
4. Allow a greater audience to participate in roadway sustainability in a meaningful way.
5. Enable sustainability tradeoffs and decisions to be made in a systematic manner.
6. Confer marketable recognition on sustainable roadway projects.

7. Allow for innovation because it is end-result oriented.

In essence, Greenroads can provide a relatively straightforward means by which owner agencies can assess their performance against their stated mission.

IMPLEMENTATION

Greenroads implementation and use will likely happen through various forms of voluntary or mandatory use. This section discusses some of the more likely paths. Presently, it is unclear which, if any, will predominate.

Voluntary Use by Consultants/Contractors

Consultants and contractors may use Greenroads as an informal list of sustainable practices that could be incorporated into a roadway project. Achievement levels could be used as goals. Early anecdotal evidence suggests that this may be the initial way Greenroads is used as owner agencies are beginning to ask consultants to incorporate sustainability into their roadway projects in a systematic manner.

Voluntary Use by Agencies

Owner agencies could set required or voluntary Greenroads goals. This may include an overall agency-wide points goal or a minimum achievement level for each project. Similar systems have shown that achieving certain benchmark levels can be successfully marketed as a value added service by designers and contractors and as positive community relations by owners (USGBC 2008). While the voluntary approach is noble, it is often difficult for public agencies to justify the potential for higher initial costs despite potential long-term benefits.

Agency Requirements

Owner agencies could adopt a formal policy of greater sustainability and use Greenroads as one metric by which its sustainability efforts can be judged. This is being done in the building industry: the USGBC lists 353 government and school agencies with such policies concerning their LEED™ system (USGBC 2010). While this may be viewed as imposing more requirements on already burdened public agencies, mandating sustainability may be the best way to ensure the perception of higher initial costs (whether true or not) does not deter sustainability efforts that may result in higher long-term benefits and difficult-to-quantify benefits.

General Sustainability Monitoring

Owner agencies could use Greenroads to assess roadway sustainability and monitor its improvement over time. Most large agencies already have pavement management systems; a Greenroads rating for each roadway or portion of roadway could be added as another data category and this could be tracked over time just as pavement management systems track roadway condition over time. In this sense, Greenroads becomes an internal sustainability benchmark and a useful tool to assist in an agency-wide approach to sustainability.

CASE STUDY

In conjunction with the Greenroads performance metric development, a case study on the 2005 WSDOT "I-5 James Street Vicinity to Olive Way Vicinity Pavement Rehabilitation" project was conducted. The goal of this Greenroads case study is threefold:

1. Provide a trial test of Greenroads usability and interpretation.
2. Calibrate Greenroads so that voluntary certification levels are neither too easy nor too difficult to obtain.
3. Determine Project Requirements and Voluntary Credits earned using existing practices as an assessment of current roadway sustainability levels.

The case study reported here is retrospective. It uses project data (e.g., bid tabulations, construction notes, specifications, plans, design, interviews and direct construction observation) to the extent that it is available to determine the Greenroads score the project would have earned as it was built in three different scenarios:

1. **As built.** The number of Project Requirements and Voluntary/Custom Credit points the project would have earned had it been evaluated using Greenroads.
2. **Reasonably possible.** The maximum number of Project Requirements and Voluntary/Custom Credit points that could be earned without significantly altering project scope if the project were striving for a minimum achievement level.

3. **Maximum possible.** The maximum number of Project Requirements and Voluntary/Custom Credit points that could be earned if the project attempted the highest possible achievement level. It is assumed that scope could be altered and costs increased, however the general intent of the project must remain the same.

Evaluation of the first scenario is as objective as possible while the last two are subjective. Greenroads version 1.0 was used for this evaluation.

Project Description

The project scope as documented by Ozlin et al. (2007) included reconstruction of the outside lane, drop lane and off ramp segments of southbound I-5 between Olive Way and James Street through downtown Seattle from I-5 milepost 164.41 to 166.36 with new PCC pavement. Existing pavement was in poor condition with multiple fractured slabs and a deteriorating HMA overlay. The project was awarded for US$ 3,948,000 and was completed in four 55-hour weekend closures (10:00 p.m. Friday to 5:00 a.m. Monday). Major work consisted of:

- Demolish and remove approximately 4,970 m^3 (6,500 yd^3) of material consisting of:
  - 230 mm (9 inches) of existing concrete pavement and HMA overlay.
  - Approximately 180 mm (7 inches) of aggregate base course.
- Place new PCC pavement consisting of:
  - 75 mm (3 inches) of HMA base material (about 2,270 tonnes or 2,500 tons)
  - 330 mm (13 inches) of doweled jointed plain concrete pavement (about 4,312 m^3 or 5,640 yd^3)

Other details can be found in Ozolin et al. (2007). Table 2 summarizes the case study Greenroads scores.

Project Scoring Comments by Category

Project Requirements

- PR-1: State funding required that the State Environmental Policy Act (SEPA), which meets or exceeds the National Environmental Policy Act (NEPA) standards for a project environmental review process.
- PR-2: No lifecycle cost analysis of the pavement was done. One could be done for little cost using RealCost 2.5 (FHWA 2009)
- PR-3: No pavement lifecycle inventory was done. One could be done for little cost using PaLATE (Consortium on Green Design and Manufacturing 2007).
- PR-4, 5 and 6: While the contractor exercised quality control and managed waste, there were no written plans submitted to the owner as required. The specifications included a construction noise mitigation strategy.
- PR-7: Required by regulation based on project size.
- PR-8: Limited stormwater treatment was included in the project, thus LID solutions were likely not appropriate. However, there was no documentation declaring this.
- PR-9: The Washington State Pavement Management System (WSPMS) addresses the entire state route network including this section of I-5.
- PR-10: Site maintenance is addressed by existing WSDOT programs.
- PR-11: Only 2 of 8 items were likely met.

Environment & Water

- EW-1: The contractor was not ISO 14001:2004 certified so this Voluntary Credit was not earned. It would not increase scope to obtain certification but would cost the contractor time, money and effort.
- EW-2 through 8: No points were earned as the project scope essentially excluded these Voluntary Credits.

Access & Equity

- AE-1: No safety audit as specifically described by the Voluntary Credit was performed however one could have been done for minimal project cost if a standard safety audit system been in place such as that of the South Carolina DOT (Wilson and Lipinski 2004).
- AE-2: Four points were given based on the following categories: surveillance (traffic cameras), information dissemination (dynamic message signs, highway advisory radio), ramp control (ramp metering) and traveler information (Internet traffic flow map, 511 service).

TABLE 2. Case Study Review.

No.[a]	Title	Pts.	As Built	Reasonable	Maximum
Project Requirements (PR)					
PR-1	Environmental Review Process	Req	Yes	Yes	Yes
PR-2	Lifecycle Cost Analysis	Req	No	Yes	Yes
PR-3	Lifecycle Inventory	Req	No	Yes	Yes
PR-4	Quality Control Plan	Req	No	Yes	Yes
PR-5	Noise Mitigation Plan	Req	Yes	Yes	Yes
PR-6	Waste Management Plan	Req	No	Yes	Yes
PR-7	Pollution Prevention Plan	Req	Yes	Yes	Yes
PR-8	Low-Impact Development	Req	No	Yes	Yes
PR-9	Pavement Management System	Req	Yes	Yes	Yes
PR-10	Site Maintenance Plan	Req	No	Yes	Yes
PR-11	Educational Outreach	Req	No	Yes	Yes
Voluntary Credits					
Environment & Water (EW)					
EW-1	Environmental Management System	2	0	2	2
EW-4	Stormwater Cost Analysis	1	0	1	1
EW-6	Habitat Restoration	3	0	0	3
Access & Equity (AE)					
AE-1	Safety Audit	2	0	2	2
AE-2	Intelligent Transportation Systems	5	4	5	5
AE-3	Context Sensitive Solutions	5	0	0	5
AE-7	Transit & HOV Access	5	0	0	5
Construction Activities (CA)					
CA-1	Quality Process Management	2	0	2	2
CA-2	Environmental Training	1	1	1	1
CA-3	Site Recycling Plan	1	0	1	1
CA-5	Equipment Emission Reduction	2	0	0	2
CA-6	Paving Emission Reduction	1	1	1	1
CA-7	Water Use Monitoring	2	0	2	2
CA-8	Contractor Warranty	3	0	0	3
Materials & Resources (MR)					
MR-1	Lifecycle Assessment	2	0	0	2
MR-4	Recycled Materials	5	0	0	5
MR-5	Regional Materials	5	0	5	5
Pavement Technologies (PT)					
PT-1	Long-Life Pavement	5	5	5	5
PT-4	Cool Pavement	5	5	5	5
Voluntary Credit Total:		**108**	**16**	**32**	**57**
Custom Credits (CC)					
CC-1	Custom Credits	10	2	2	2
Greenroads Total:		**118**	**18**	**34**	**59**
Greenroads Certification Level:			**None**	**Certified**	**Gold**

Note: Credits that do not apply in any scenario are omitted.

- AE-3: Could have been done however given that the project was scoped as pavement replacement it would have been a significant scope change to include any context sensitive solutions.
- AE-4: No policy or plan in place at the time of construction.
- AE-5 and 6: being a pavement replacement effort, the project scope excluded alternate transportation modes.
- AE-7: This credit was not met but could have been given a larger project scope.
- AE-8: No scenic views as defined by this credit.
- AE-9: The project did not significantly alter any surfaces besides pavement so adding art or other cultural references would have been a significant scope change.

Construction Activities

- CA-1: The contractor was not ISO 9001:2000 certified (ISO 9001:2008 was not in effect then) so no points were earned. It would not increase scope to obtain certification but would cost the contractor money.
- CA-2: The project involved several pre-construction training sessions/meetings. We do not know whether all required environmental issues were covered but have given credit anyway.
- CA-3: Not done but would be within the existing scope to do so.
- CA-4: Given the project was in 2005 it is unlikely any points could have been earned.
- CA-5: Project paperwork provided no evidence of exhaust retrofits or EPA Tier 4 compliance so no points were given. Points could be obtained without a significant scope change however it would cost the contractor money.
- CA-6: The Caterpillar AR-1055B asphalt paver used to pave the HMA base course was equipped with a National Institute for Occupational Safety and Health (NIOSH) recommend exhaust ventilation system. Project photos confirm this.
- CA-7: Not done in accordance with the credit requirements but it would be within the existing scope to do so.
- CA-8: The project did not use a 3-year warranty. Providing such a warranty was possible but would involve significant scope change.

Materials & Resources

- MR-1: No LCA was done. A LCA could have been done but would likely have been a relatively expensive scope change.
- MR-2: Project scope only included subgrade and existing pavement removal. While the left three lanes remained in place, the project scope did not involve any work on these lanes so they cannot be counted as reused pavement.
- MR-3: Project scope did not include significant subgrade work.
- MR-4: PCC mix designs for both the slipform paver and hand paving did not include substantial recycled material or supplementary cementitious material (SCM).
- MR-5: The PCC was produced at Stoneway Concrete in Seattle, located 4.8 km (3.0 miles) from the southernmost portion of the project. The cement was produced next door at Ash Grove Cement Company's Seattle location. The HMA binder was produced in South Seattle. The aggregate was quarried at Pioneer Aggregates in Dupont, WA that is 76.8 km (47.7 miles) away from Stoneway by road. This makes the total distance travelled by the aggregate 81.6 km (50.7 miles), which exceeds the 50 miles required to qualify this material in this credit. Since the aggregate represents the majority of project material by weight, this credit is not earned because it did not meet the minimum credit requirements for 60% of the material by weight traveling less than 50 miles total.
- MR-6: The project scope did not include any significant energy consuming roadway devices.

Pavement Technologies

- PT-1: The pavement design is 330 mm (13 inches) of PCC over 75 mm (3 inches) of HMA. Subgrade resilient modulus in this area is typically in excess of a CBR of 10 (although no measurements were taken). If an exception is made to the minimum base thickness of 150 mm (6 inches), which seems appropriate given that the base material is HMA, then the requirements are met. The exception would need to be approved by Greenroads.
- PT-2: The pavement is not permeable nor is permeable pavement appropriate for freeway traffic in this application.

- PT-3: The HMA portion of the job consists of 2,270 tonnes (2,500 tons), which corresponds to about 1,219 yd^3 (932 m^3) using a rough rule-of-thumb of 1.42 tonnes/m^3 (2.05 tons/yd^3) for HMA. This means the HMA was only about 17.7% of the total volume of pavement (PCC and HMA) placed. Therefore, even if it was all warm mix asphalt (WMA) it would fall short of the required 50% needed to qualify for this credit.
- PT-4: No albedo measurement was made but the concrete surface is likely to exceed the required 0.3.
- PT-5: No sound measurements were taken but the transverse tining used to texture the surface is not likely result in an On-Board Sound Intensity (OBSI) of 99 dBA or less needed to meet requirements for this credit. It is likely that advanced texturing techniques could achieve 99 dBA but would require a significant scope change to achieve.
- PT-6: The section is monitored with WSPMS, which has no means to tie pavement performance to construction data. Such a system could be implemented (White et al. 2002) but would require substantial work.

Custom Credits

- CC-1: Two points are given for construction speed since it lessened user delay although no quantification of this was done.

Observations

- The case study could be assessed with a reasonable amount of available information. Nevertheless, some items were estimated, which would not be allowed for official certification.
- Apart from the four weekend closures, this project did not use any unusual practices. Therefore, WSDOT's standard practices were able to achieve 16 points, which is significant. Without significantly increasing scope, this project could obtain 34 points which would meet the minimum achievement level.
- Projects with only one or two sustainability feature (in this case, the rapid construction over four weekends) are not likely to meet any achievement level. However, a more holistic approach to sustainability that considers all seven components could.
- Via the Construction Activities category, contractors can achieve 14 points through mostly internal strategies. Contractors adopting more sustainable practices may be able to gain a significant competitive advantage if Greenroads certification is an agency goal.
- The seven Project Requirement items not done were all forms of documentation. Most of these (e.g., quality control plan, environmental maintenance plan) can be generated once by the agency or contractor and then reused on future projects with minor changes.
- The financial impact of sustainable choices made in the case study project and those suggested by the two additional scenarios are not known but should be investigated.

CONCLUSIONS AND RECOMMENDATIONS

This paper described a proposed performance metric for quantifying sustainable practices associated with roadway design and construction. Importantly, sustainability is defined as having seven key components: ecology, equity, economy, extent, expectations, experience and exposure. By Greenroads standards, a sustainable roadway project is one that carefully an overtly integrates these components into the design and construction process.

Greenroads is a straightforward performance metric that can help produce more sustainable roadways. Version 1.0 consists of 11 Project Requirements, 37 Voluntary Credits (worth 108 points) and up to 10 points worth of Custom Credits. Project-level sustainability performance can be assessed by meeting all Project Requirements and any number of Voluntary Credit points. Greenroads also sets "achievement levels" at different point values in order to provide recommended scoring levels. Greenroads can be implemented in a number of ways including (1) voluntary consultant use, (2) voluntary agency use, (3) agency requirements, and (4) as a general performance metric for roadway sustainability. The expected benefits of Greenroads include:

1. A means to assess roadway sustainability and make sensible sustainability tradeoffs through the use of a common metric.

2. Greater participation in roadway sustainability through the use of a straightforward and understandable system.
3. Improved awareness of roadway sustainability through marketing.
4. Encouragement for sustainability innovation.

The WSDOT case study provides insight into Greenroads and how it might influence roadway projects. Key observations are:

- It is possible to rate a project using existing project data.
- WSDOT standard practice already contains many sustainable elements
- Certification generally requires a focused approach to integrate sustainability into roadway design and construction rather than a piecemeal use of individual sustainable practices.
- By changing basic practices, stakeholders can market their sustainability efforts.
- It is possible to reach the minimum achievement level without substantially altering project scope.

Greenroads continues to be a work in progress. System development and case studies point out the following key needs for future work:

- More case studies need to be done; especially those involving more than paving operations. Impacts on geometric design, traffic and equity and training decisions is not well understood. Currently, 16 case studies are ongoing.
- The financial impacts associated with Greenroads Project Requirements and Voluntary Credits need to be studied (this is now in progress). The benefits and costs should be clear to stakeholders.
- Actual projects where the Greenroads metric is used would provide valuable information on the effort, initial cost and impact of Greenroads on projects.
- Greenroads needs to be vetted by owner organizations and industry.

Sustainability has become an important topic in engineering and construction, of which roadway work is a substantial part. Greenroads can potentially provide a common performance metric for considering sustainability in roadway design and construction. Fundamentally, such a metric can help people make better roadway sustainability decisions and improve over time.

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