

Greenroads: Development of a Sustainability Rating System for Roadways

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ABSTRACT

Greenroads (www.greenroads.us) is a proposed standard for quantifying sustainable practices associated with the design and construction of roads. It is a rating system that awards credits for approved sustainable choices/practices which can be used to certify roadway projects based on the total credits earned. Such a standard can (1) allow informed sustainability decisions, (2) provide a quantitative means of sustainability assessment, (3) stimulate improvement and innovation in roadway sustainability, and (4) provide baseline sustainability standards.

Greenroads consists of 62 credits and 11 requirements in 7 categories that can be used to achieve certification. System development and a City of Seattle case study suggest (1) existing project data can be used to rate projects, (2) some credits need refinement, (3) projects need to be holistically focused on sustainability to achieve certification, (4), the financial impact *Greenroads* use must be studied, and (5) a pilot project is needed Green Roads presents a viable system for assisting roadway sustainability decisions.

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 proposed standard, 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 certify projects based on total point value. This standard 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 certified 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 implications for project selection, design/construction decisions and asset management (including pavement management). *Greenroads* was first introduced in 2007 as an initial concept with associated credits and six preliminary case studies (1). Since then, it has undergone significant revision based on professional and potential stakeholder opinion as well as empirical evidence. A stable Version 1.0 for evaluation and use is due out online in January 2009. This system can be freely used and modified by anyone, however the official version will reside online (www.greenroads.us) and be maintained by its developers for general use. Options concerning its ultimate use and ownership remain open.

This paper presents the *Greenroads* rating system in its current form. It includes a discussion of the perceived need for such a system and the underlying definitions and values that used to develop the system. A discussion of credits and credit categories is intended to familiarize the reader with the general system and provide examples of what credits entail without reviewing the entire system in detail. Potential avenues to implementation and envisioned uses are discussed followed by a case study where it was applied to a local road project.

SUSTAINABILITY DEFINITION

For the purposes of this paper, “sustainability” follows the definition of “sustainable development” put forth by the Brundtland Commission: “...development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (2). The term “needs” is interpreted as having three basic components: economic, environmental and social. These needs may be in competition with one another but must be balanced when making roadway design and construction decisions. This act of balancing requires us to define our expectations in these three areas and the extent to which they apply over time and space. We use expertise in the form of engineering and science, and exposure in the form of education and

communication to define expectations and extent and to develop solutions that achieve a balance of economic, environmental and social needs. 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) (3) lists 157 government and school agencies that have adopted formal policies defining building sustainability goals or requirements. More broadly, the free market economy seems to be rapidly adopting sustainable practices as a means to make money (4).

To date, roadways typically approach sustainability in a piecemeal manner. Typical means for addressing each of the three components have been:

- **Economic.** Project evaluative procedures, budgetary constraints and political or economic pressures
- **Environmental.** Regulations describing minimum acceptable standards.
- **Social.** Political or mandated processes for ensuring environmental justice, cultural and aesthetic considerations.

Although there are processes that attempt to integrate these efforts on a project level (e.g., National Environmental Policy Act – NEPA and state equivalents, cost/benefit analyses, etc.) none are purposefully organized around the central guiding principal of sustainability yet. Individual efforts have made progress

THE NEED FOR A RATING SYSTEM

“Sustainability” as defined by this paper is conceptual and thus does not directly define specific actions or decisions in the realm of roadway design and construction. *Greenroads* is a straightforward means of translating these ideas to a set of definable design and construction practices that are likely to result in a more sustainable roadway. The need for such a system arises for four basic reasons. First, roadways can be more sustainable than they currently are. Current standards and decision tools (e.g., life-cycle cost procedures (5)) do not fully address sustainability. For instance, while pavements are heavy users of recycled material (6) their design and construction are not based on life cycle emissions or energy use, and environmental considerations can be limited to regulatory compliance. Second, most roadway sustainability efforts to date have not applied a consistent standard. 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 rating system could help with all these issues. Such a system should be straightforward and simple 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* (7) and the Green Highways Partnership (8). 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 rating system for roads. Each stakeholder is likely to have opinions on how Greenroads should work. Stakeholders will be engaged in a greater effort starting in 2009 once Version 1.0 is done in order to give them a baseline product on which to begin commenting. 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 parking lot design
- Contractors: heavy construction, road and paving contractors
- Regulatory agencies: U.S. Environmental Protection Agency
- 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 related sustainable technologies.

GREENROADS RATING SYSTEM

This section first discusses the general underlying philosophy then describes the rating system in detail including boundaries, categories, credits and certification. *Greenroads* Version 1.0, a fully developed stable rating system will be out and available for trials in the beginning of 2009.

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 evolves.

General Philosophy

The *Greenroads* rating system is designed to promote more sustainable solutions within and beyond existing federal, state and local regulations. Specifically, *Greenroads* credits are designed to influence decisions regarding sustainability options where they are not precluded by regulation or where regulation allows a choice between options that could have sustainability impacts. Green Roads is also meant to encourage organizations to include sustainable practices in their company-wide strategy and daily work practices. Importantly, *Greenroads* is not meant to dictate design or trade-off decisions. Rather it provides a tool to help with such decisions. The fundamental tenets of *Greenroads* are:

- **Straightforward and understandable.** Non-experts should be able to understand the system. Simplicity is valued over excessive detail because it is more understandable. Credits are often simplistic interpretations of complex ideas; they are bound to contain some controversy however the interpretation should hold true to the fundamental idea.

- **Use empirical evidence and existing evaluative techniques.** Credits are based on a preponderance of empirical evidence and, to the extent possible, should be evaluated using existing tools and techniques.
- **Credit is commensurate with impact.** Items that have high economic, environmental or social impact are given more credit than low impact items.
- **Flexibility.** *Greenroads* should be able to accommodate a broad range of both urban and rural roadway projects from preservation overlays to major new corridor development. Credits should be applicable anywhere in the U.S. International versions may be developed in the future.
- **Continual evolution.** Over time, better ideas, more complete knowledge and technology advances will require *Greenroads* to be updated and changed.
- **Minimal bureaucracy.** Obtaining credits and certification requires documentation but documents should either come from existing documents (e.g. plans and specifications) or be simple and inexpensive to produce from existing documents.
- **Beyond minimum requirements.** *Greenroads* should spur innovation and encourage design and construction decisions based on sustainability considerations that go beyond regulatory requirements. While regulatory requirements and design standards contribute to sustainability, a rating system that awards credit for these items alone becomes a marketing tool at best that is technically redundant and administratively burdensome.

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). This means that some typical items associated with roadways are either excluded or only considered marginally:

- **Materials manufacturing or refining.** Items such as cement and asphalt manufacturing/refining are only considered in life cycle inventories or analyses.
- **Structures.** Bridges, tunnels, walls and other structures are considered only as a collection of materials. Points can be awarded for materials used; however the structural design, aesthetics and other non-material qualities are excluded. A future system focused on structures could be incorporated into *Greenroads* but none currently exist.
- **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.
- **Maintenance and preservation.** Since certification occurs at substantial completion, plans for maintenance and preservation are given minimal credit. Although maintenance and preservation actions have a large impact on overall roadway sustainability, they occur after certification and cannot be verified in the long term.
- **Roadway use.** Traffic and other direct use issues are excluded as they cannot be adequately predicted or verified in the long term. Design decisions that affect how a facility might be used are given credit.

Categories, Credits and Certification

Greenroads consists of credits in seven categories: project requirements, environment and water, access and equity, construction activities, materials and resources, pavement technologies, and exemplary performance. Each of these categories contains a number of credits. A credit is an individual design or construction decision or action that can improve the sustainability of a roadway project. In order to receive points for the credit, designers and constructors must meet the intent of the credit and submit supporting documentation. Credit title, ideas and categories have undergone a major revision since 2007 (1) but are now stable and should remain so for remainder of development.

Credits based on fundamental sustainability values. All credits are directly applicable to at least one component of sustainability (economic, environmental, social). In order to assist credit writing each sustainability component is expanded into a short list of fundamental values:

- Economic: cost, durability, quality, efficiency
- Environmental: water, air, natural resources, habitat
- Social: equity, safety, culture, access

Just as with the components of sustainability, these fundamental values are interdependent and may, at times, be at odds with one another. This reinforces the idea that sustainability decisions are often thoughtful compromises between competing values.

Credit weighting. *Greenroads* credits are weighted according to their sustainability impact and the duration of that impact. In general:

- 1 credit: low and short-term impact.
- 2 credits: combinations of low/long-term or high/short-term impact. Also used for organizational incentive credits where significant effort would be required to meet the credit requirements.
- 3 or more credits: high and lasting impact.

Table 1 lists all *Greenroads* credits and their general intent. Not every credit is applicable to every roadway project. The following briefly discusses each category and gives an example credit. More complete discussion of these items can be found on the *Greenroads* working website at: www.greenroads.us.

TABLE 1 Greenroads Credit Listing by Category

Item	Credits	Intent
Category: Project Requirements (PR)		
PR-1: NEPA Compliance	REQ	Evaluate options, meet regulations
PR-2: Pavement Preservation Plan	REQ	Have a plan to monitor and preserve pavement
PR-3: Environmental Maintenance Plan	REQ	Plan for landscaping and cleaning/care of roadway
PR-4: LID Techniques for Stormwater	REQ	Use low impact development (LID) techniques
PR-5: Educational Outreach	REQ	Information on roadway and green techniques used
PR-6: Construction Quality Control	REQ	Quality control plan for construction
PR-7: C&D Waste Management Plan	REQ	Divert 70% of waste from landfill
PR-8: Life Cycle Cost Analysis (LCCA)	REQ	Perform a LCCA according to FHWA standards (5)
PR-9: Life Cycle Inventory Tool (LCI)	REQ	Perform LCI of roadway structure
PR-10: Stormwater Pollution Prevention Plan	REQ	Temporary erosion and sediment control plan
PR-11: Noise Mitigation Plan	REQ	Have a plan or a study that concludes one is not needed
Total PR items	11	
Category: Environment & Water (EW)		
EW-1: Environmental Management System	1-2	ISO 14001 certification for contractor/designer/owner
EW-2: Stormwater Management Plus	2	Go above and beyond regulatory requirements
EW-3: Native Landscaping	1	Encourage wise flora choices and no water use
EW-4: Ecological Connectivity	1	Connect habitat across roads (viaducts, fish passage)
EW-5: Reduce Light Pollution	1	Discourage light pollution of surrounding areas
EW-6: Life Cycle Cost Analysis of BMPs	1	Do LCCA to assist in decision-making
EW-7: Habitat or Watershed Creation	2	Create habitat/watershed beyond regulatory req.
Total EW points available	10	
Category: Access & Equity (AE)		
AE-1: Safety Audit	1	Perform a roadway safety audit
AE-2: Intelligent Transportation Systems	2	Install systems to improve efficient use of facility
AE-3: Promote Art & Culture	1	Promote art/culture along the road alignment
AE-4: Scenic Views	1	Provide scenery views where appropriate
AE-5: Pedestrian Access	1	Improve pedestrian access where appropriate
AE-6: Bicycle Access	1	Improve bicycle access where appropriate
AE-7: Americans with Disabilities Access	1	Improve/provide ADA access
AE-8: Transit Access	1	Provide or improve transit access or efficiency
Total AE points available	9	

Category: Construction Activities (CA)		
CA-1: Quality Process Management	2	Encourage ISO 9001 certification for the contractor
CA-2: On-Site Recycling & Trash Collection	1	Provide to promote environmental stewardship
CA-3: Track Water Use	1	Track water in order to build database of water use
CA-4: Reduce Fossil Fuel Use	1-2	Use biodiesel, hybrids to reduce fossil fuel use
CA-5: Reduce Equipment Emissions	1-2	EPA Tier 4 standards for 50/100% of non-road equip.
CA-6: Reduce Paving Emissions	1	HMA Pavers to meet NIOSH standards
CA-7: Environmental/Safety Training	1	Promote environmental and safety concerns
CA-8: Performance-Based Warranty	3	Guarantee performance for 3 years after construction
Total CA points available	13	
Category: Materials & Resources (MR)		
MR-1: Enhanced LCA	2	Detailed assessment through 3 rd party
MR-2: Native soil rehabilitation	1	Use native material rather than import fill
MR-3: Pavement Reuse	2	Reuse existing pavement structure
MR-4: Recycled Content	1-4	Use recycle content – points vary with percentage
MR-5: Regionally Provided Material	1-2	Use materials averaging 50 miles/ton travel or less
MR-6: Energy Efficiency	1	Improve energy efficiency of lighting and control sys.
Total CA points available	12	
Category: Pavement Technologies (PT)		
PT-1: Long Life Pavement	3	Design pavements for long life to reduce impacts
PT-2: Pavement Performance Monitoring	1	Collect QC and performance data and integrate
PT-3: Warm Mix Asphalt (WMA)	2	Use WMA to reduce energy and fuel use
PT-4: Cool Pavement	1	Reduce heat radiating from pavement
PT-5: Permeable Pavement	1	Added credit for using as a LID technology
PT-6: Quiet Pavement	3	Reduce tire-pavement noise
Total PT points available	11	
Category: Exemplary Performance (EP)		
EP-1: Exemplary Performance	1-6	Innovative techniques not described in exiting credits
EP-2: Professional Accountability	1	Take course in sustainable transportation infrastructure
Total EP points available	7	
Total Green Roads points available	62	

Project Requirements (PR)

Project Requirements contains all credits that are required for *Greenroads* certification; all other credits are optional. Thus, this category defines, at a minimum, what a *Greenroads* certified roadway is. Credit topics in this category are drawn from each of the other categories a represent some fundamental sustainability ideas translated into reasonable requirements that should be

attainable without significantly altering project scope. This category requires a total of 11 credits as summarized in Table 1.

Credit Example: PR-5 Educational Outreach

Credit text: Make information publically available either by roadway sign or website that indicates (1) the project is a Greenroads project, and (2) the features of the project that make it more sustainable.

Method: The owner submits evidence of the publically available information. This could be in the form of contract specifications that call for a roadway sign or website, a link to the website in question or a photograph of the sign in place.

Reasoning: Communication and education are essential to increasing sustainability knowledge and awareness. In the “Sustainability Definition” section they are listed as two of the three tools used to develop sustainable solutions.

Environment and Water (EW)

Environment and Water addresses the fundamental values of cost, water, air, natural resources, and habitat. “Environment” refers to ecological health relating to more subjective perceptions such as natural habitat, vegetation, and light. “Water” refers to considerations of the hydrological cycle, water quality and water conservation. Many of these considerations are already regulated (e.g., Clean Water Act). The intent of this category is to establish credit requirements that do not conflict with established regulation but rather influence decision making where choices are possible or encourage items beyond regulatory requirements. A total of 10 credits can be achieved in this category as summarized in Table 1.

Credit Example: EW-1 Environmental Management System

Credit text: Either the general contractor, primary design consultant or owner is ISO (International Organization for Standardization) 14001:2004 certified. One point for each of the previously listed entities that is certified up to a maximum of two points.

Method: Submit a copy of the official certificate. Certification can be obtained from a number of ISO-accredited organizations through a management system auditing process.

Reasoning: According to ISO (9), “An (environmental management system) meeting the requirements of ISO 14001:2004 is a management tool enabling an organization of any size or type to:

- identify and control the **environmental impact** of its activities, products or services, and to
- **improve** its environmental performance continually, and to
- implement a **systematic approach** to setting environmental objectives and targets, to achieving these and to demonstrating that they have been achieved.” (9)

Certification can provide assurances to external stakeholders (such as owners or the general public) that the principal participants in a roadway project have a systematic way of managing their relationship to the environment (9). Additionally, certification can have organizational benefits not directly related to a *Greenroads* project including supporting environmental marketing claims, assuring management and employees that the organization is in control of its activities and is environmentally responsible (9). The most recent ISO data (December 2006) shows 5,585 ISO 14001 certified organizations in the U.S.

Access and Equity (AE)

Access and Equity addresses the fundamental values of cost, equity, safety, culture, and access. “Access” means that roadways and related features should provide be usable by as many modes of transport as appropriate. It is especially applicable to transit, pedestrian and bicycle transportation modes. More fundamental issues of access such as whether or not a road should be built based on community access needs is beyond the scope of *Greenroads*. “Equity” relates to safety, social and aesthetic human needs (10).

Credit Example: AE-1 Roadway Safety

Credit text: Conduct a road safety audit (RSA) on the roadway in question in accordance with the procedures set forth in *FHWA Road Safety Audit Guidelines* (11).

Method: Conduct a formal RSA and submit the formal report and response to the report.

Reasoning: Roadway crashes and their resultant injuries and costs have an immense impact on society. Each year highway crashes in the U.S. injure 3 million, kill 43,000 and cost over \$230 billion (11). *NCHRP Synthesis 336* suggests RSAs can reduce accident occurrences on audited sites when compared to non-audited sites at a typical cost of only 5% of engineering design costs (11).

Construction Activities (CA)

The Construction Activities category addresses the fundamental values of cost, durability, quality, efficiency, water, air, natural resources, habitat and safety. Construction activities relate to construction quality, safety and environmental impact. While they take place over a relatively short period of a roadway’s life, construction activities can be major sources of pollution, waste, energy use and health issues. For example, data from a 2006 report to Commission of the European Directorate-General for Energy and Transport (12) showed that for the 14 roads examined, total energy used in construction ranged from 73 to 236% (median of 122%) of the total energy used in yearly vehicle operation of that same road. A total of 13 credits can be achieved in this category as summarized in Table 1.

Credit Example: CA-1 Reduce Diesel Emissions.

Credit text: 50% of the non-road diesel engine fleet have emission reduction exhaust retrofits and add-on fuel efficiency technologies complying with the Environmental Protection Agency’s (EPA) Tier 4 emission standard (13).

Method: This credit applies to non-road diesel engines only; road rated dump trucks are excluded, however they may be included in the future using the 2007 Heavy-Duty Highway Rule (14).

Count the number of non-road diesel engines and ensure that at least half are EPA Tier 4 compliant. Tier 4 controls are being phased in and by 2015 all new non-road diesel engines must comply (13).

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 (15,16). Emissions from diesel engines include over 40 cancer causing substances, and diesel exhaust is likely to be carcinogenic to humans by inhalation at occupational and environmental levels of exposure (17). Seventy percent of the cancer risk from airborne pollutants is from diesel exhaust, mainly due to the PM_{2.5} emissions (18). In 2002 in Washington State, construction activities alone were responsible for 18% of PM_{2.5} emissions (18). 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 (13). This credit is to encourage construction equipment owners to buy new vehicles and retrofit older ones to meet Tier 4 standards. The credit limitation is based Washington State's *Diesel Particulate Emission Reduction Strategy* (18).

Materials and Resources (MR)

This category addresses the fundamental values of cost, durability, water, air, natural resources and habitat. "Materials" and "resources" refer to the materials used within the roadway right-of-way. They include materials used in the roadway structure, structure materials (e.g., bridges, tunnels, walls) and associated appurtenances (e.g., lights, benches, sidewalks, etc.). Large volumes of non-renewable materials and resources go into constructing a roadway. Each year U.S. roadway construction uses roughly (19,20,21):

- 1.3 billion tons of virgin aggregate worth \$10 billion.
- 40 million tons of asphalt worth \$13 billion.
- 10 million tons of cement worth \$1 billion.

Additionally, various sources have reported information that correspond to the following ranges for constructing one lane-mile of freeway pavement:

- Raw material use: between 7,000 and 12,000 tons (22,23)
- Energy consumption: between 3 and 8 TJ of energy (22,24,25)
- Emissions: between 500 and 1,200 tons of CO₂ equivalent expressed as Global Warming Potential (GWP) (22)
- Waste: upwards of 2,500 tons of waste if the roadway materials are not recycled at end-of-life (23)

A total of 12 credits can be achieved in this category as summarized in Table 1.

Credit Example: MR-4 Recycled Content.

Credit text: Use recycled content in the project. As a minimum, the high-type pavement surface (e.g., HMA or PCC) must be included. Other pavement layers (e.g., base, subbase), general fill and structural material may also be included but if done so must be included in all applicable

credit calculations. Credits are given based on minimum amounts of recycled material in the structure as follows:

- 1 point: 20% in the hot mix asphalt (HMA) or portland cement concrete (PCC) layers or 40% of the total material structure if base course layers, structures or fill are included in the calculation.
- 2 points: 30% or 50%
- 3 points: 40% or 60%
- 4 points: 50% or 70%

Method: Calculate recycled content based on weight in each “assembly”. An assembly is a discrete component of a composite material. For example, HMA consists of two assemblies: asphalt binder and aggregate. HMA would get one credit if either the asphalt binder or the aggregate assemblies contain at least 20% recycled material. The 20% value is based on the use of reclaimed asphalt pavement (RAP) in new HMA pavements and the use of fly ash in PCC pavements. Survey results from the RAP expert task group (ETG) formed by the FHWA found a range of allowable RAP use but “...in much of the country, 15 percent seems to be the amount used in surface courses.” (26). On average, greater percentages were reported as allowable for intermediate and base layers. The American Coal Ash Association reports that typically between 15 and 30 percent of PCC cementitious material is replaced by fly ash (27). A stretch goal of 20 percent recycled material was selected as the credit limit based on these numbers.

Reasoning: Roads have generally been praised for their use of recycled materials. For instance, the FHWA (5) claims 80% of all HMA is recycled making it one of the most recycled items in the U.S. However, 20% is still sent to landfill and over 50% is used as lower value base material instead of high-value surfacing (28). Therefore, although recycling quantity has been high, it can be increased and more recycled material could be used in higher value materials.

Pavement Technologies (PT)

This category addresses the fundamental values of cost, durability, water, air, natural resources and habitat. “Pavement Technologies” refer to pavement structural and material design decisions that have impacts on sustainability. This category is separate from Materials & Resources because it does not directly address material composition but rather the use of the pavement itself as a material that can reduce detrimental impacts or create positive impacts. While no other roadway structure has its own category, this category is justified because pavements and their underlying structure represent such large use of many different materials including HMA, PCC, aggregate, fly ash and others (19,20,21,27). Whereas other *Greenroads* categories contain topics that are regulated to some degree, the use, reuse and recycling of materials in pavement structures is largely voluntary today. Therefore, *Greenroads* could have more influence in materials and their use in pavements than in most other categories. A total of 11 credits can be achieved in this category as summarized in Table 1.

Credit Example: PT-4 Cool Pavement.

Credit text: Use a pavement surface with a minimum albedo of 0.3 or use a porous pavement.

Method: ASTM E 903 provides measurement procedures. Albedo, or solar reflectance, is a measure of a material's ability to reflect sunlight on a scale of 0 (all radiation is absorbed) to 1 (all radiation is reflected). An increase in albedo by 0.1 produces a change in pavement surface temperature of about -7°F (-4°C) (29). For conventional paving materials, albedo usually ranges from 0.05 to 0.40. As pavement ages albedo can change significantly with HMA albedo increasing from 0.05-0.10 new to 0.15-0.20 when weathered and PCC decreasing from 0.35-0.50 new to 0.25-0.30 when weathered. The air void structure in porous pavement allows evaporative cooling and thus can also be considered for this credit.

Reasoning: Pavement surfaces absorb solar energy and store it as heat in the pavement. Studies in California (29) have estimated that if the solar absorption of all pavements were reduced from 90% to 65%, the peak air temperature in an urban area would decrease by 1°F. Cool pavements reduce solar energy absorption and consequently radiate less heat to the surrounding environment. Also, less heat absorption could result in lower thermal stresses within pavements leading to longer life and lower life cycle costs.

Exemplary Performance (EP)

The intent is to give project teams the possibility of earning *Greenroads* credits for additions and performance better than that outlined in the rating system. For instance, a viable scheme to place thin-film solar cells on a freeway noise wall to generate electricity could earn one or several exemplary performance credits depending upon its impact. Improving sustainability knowledge is also considered exemplary performance. A total of 7 credits can be achieved in this category as summarized in Table 1.

Certification

Greenroads contains 62 possible points. Certification is based on achieving a minimum number of credits. The minimum level of certification is based on achieving roughly 40% of the points excluding EP points. The following certification levels are provisionally used:

- Certified: 20-26 credits.
- Silver: 27-32 credits.
- Gold: 33-38 credits.
- Evergreen: 38 credits or more.

These certification levels have yet to undergo extensive calibration, the goal of which would be to make them generally unattainable using current roadway design and specification practices but attainable without drastically changing the scope of work. The six Washington State Department of Transportation (WSDOT) case studies presented by Soderlund et al. (1) and the City of Seattle case study presented later on are, in part, a first attempt at calibration.

BENEFITS

The ultimate benefit of *Greenroads* is more sustainable roadways. This means less impact on the environment, lower life cycle costs and more positive societal outcomes. 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 (30), a crude proxy for DOT missions, shows 10 DOT mission statements contain ideas directly

relating to all three components of “sustainability” as defined in this paper (economy, environment, society) 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 system which defines basic roadway sustainability attributes.
2. Allow a greater audience to participate in roadway sustainability in a meaningful way.
3. Allow sustainability tradeoffs and decisions to be made in a systematic manner.
4. Provide means for sustainability assessment.
5. Confer marketable recognition on sustainable roadway projects.
6. Allow for sustainability innovation because it is end-result oriented.

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

IMPLEMENTATION

Implementation of and participation in *Greenroads* will likely happen through various forms of voluntary or mandated use. This section discusses the most likely paths. Presently, it is unclear which, if any, will predominate.

Voluntary Use by Consultants/Contractors

Consultants and contractors could use *Greenroads* as an informal list of sustainable practices that could be incorporated into a roadway project. Certification levels could be used as standard sustainability goal levels. 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.

Voluntary Use by Agencies

Owner agencies could set goals (required or not) of a particular *Greenroads* certification level. In addition to improving sustainability similar certification systems have shown that certification can be successfully marketed as a value added service by designers and contractors and as positive community relations by owners (31). While the voluntary approach is noble, it is often difficult for public agencies to justify higher initial costs despite potential long-term benefits.

Agency Requirements

Owner agencies could adopt a formal policy of greater sustainability and use *Greenroads* to specify its minimum standards. This is being done in the building industry: the USGBC (1) lists 157 government and school agencies with such policies concerning their LEED™ system. While this may be viewed as imposing more requirements on already burdened public agencies, mandating sustainability may be the best way to ensure higher initial costs do not deter sustainability efforts that may result in longer-term benefits and difficult-to-quantify benefits.

General Sustainability Monitor

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.

CASE STUDY

In conjunction with the *Greenroads* rating system development, a case study on a simple overlay project by the City of Seattle. This supplements the six WSDOT case studies (1) that used an earlier version of *Greenroads*. The goal of all *Greenroads* case studies is threefold:

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

The case study reported here is extremely basic (other more elaborate ones are being conducted at the time of this writing). It uses project data (e.g., bid tabs, construction notes, specifications, plans, design, interviews and direct construction observation) to determine what *Greenroads* credits the project would have earned in three different scenarios:

1. **As built.** The number of credits the project would have earned had it been evaluated using *Greenroads*.
2. **Reasonably possible.** The maximum number of credits that could be earned without altering project scope if the project were striving to earn certification.
3. **Maximum possible.** The maximum number of credits that could be earned if the project attempted to achieve the highest certification level possible. 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.

Project Description

- Project name: 2008 Arterial Asphalt and Concrete: Denny/Western/Elliott/15th Ave W (http://www.seattle.gov/Transportation/denny_15th_pave.htm)
- Project time: Spring-Summer 2008.
- Owner agency: City of Seattle
- Contract price: \$6.6 million
- Location: Denny Way, Western Ave. W and Elliot Ave. W. All near the waterfront just north of the Seattle central business district.

TABLE 2 Case Study Credit Review

Item	Available	As Built	Reasonable	Maximum
Category: Project Requirements (PR)				
PR-1: NEPA Compliance	REQ	Yes	Yes	Yes
PR-2: Pavement Preservation Plan	REQ	Yes	Yes	Yes
PR-3: Environmental Maintenance Plan	REQ	No	Yes	Yes
PR-4: LID Techniques for Stormwater	REQ	Yes	Yes	Yes
PR-5: Educational Outreach	REQ	Yes	Yes	Yes
PR-6: Construction Quality Control	REQ	Yes	Yes	Yes
PR-7: C&D Waste Management Plan	REQ	No	Yes	Yes
PR-8: Life Cycle Cost Analysis (LCCA)	REQ	Yes ^a	Yes	Yes
PR-9: Life Cycle Inventory Tool (LCI)	REQ	Yes ^a	Yes	Yes
PR-10: Stormwater Pollution Prevention Plan	REQ	Yes	Yes	Yes
PR-11: Noise Mitigation Plan	REQ	Yes	Yes	Yes
Total PR items	11	9	11	11
Category: Environment & Water (EW)				
EW-1: Environmental Management System	1-2	0	1	2
EW-2: Stormwater Management Plus	2	0	0	0
EW-3: Native Landscaping	1	0	1	1
EW-4: Ecological Connectivity	1	0	0	0
EW-5: Reduce Light Pollution	1	0	0	0
EW-6: Life Cycle Cost Analysis of BMPs	1	0	1	1
EW-7: Habitat or Watershed Creation	2	0	0	0
Total EW points available	10	0	3	4
Category: Access & Equity (AE)				
AE-1: Safety Audit	1	0	0	1
AE-2: Intelligent Transportation Systems	2	2	2	2
AE-3: Promote Art & Culture	1	0	0	1
AE-4: Scenic Views	1	0	0	0
AE-5: Pedestrian Access	1	1	1	1
AE-6: Bicycle Access	1	1	1	1
AE-7: Americans with Disabilities Access	1	1	1	1
AE-8: Transit Access	1	1	1	1
Total AE points available	9	6	6	8

Category: Construction Activities (CA)				
CA-1: Quality Process Management	2	0	1	2
CA-2: On-Site Recycling & Trash Collection	1	0	1	1
CA-3: Track Water Use	1	0	1	1
CA-4: Reduce Fossil Fuel Use	1-2	0	0	1
CA-5: Reduce Equipment Emissions	1-2	1	1	2
CA-6: Reduce Paving Emissions	1	1	1	1
CA-7: Environmental/Safety Training	1	1	1	1
CA-8: Performance-Based Warranty	3	0	0	3
Total CA points available	13	3	6	13
Category: Materials & Resources (MR)				
MR-1: Enhanced LCA	2	0	0	2
MR-2: Native soil rehabilitation	1	0	0	0
MR-3: Pavement Reuse	2	2	2	2
MR-4: Recycled Content	1-4	1	2	4
MR-5: Regionally Provided Material	1-2	2	2	2
MR-6: Energy Efficiency	1	0	0	0
Total CA points available	12	5	5	10
Category: Pavement Technologies (PT)				
PT-1: Long Life Pavement	3	3	3	3
PT-2: Pavement Performance Monitoring	1	0	0	1
PT-3: Warm Mix Asphalt (WMA)	2	0	1	1
PT-4: Cool Pavement	1	0	0	1
PT-5: Permeable Pavement	1	0	0	0
PT-6: Quiet Pavement	3	0	0	0
Total PT points available	11	3	3	6
Category: Exemplary Performance (EP)				
EP-1: Exemplary Performance	1-6	0	1	3
EP-2: Professional Accountability	1	0	1	1
Total EP points available	7	0	2	4
Total Green Roads points available	62	17	25	45
Greenroads Certification Level		None	Certified	Evergreen

Notes:

- a. Done by the evaluator as part of a class project

A complete discussion of this case study can be found at:

http://pavementinteractive.org/index.php?title=Project:CEE597/CaseStudy/SP08/Group3/GreenRoads_Score. Comments on the credit review:

- The City of Seattle is fairly progressive in the area of sustainability. They have policies concerning the use of Low Impact Development (LID) techniques, a website for public comment, recommended plant lists for median plantings and bicycle friendly drainage grates.

- For this project and other overlay projects the City of Seattle looks to expand the scope slightly to include other roadway features not normally included in overlay projects (e.g., pedestrian improvements, bicycle-friendly channelization) as they feel they can achieve better bid prices than if these improvements were undertaken separately.
- If the reviewer was uncertain about whether or not a credit would have been obtained then no points were given. This applied to: PR-3, PR-7, EW-3, CA-2 and MR-2.
- As constructed, this project came close to certification. This was a result of the progressive City of Seattle views on sustainability.

The following observations were made based on the case studies:

- It is possible to rate a project using *Greenroads* using existing project data and standard agency policies.
- Some credits need refinement. As with specifications, credits need to be precise in their language and requirements to ensure consistent interpretation. Specifically, accounting methods for percentages of area, boundaries, and percentages of material need to be more precisely defined.
- Even simple overlay projects, like the case study, can obtain certification if they designed and constructed with sustainability in mind. Soderlund et al. (1) found that standard WSDOT projects tended to score low, which could be attributed to no explicit focus on sustainability. Even projects that feature sustainability components do not score well suggesting that a holistic project effort is needed to obtain certification (1).
- In the area of Construction Activities, a contractor could upgrade its fleet and institute a few general procedures and be able to achieve 4-8 points for every project on which they work.
- The potential additional cost associated with pursuing *Greenroads* certification needs to be investigated.
- Cases that involve more general corridor improvements must be studied. The chosen case study was just an expanded roadway resurfacing.

CONCLUSIONS AND RECOMMENDATIONS

This paper described a proposed standard for quantifying sustainable practices associated with roadway design and construction. Importantly, sustainability is defined as having three components: economic, environmental and social. A sustainable roadway is one that balances these three components and seeks the best outcomes for each.

Green Roads is a straightforward rating system that can help produce more sustainable roadways. It consists of 62 possible credits and 11 requirements in 7 categories. Roadways can be certified by achieving a minimum number of credits with more credits resulting in higher certification levels. In the next year *Greenroads* will likely undergo changes as it is presented for review and comment to interested potential stakeholders. *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 monitoring system for roadway sustainability. The expected benefits of *Greenroads* include:

1. Greater participation in roadway sustainability through the use of a straightforward and understandable system.
2. A means to assess roadway sustainability and make sensible sustainability tradeoffs through the use of a common metric.
3. Improved awareness of roadway sustainability through marketing.
4. Encouragement for sustainability innovation.

The City of Seattle case study combined with those of Soderlund et al. (1) provide insight into *Greenroads* and how it might influence roadway projects. Key observations are:

- It is possible to rate a project using existing project data.
- Some credits need refinement.
- Certification generally requires a focused approach to integrate sustainability into roadway design and construction.
- By changing basic practices, stakeholders can market their sustainability efforts.
- It is possible to obtain certification 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:

- Each credit needs to be developed in detail. This work is ongoing and should be done by early 2009.
- More case studies need to be done; especially those involving more than paving operations. To date, *Greenroads* impact on geometric design, traffic and social decisions is not well understood.
- The financial impacts of pursuing *Greenroads* certification need to be studied. The benefits and costs of certification should be clear to stakeholders.
- A pilot project needs to be done. An actual project where *Greenroads* standards are used in order to achieve certification would provide valuable information on the effort, initial cost and impact of a *Greenroads* project.
- *Greenroads* needs to be vetted by owner organizations and industry. This is scheduled to begin in 2009.

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

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