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Methodologies for Measuring Sustainability in the Construction of Transportation Infrastructure

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Abstract
Sustainability has become increasingly important to the public and to decision makers. Much of the attention given to sustainable construction has focused on buildings, with high profile LEED projects taking center stage. Although less visible to the public, sustainability is becoming increasingly important in other projects such as transportation infrastructure projects, which are very important to the public but generally have a much lower profile than vertical construction. Sustainable infrastructure construction will play an increasingly important role both in the U.S., where much of the infrastructure is in substandard condition and requires reconstruction, and worldwide, as countries such as China and India expand their infrastructure to meet the demands of a developing economy. The purpose of this paper is to provide an overview of sustainability rating systems for infrastructure construction, specifically airports and roadways, as well as provide insight into how sustainable construction practices can be supported by agencies and leveraged across transportation modes. Specific projects that highlight both proven and innovative sustainable practices are also included.

Keywords
Sustainable construction, transportation infrastructure, LEED, Envision, airports, roadways

1. Introduction

Increasing interest in sustainability has affected every industry and sector, including construction. Although most attention has focused on buildings, sustainable practices are also being employed in transportation infrastructure construction. The impact of increased sustainability in transportation infrastructure construction is significant. The US transportation construction market is strong and growing, with projections for $191.7B in 2015 (Ragone, 2014). Surface transportation and airports represent the majority of the transportation need, as shown in Figure 1 (American Society of Civil Engineers (ASCE), 2013), and will be the focus of this paper.

Worldwide, investments in transportation infrastructure are significant and growing. It is estimated that air passenger travel may double in 15 years, and air freight may triple in 20 years (Organisation for Economic Co-operation and Development, 2011), emphasizing the dramatic impact that infrastructure has on economic development. Globally, the United Nations has identified Sustainable Buildings and Construction as one of five initial programs prioritized for implementation (United Nations Environment Programme, 2014). The importance of sustainable construction is well placed: in 2015, $13.1B in terminal and runway construction are projected, and $96.2B is projected for roadways, bridges and tunnels (Ragone, 2014). Clearly, improvements to the sustainability of infrastructure construction practices can have dramatic impact.

Sustainability can be interpreted in a number of ways, and often includes a focus on both construction and operations. The triple bottom line approach suggests that a sustainable organization or project must be

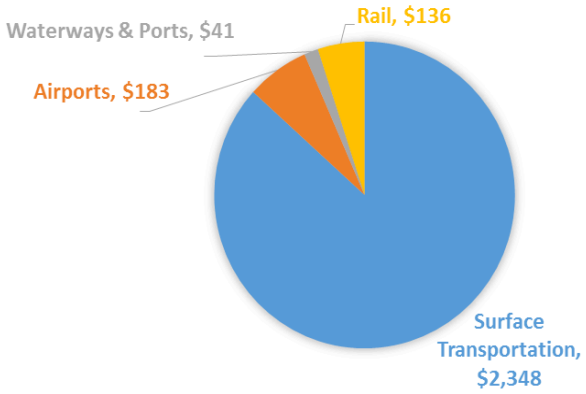

Figure 1. Estimated Annual Transportation Infrastructure Needs in the U.S. (ASCE, 2013)

financially secure, must minimize environmental impacts, and confirm with societal expectations (Elkington, 1994). Methods for assessing the sustainability of infrastructure investments include the internationally recognized LEED, Envision, GRI, and ISO rating systems. Rating systems specifically targeted to airports and surface transportation systems have also been developed. This paper provides an overview of these rating systems to provide a context for sustainability in infrastructure construction in the transportation sector.

2. LEED

Leadership in Energy and Environmental Design, more widely recognized by its acronym LEED, represents a design framework and certification process. LEED has expanded from one standard for new building construction to five rating systems and four levels of certification. The rating systems now encompass interior design, operations and maintenance, homes and neighborhood development in addition to construction. Certification levels include Certified, Silver, Gold and Platinum (best) based on a credit system. LEED certification or principles of LEED is often pursued for new airport terminal building construction; it has also been obtained for airport campuses (e.g., Indianapolis International Airport), as shown in Table 1. Although LEED Neighborhood Development does encompass infrastructure at the local level, the emphasis is primarily design rather than construction focused, with an emphasis on site location, design features, a community centered environment, multi-modal transportation and conservation. Credits directly affecting construction practices are minimal, and include required credits for Construction Activity Pollution Prevention, and optional credits for Historic Resource Preservation and Adaptive Reuse (2 credits), Minimized Site Disturbance (1 credit) and Recycled and Reused Infrastructure (1 credit), which collectively represent only a small fraction of the possible credits for the total project (4 of 110 credits). Costs include documentation and fees based on project size, with an estimated cost of 3 to 5 cents per sf of new construction ($30,000 to $50,000 for a $1M project) (US Green Building Council, 2014).

3. Envision

Whereas the focus of LEED is typically buildings, the focus of the Envision rating system is horizontal infrastructure. It was developed by the Instiute for Sustsainable Infrastructure and the Zofnass Program for Sustainable Infrasture at Harvard University, and quantifies credits in the categories quality of life, leadership, resource allocation, natural world and climate and risk. The Envision tools can be used at any project stage. As a relatively new tool, only five projects have earned Envision awards to date, none of which are for airports, bridges or roadways. At leat 300 other projects are using the Envision program as a tool, and 30 of these are expected to complete the verificaiton process. Envision recognizes five achievement levels: Improved, Enhanced, Superior, Conserving, and Restorative (optimal), and includes

Table 1. Sample Projects

Facility	Certification	Project	Notable Components
San Diego Airport (Green Building Elements, 2014)	LEED Platinum, 2014	460,000 sf expansion of terminal, 1.3 M sf apron and taxiway	• Energy efficient high performance glazed glass and natural lighting, efficient baggage management • Materials selection • Construction waste reduction (> 90% reduced waste) • Energy use monitoring for future operation
Indianapolis International Airport (Indianapolis Airport Authority, 2012)	LEED Certified, 2012	1.2 M sf campus including terminal, concourses, transportation center, parking garage	• Natural lighting, energy efficient HVAC, building controls and water fixtures • Recycling for construction material and terminal operations • Low impact construction including recycled and regional construction materials • Reduction in aircraft taxi times
Santa Barbara (Johns, 2013)	LEED Gold, 2013	72,000 sf included aircraft parking ramp, parking, and roadway and relocation and rehabilitation of terminal	• Recycled concrete and asphalt for new terminal road and parking lot • High efficiency water fixtures (30% reduction) • Bike racks and lockers for alternative transportation • Renewable energy photovoltaic system • Recycled materials for wood
I-69 Section 5 Bloomington (Indiana Department of Transportation, 2011)	Greenroads Registration Pending	Rehabilitation and upgrade of 21 miles of existing 4-lane roadway to interstate standard	• Avoid, minimize or mitigate impact on streams and wetlands; protection from contamination sites • Best management practices for erosion and sediment control • Respect cultural and historic features include bridges, cemeteries, buildings and districts • Protect wildlife and their habitats • Reduce noise impacts and minimize air quality impacts (including emissions and dust control)
Bagby Street Reconstruction Houston (Greenroads, 2014)	Greenroads Silver Certified, 2013	0.62 mi of reconstruction on a collector for $9.6M	• Cool pavement: reduce impact on air temperature due to pavement reflectance and minimize stormwater runoff temperatures by using porous pavement • Regional and recycled materials

both quantitative and qualitative assessments for credits. The Envision system is designed to cover all civil infrastructure including roads, bridges, airports, railways, dams, piplines, and parks. There is a fee for certification, based on the project size, ranging from $2,400 for a project less than $2M to $28,000 for a project up to $250M (non-member fee is higher). The rating system focuses on design, contruction and operation of the project to ensure continued sustainable operation throughout the life of the asset (Institute for Sustainable Infrastructure, n.d.).

4. GRI G4

Global Reporting Initiative, more commonly known by the acronym GRI, is an internationally recognized framework for sustainability reporting that was formed with the support of the United Nations. The first guidelines were published in 2000, and the current G4 guidelines provide a tool for organizations to articulate sustainability goals with stakeholders and quantify achievements (GRI, 2013). Additional guidance relevant for roads and airports includes the construction and real estate, as well as airport operators supplements. The construction and real estate sector encompasses buildings, as well as roads, tunnels, bridges and airports. Both the construction and airport operators supplements disclose

information related to economic (e.g., procurement practices), environmental (e.g., materials, energy, water, emissions, transport, noise), and social (e.g., labor practices, human rights, and society) considerations. Airport operators' information may be relevant not only for airport operators, but also for contractors who provide construction services on an on-going basis at airports for activities such as pavement maintenance. Due to the high standards and tight tolerances for runways, pavement maintenance is an on-going activity for many large airports. Although internationally airports are increasingly utilizing this reporting system, U.S. airports have been slower to do so. There are exceptions, however, the Indianapolis International Airport includes GRI indicators in the 2013 IAA Sustainability Report (White et al, 2013). The most recent compilation of top ten airports based on sustainability using the G4 guidelines included airports in New Zealand, Asia and Europe (Jordao, 2009).

5. ISO 14001

ISO 14000 provides an internationally recognized framework for the establishment and implementation of an environmental management system by the International Organization for Standardization (ISO). While ISO was originally founded in 1947, the environmental management system 140000 series was initiated in 1996 to set forth a framework for voluntary regulation rather than certification. The ISO 14000 series can be used for internal information, as well as to communicate an environmental commitment to the public, customers, and clients. ISO 14001 maps out a framework to improve resource efficiency, reduce waste, and control costs. Organizations set their own targets, and then use the tools provided by ISO 14001 to implement environmental control processes, perform monitoring, compare results with objectives to evaluate performance, and alter tactics to renew or modify plans and goals (ISO, n.d.). The number of construction firms that have implemented ISO 14001 is limited, largely because it is not always economically feasible, has not been demanded by clients, and has not been demonstrated to result in significant environmental benefits (Valdez and Chini, 2002); however, internationally, it has been recognized as a potential catalyst for improvement (Zeng et al, 2003).

6. Airport Sustainability Practices and Rating Systems

Top sustainable construction practices in the airport industry include reuse and recycling of construction aggregate and waste, energy efficient products, use of local materials, LEED certification, life-cycle analysis, anti-idling campaigns (e.g., Denver, O'Hare and Midway International Airports) and requirements for equipment, and minimizing site disturbance for erosion and stormwater control. Incentives for sustainable practices include cost considerations, compliance with local zoning, permitting and local government sustainability requirements. Possible impediments to sustainable practices include the need for compliance with strict Federal Aviation Administration (FAA) regulations. For example, warm-mix asphalt (WMA) requires a lower temperature than hot mix asphalt (HMA), saving fuel and reducing emissions. Although WMA was used in 2009 on a runway at Boston's Logan Airport, and in 2012 on a taxiway at O'Hare Airport, applications are limited since FAA does not have a specification for WMA. Some research indicates that WMA may have a lower lifespan, and a lower tolerance for high summer temperatures (Ricondo et al, 2011).

Material reuse includes recycled aggregate and vegetation. Although there are limits related to FAA specifications for runway and taxiway use of recycled materials, recycled aggregate can be used as backfill, and on the landside at airports. The FAA provides strict regulations regarding construction and standards on the airside of airports; the airside includes runways and other facilities for aircraft. There is much more latitude for utilization of recycled and alternative materials for construction on the landside of airports, which includes the terminals and facilities for passengers and ground access to the airport. In the $300M Terminal Improvement Program, Oakland International Airport established three on-airport sites to facilitate reuse of asphalt and concrete, and also vegetation and soil (Ricondo et al, 2011). It is estimated that over 500,000 cy of construction materials will be recycled in the next five years, saving $5M (Port of Oakland, n.d).

Both Chicago and Los Angeles have developed sustainability rating tools that are targeted for their airport infrastructure and are applicable for implementation by other airports.

Chicago Department of Aviation. The Chicago Department of Aviation (CDA) developed the *Sustainable Airport Manual* to support activities at both O'Hare and Midway airports, as well as for use by other airports (CDA, 2013). The manual covers administrative procedures, planning, design and construction, operations and maintenance, and concessions and tenants. A substantial portion of the manual is devoted to design and construction, and encompasses a range of topics including sustainable sites, materials, resources and construction practices, as shown in Table 2. The manual provides a comprehensive means for assessing sustainability using checklists and points to assess proposed plans and on-going progress toward organizational goals. Activities at O'Hare and Midway must comply with all the sustainability requirements of the City of Chicago, since the airports are owned by the city.

Table 2. Selected Construction Components in CDA *Sustainable Airport Manual*

Sustainable Sites	Materials and Resources	Construction Practices
Construction activity pollution prevention	Building and infrastructure reuse	Clean fuel and low-emission construction vehicles
Adopt CDA Best Management Practices (BMP)	Construction waste management	Construction equipment maintenance
Brownfield redevelopment	Balanced earthwork	Construction activity pollution prevention
Stormwater Design	Aggregate and material reuse	Construction waste management
	Recycled content	Construction material conveying
	Local/regional content	Construction noise
	Equipment salvage and reuse	Sustainable temporary construction materials

Los Angeles World Airports. Los Angeles World Airports (LAWA) developed the *Sustainable Airport Planning, Design and Construction Guidelines* (2010); this document is based on the triple bottom line approach (Elkington, 1994) and focuses on an economic, environmental and social framework for sustainability, as shown in Figure 2. The manual provides a point system for the categories Planning and Design and Construction to attain the three sustainable levels: Sustainable, Business Class and First Class (best). In addition to planning and design guidelines, there is a list of construction performance standards, a construction checklist, and a certification statement to support sustainable construction. Sample categories for the construction checklist include: project logistics, constractor sustainability, stormwater management and erosion control, construction water conservation, construction air quality, construction waste management construction vehicles and equipment, noise control, lighting, landscape maintenance, health & safety. An excerpt of the checklist is shown in Figure 3.

7. Surface Transportation Sustainability Practices and Rating Systems

The Green Highways Partnership (GHP), a public-private partnership to advance environmental sterwardship, provides a rating system for Greenroads. Every Greenroads project must meet certain requirements in order to be certified: environmental review process, lifecycle cost analysis, lifecycle inventory, quality control plan, noise mitigation plan, waste management plan, pollution prevention plan, low impact development, site maintenance plan, educational outreach plan. Eight Construction Activities are included as part of 37 voluntary or custom credits: quality management system (ISO 9001 for the general contractor), environmental training, site recycling plan, fossil fuel reduction (alternative fuels for construction equipment), equipment emissions reduction (EPA Teir 4 standards for non-road equipment), paving emissions reduction (pavers meet NIOSH requirements), water tracking, and contractor warranty.

Figure 2. Triple Bottom Line (LAWA, 2010)

Project Name: _____

☐ Draft Date: _____ ☐ Final (Please sign last page)

Yes	Maybe	No	Possible Points	Number	Performance Standard Title
Construction Indoor Air Quality					
			1	CN5-IA-1	Construction IAQ Management Plan - During Construction
			1	CN5-IA-2	Construction IAQ Management Plan - Before
			2		TOTAL
Construction Waste Management					
			1	CN6-WM-1	Recycle & Reuse of Constuction Materials
			1	CN6-WM-1	Recycle & Reuse of Constuction Materials
			2	CN6-WM-2	Salvage Materials & Resources
			4		TOTAL

Figure 3. Excerpt for LAWA Sustainable Airprot Checklist (LAWA, 2010)

The materials and resources custom credits also reflect many construction related activities and include life cycle assessment, pavement reuse, earthwork balance, recycled materials, regional materials and energy efficiency. Greenroads provides certification at four levels: bronze, silver, gold and evergreen (best); A-lined Assessment, which provides preliminary guidance; and Pilot Project designation, which provides a learning opportunity for the owner-agency and feedback to the Greenroads Foundation. Greenroads may be used for the rehabilitation of existing facilities or the construction of new roads (University of Washington et al, 2011). Over 120 projects are registered, including A-lined, certified and Pilot Projects. Fees vary based on project size and crediital desired; approximate example costs are $8,000 for a detailed pilot project, $4,000 for certification for a project $3M or less, and $35,000 for a $100M project) (Greenroads, n.d.).

The University of Washington and the Washington Department of Transportation were lead organizations for the developmenot of Greenroads. New York State Department of Transportation (NYSDOT) has also been a leader in the area of sustainability, with the development of the GreenLITE (Leadership in Transportation Environmental Sustainability) program, a self-certification program with four levels: certified, silver, gold and evergreen (best). One guiding principle of GreenLITES is to increase the awareness of sustainability, and the self-certification framework is flexible to accomodate local and regional priorities. It reflects five categories: sustainable sites, water quality, materials and resources, engery and atmosphere and innovation. Although the innovation category can encompass construction, there are limited structured categories related to construction, including avoiding trees and established vegetation, sound erosions and sediment control, designation of a qualified environmental construction monitor to oversee sensitive environmental areas, and seeding clear zones to reduce the need for future maintenance and increase carbon sequestration, reuse of trees, removal of contaminated soil beyond project requirements, and specification of local seed stock and plants (NYSDOT, n.d.).

Illinois Department of Transportation (IDOT) has developed a sustainability program called the Illinois-Livable and Sustainable Transportation rating system (I-LAST), a tool to evaluate the use of sustainable practices and the impact of these projects on the livability, sustainability and the environment. I-LAST is a scorecard for self-assessment that addresses 153 items in the areas of planning, design, environmental, water quality, transportation, lighting, materials, and innovation, and was developed in conjunction with Illinois builders and engineers associations (IDOT and Illinois Sustainability Group, 2012).

The impact of sustainability efforts can be substantial. In Illinois, it is estimated that the amount of recycled material in highway projects has increased fourfold in the four years from 2009 to 2013. One innovative total recycle asphalt process utilizes 97% recycled material, including recycled concrete and

slag for aggregate, recycled asphalt pavement (RAP) and shingles (RAS). The 3% new material is aspahlt binder. Another initiative is the replacement of cement with fly ash and blast furnace slag in concrete (Lippert et al, 2013).

Numerous agencies in other states also utilize recycled materials and sustainable practices such as WMA in roadway construction, not only for sustainability but also for cost considerations. As these practices become more widely used, they are included in standard specifications for state roadway construction. States are not only using a wider variety of recycled materials, but are also finding ways to increase the percent of recycled materials. As demonstration and early projects mature, the longevity of construction methods can be more accurately evaluated. The Federal Highway Administration (FHWA) continues to monitor high RAP projects in a number of states, which allows assessment not only over time, but also over a range of weathering conditions since the projects tracked are in multiple states. Since FHWA provides funding (and associated constraints) for both state and local projects, their guidance and support for sustainable practices is critical. The three key elements that must be satisfied from FHWA's perspective are that recycling be cost effective, environmentally responsible, and provide adequate performance (FHWA, 2014).

5. Discussion

The most successful sustainability initiatives are cost effective in addition to reducing negative environmental impacts. In these cases, sustainable practices often become the de facto design standard and are written into standard construction specifications (e.g., Iowa DOT, 2010, Ohio DOT, 2014). Sustainability is also supported by an increased focus at the federal level on asset management and life cycle cost analysis. Perhaps the most notable impact of sustainability practice is the synergistic effect that occurs when agencies take a leadership role in sustainability. For example, the sustainability efforts at the state level in Illinois, Washington State and New York State have created a framework that supports local efforts to implement sustainability. Many local agencies utilize state specifications, both for convenience and to assure eligibility for state funded local projects. As a result, incorporating sustainable practices at the state level can have a multiplier effect. For example, once a plant is set up for the use of RAS, it will continue to use mixes that utilize RAS, and local agency projects may use as much or more than state projects (Lippert, et al, 2014). The resulting multiplier effect can be dramatic since there are approximately four times as many miles of local roads as state roads in the U.S. (US Census, 2008).

In another example of multi-agency and multi-modal synergy, the implementation of WMA on taxiways in the O'Hare modernization project was supported by research conducted at the University of Illinois, in support of sustainability research funded by IDOT. Without the support of IDOT and the University of Illinois, O'Hare may not have been the first airport in the Great Lakes Region (and among the first in the US) to utilize WMA on a new taxiway (Ande, 2012). The synergistic effect of sustainability is also seen in a multimodal context at O'Hare. Because there are limitations regarding the use RAP in runway pavements, there is substantial RAP available when runways are reconstructed. In Chicago, the excess RAP is utilized in nearby roadway projects that do not have RAP limitations associated with them. In this case, although the RAP is not utilized on site, transportation costs are minimized by using it locally and regionally.

6. Conclusion

The construction, maintenance, and operation of transportation infrastructure has significant environmental impacts. This paper presents a number of tools that can be used to assess sustainability in the construction of transportation infrastructure and provides examples of projects that have incorporated sustainability. As society becomes increasingly interested in sustainability, and as technologies make sustainable practices more viable, sustainable construction practices will be increasingly incorporated into

projects and standard specifications for infrastructure. There are examples that demonstrate the excellent opportunities for increasing sustainability through multi-agency and multi-modal collaboration.

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