Where are the Sustainable Bridges in the United States?

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ABSTRACT: This paper investigates what sustainable bridge design is and is not and describes the need for a national sustainable bridge design standard. Issues discussed include quantifying specific sustainable metrics and the potential benefits of pursuing sustainable bridge design. A concept rating method is proposed which will not only garner community awareness and support for such projects but also provide an ability to capture funds earmarked for sustainable capital improvement projects. A realistic evaluation will be given of the current state of sustainable bridge design in the United States as well as a roadmap for moving forward.

1 INTRODUCTION

1.1 *Public Consciousness*

When used, the term "Sustainable Bridges" tends in the public and the professional's mind to conjure up images of picturesque glue laminated structures blending in harmoniously with their surroundings deep in a national park type setting. While beautiful and grand, the concept would seem to have very little applicability to real word problems faced by either the bridge owner or bridge professional.

As we will show, in reality such notions and images are off the mark. Sustainable design as an overarching concept is now well entrenched and has proved its worth in the building and planning industry, and is starting now to make inroads in both the civil and structural fields. It is then only natural that the ideas embedded in this concept would start to impact both the philosophy and day-to-day business of bridge design, ownership and maintenance for structures of virtually all shape and size.

1.2 *Encapsulating Sustainable Bridge Design*

Sustainable Design is commonly defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland Commission, 1987). Extrapolating from this basic definition, a sustainable engineering project such as a bridge can be defined as one that is conceived, designed, constructed, operated, maintained, and eventually put out of service in such a fashion that these activities demand as little as possible from the natural, material and energy resources of the surrounding supporting community.

In practice, sustainable bridge design is not about strictly environmental concerns, or about energy conservation. Instead, it is a more holistic, top to bottom review and evaluation of a bridge project's merit and compatibility with both the local human and natural populations on both the micro and macro scale. Further, it is a useful tool to quantify and determine the true value of even indirect or unintended deterioration done to our environment, society and the community at large.

To see this, consider the typical bridge designer. Assume that a single engineer is performing all of the required duties necessary to design a fairly typical collector crossing over a waterway. A partial list of the responsibilities necessary to complete this task might include the following:

Table 1. Typical Bridge Design "Hats"

Task	Phase
Feasibility Study	Planning
Siting	Planning
Type Study	Planning
Geometric Design	Design
Hydraulic Analysis	Design
Structural Design	Design
Cost Estimate	Design
Materials Testing	Construction
Shop Drawing Review	Construction

Each of the items in the lists above is referred to as a "hat" because the single engineer cited responsible for each of these tasks dons the hat somewhat independently from the others. For example, the geometric design of a bridge naturally has some bearing on the final structural design. But, during the traditional design process, the engineer performing the design typically dons her highway design hat

to layout the geometry for a new structure, then dons a different structural engineering hat to ensure that the bridge is adequately reinforced. Each of the hats can be thought of as occurring at finite, discreet moments during the planning, design, and construction phases. This concept can also be brought to bear to bad effect when each of the tasks above is performed by different engineers who aren't regularly communicating!

Sustainable bridge design, when using the supplied definition and applied to the above case, is not another hat to be donned. This is because sustainable design is not an individual task to be performed at a discreet point in the bridge design process. In order to produce a project that is truly sustainable throughout the structure's life, each of the tasks above need to be considered from a sustainable standpoint. For instance, when siting the bridge, is it better to place it within wetlands or in the dry? When performing hydraulic analysis, how will the constriction and reduced hydraulic opening caused by this structure impact the upstream and downstream ecosystems? During the construction phase, where did the materials used in the structure come from, and are they being used to their greatest effect?

In order to meet the burden of our definition of sustainable design, what is required is not a new hat, but a new pair of glasses to look at each project step. In order to deliver a truly sustainable bridge, sustainable goals need to be considered and accounted for throughout almost every phase of the planning, design, and construction process.

2 QUANTIFYING SUSTAINABLE BRIDGE DESIGN

2.1 *Establishing metrics*

With a useful definition applied to the concept, the next logical question becomes how is a sustainable bridge project's goals measured and quantified?

In the United States, there is currently no national standard for the measurement or ranking of sustainable bridges like the U.S. Green Building Council's benchmark LEED® standard for buildings. However, looking at that standard, it may be possible to extract from it some useful metrics to help in the measurement of bridges.

The LEED guidelines break down each sustainable design goal into one of 5 overarching categories (U.S. Green Building Council, 2006). For comparison's sake, each of these goals will be matched with a comparable bridge design metric:

Table 2. LEED Design Goals vs. Sustainable Bridges

LEED Design Goals	Equivalent Bridge Design Goal
Sustainable Sites	Sustainable Sites
Water Efficiency	Water Efficiency
Energy and Atmosphere	Energy and Transportation
Materials and Resources	Materials and Resources
Indoor Environmental Quality	N/A
Innovation in Design	Innovation in Design

Historically, each of these larger LEED categories includes sub goals, each of which is worth one or more available points. After tallying the points earned on a project, certifications goals such as certified, silver, gold and platinum are achieved at their respective point plateaus.

A similar system could be extended to include a standardized metric for bridge sustainability. As noted previously, any useful metric should include points that cover aspects of the entire bridge lifecycle. Out of the goals listed above, only the LEED category of Indoor Environmental Quality, which is concerned with indoor pollutants, seems to have no corresponding equal in a sustainable bridge metric.

Each of these potential sustainable bridge categories will now be described in detail.

2.2 *Sustainable Sites*

The hallmark of a sustainable site is – is this the right location for this structure? Will the placement of the bridge at this location have a large negative impact to the people that use it, and to the environment it spans over? Are the construction methods employed to the benefit of the larger community? Points in a possible sustainable site category could include the following considerations:

Table 3. Potential Sustainable Bridge Site Points

Does the site employ available best practices in sedimentation and erosion control?
Does the bridge connect two well-established existing developments, or is it a bridge to "nowhere"?
Does the proposed structure add to the economic and social value of the two bodies it connects?
Does the bridge disturb a greenfield, wetland or farmland?
Does the bridge replace or improve an existing structure or is it a new structure?
Are the footings and piers required, and how does their placement impact the surrounding environment?
Can a bridge in one location replace several smaller bridges in disparate locations?
Are there available animal crossings over/under the structure appropriate for indigenous species?

2.3 *Water Efficiency*

A water efficiency category is used to control the quality and quantity of water used both to construct and that runs off the structure after its installation. Potential points could be awarded for the following:

Table 4. Potential Sustainable Bridge Water Efficiency Points

For water crossings, how does the hydraulic opening impact the flood performance up and down stream?
Was non-potable water used during the construction process? How much?

What systems are in place to ensure that runoff off the bridge is minimized (grass swales along the curb, etc.)?
What systems are in place to ensure runoff off the structure is of high quality?

2.4 *Energy and Transportation*

It has been noted that transportation represents 10 percent of the world's gross domestic product, is responsible for 22 percent of global energy consumption and 25 percent of fossil fuel burning across the world (Center for Environmental Excellence by AASHTO, 2009). The proposed purpose of an energy and transportation credit is to ensure that the structure is designed and constructed to minimize the energy and transportation needs of the surrounding community.

Table 5. Potential Sustainable Bridge Energy and Transportation Points

Is the bridge equipped with remote health monitoring sensors to reduce the need or frequency of hands-on inspections?
Can on site generation sustain the bridge's own electrical needs?
Are the bridge electrical components energy efficient?
Is the bridge equipped with an HOV/HEF (High Efficiency Vehicle) lane?
For toll roads or signature structures, is the bridge equipped with automated toll taking/changeable message signs/traffic queuing features?
Does the bridge include sidewalks and/or bicycle lanes?

2.5 *Materials and Resources*

A material and resource category ensures that the choice in bridge materials are appropriate for the site and the future maintenance and recycling of the structure.

Table 6. Potential Sustainable Material and Resource Points

Are the materials used in the structure recycled?
If rehabilitated, are the materials from the old structure reused in the new?
If rehabilitated, how much of the original structure is utilized in the new design (abutment stems, piers, etc)?
Are materials regionally available or brought in from long distances?
Are new materials or processes utilized that reduce the overall quantity demands for the structure?
Are otherwise landfilled materials used in the bridge construction (i.e. – fly ash or slag in concrete mix)?
Is the bridge designed with a complete Life Cycle Analysis in place?
Is the wood used on the jobsite from the Forest Stewardship Council (FSC) or other approved logging operations?

2.6 *Innovation in Design*

The innovation in design credit is an opportunity for designers and contractors to show their creative thinking for a given project. Points here can be awarded for original, documentable concepts in education, maintenance, new technology, or other pertinent features.

2.7 *Other Sustainable Bridge Metrics*

It is worth noting that other both academic and working sustainable bridge metrics are included in the other reading section of the references.

3 POTENTIAL BENEFITS OF SUSTAINABLE BRIDGES

3.1 *Hard benefits*

After sustainable bridges have been defined and quantified, the inevitable question then becomes what are the tangible benefits for investing the extra layer of effort and resources into such a project?

Hard evidence for the benefits of this type of design is an area that requires more real world examples and academic and field study. However, from the above metrics, a list of proposed benefits for this type of design could include the following:

Table 7. Potential Sustainable Bridge Design Benefits

Bridges that utilize fewer raw materials on the jobsite
Bridges that utilize less time and energy to construct
Bridges that funnel materials away from overcrowded landfills.
Bridges that meet their own electrical needs
Bridges that help deal with the coming needs of 21st century travel of faster and more efficient transportation
Bridges that encourage alternate modes of transportation
Further funneling of federal research dollars into bridge design and materials
Bridges that produce fewer upstream and downstream impacts to both the natural and developed communities
Sustainable bridge designs through its encapsulated thought process could help streamline the permitting process
Bridges that are able to monitor their own health and alert owners to critical conditions
Bridges that better enhance the social and economic communities and tie established neighborhoods together

3.2 *Soft and financial benefits*

The potential soft benefits of a sustainable bridge also should not be overlooked. Despite the down economy, given the current administration goals and popular media, public interest in all things green has garnered enough attention to warrant its own Green Confidence Index in 2009.

This interest can be used to potentially great effect. If available, the quantified label of "sustainable" can be used to gain greater attention and funding from sources ranging from the local to the national stage. The label of sustainable could be a strong selling point with local authorities, planning and zoning boards and media outlets. Funding for sustainable bridge pilot projects could be earned from such unusual sources such as local university grants and partnerships, the US EPA or the Department of Energy. The latter of these currently has a grant program for the investigation of and implementation of sustainable facilities and infrastructure

with topics as varied as lowering energy use and costs to investigating a potential project's Life Cycle Analysis. These funds could be used in conjunction with the typical transportation related funding sources such as FHWA, FTA and affiliated state and local resources. With today's budget shortfalls, sustainable funding sources could offer some relief.

4 CURRENT STATE OF SUSTAINABLE BRIDGES IN THE UNITED STATES

4.1 *Overview*

As has been noted, there currently is no national standard for quantifying sustainable bridges in the Unites States. The number of bridges conceived and branded with "sustainable" labels as of the time of this writing is minimal.

One factor for the lack of more bridges designed with sustainable goals is the noticeable gap in the lack of a national standard. With no reliable national standard or best practices established, it is hard to distinguish between a conventional and sustainable design and no way to elevate one project's features over another's. Of the bridges that have been built, it is hard to distinguish many of these bridge's claims to the label of "sustainable" or even to the more nebulous label of "green" as the lack of an agreed upon standard allows even the installation of just one pertinent feature to title the entire crossing.

Sustainable design is a modern day topic that requires academic study, modeling, and thought to move forward in a meaningful way. This field of research should be applied to supplying hard data to the following currently unanswered questions:

Table 7. Fields of Study in Sustainable Bridge Projects

What are the performance benefits or detriments of a sustainable bridge versus a traditional one?
What is the cost premium of a sustainable bridge / sustainable bridge component? What are the economic incentives?
What new or proposed materials are available to contribute gainfully to a sustainable bridge product?
What impact do these metrics have on the actual sustainability of a bridge crossing?

In the United States, the national leader and organizing force in unifying and enforcing such a national standard should be AASHTO. Since many of the concepts presented here go beyond what it considered in the traditional design context, a separate sustainable guide would be appropriate with supplements back into the standard design, maintenance and rating guidelines currently available. AASHTO would also be the ideal conduit to roll out a sustainable bridge design guide as a piece of a national sustainable transportation standard.

A national standard could also serve to regulate the now wild west feel of the sustainable materials marketplace. Currently, with no oversight, a new material vendor or process can apply labels at will with little or no tangible benefits available. If a bridge owner or bridge designer knows that a given product has a direct impact on a given sustainable metric, the material vendor has a much more legitimate claim on these labels.

4.2 *Conclusions*

It is time for the more insular world of bridge engineering and maintenance to join the growing numbers of professionals from all trades that are realizing the power and purpose of sustainable design. Not to be confined just to the building industry or the "green fringe," bridge professionals involved with all aspects of the typical bridge lifecycle can benefit from a national, standardized set of sustainable bridge metrics. Further study and research of both national and international standards will be required to solidly establish the end value and proper weighting of any standard set of proposed metrics. In the meantime, the metrics proposed in this paper and elsewhere can be used as a launching point for potential pilot projects to facilitate further study in this emerging transportation field.

5 REFERENCES

Brundtland Commission. 1987. *Our Common Future*, Report by the Brundtland Commission. Oxford University Press

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Center for Environmental Excellence by AASHOTO. 2009. *Sustainability.* Web. http://environment.transportation.org/environmental_issues/sustainability/

5.1 *Other Reading*

Other sources with both academic and applied sustainable metrics include the following:

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