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Developing a Rating Metric for Sustainable Bridges | 8

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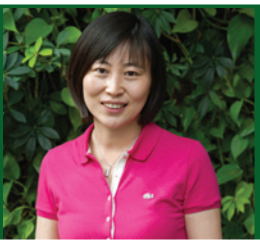

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Sustainability is recognized as one of the key issues in design, construction and life-long maintenance of structures. Transportation accounts for 10 percent of the world's gross domestic product, and consumes 22 percent of global energy and 25 percent of fossil fuel. As sustainability has asserted itself in the public's eye, bridge professionals have rushed to develop criteria for the design and construction of sustainable bridges. The three main categories that define and distinguish sustainable bridges are: lower energy input, increased durability, and simplified deconstruction. A sustainable bridge is the one that "is conceived, designed, constructed, operated, maintained, and 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 community."[5] Currently, there is no national standard for the measurement of sustainable bridges in the United States. Without a reliable standard, it is difficult to distinguish between a conventional design and sustainable design, and it is hard to promote any sustainable features in bridge design by the claims to the label of "green" or "sustainable." It is important to develop a rating system with a meaningful, measurable, and cost-effective metric to define sustainable bridges.

The U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) Green Building Rating System is the nationally accepted benchmark for the design, construction, and operation of high performance green buildings. LEED describes a common standard of measurement for sustainable buildings and defines rating systems for new construction, existing buildings, commercial interiors, core and shell projects, homes and neighborhood development[3] [4]. However, LEED does not include structures other than buildings. LEED's approach could be applicable to bridge design and construction, and it is possible to use a similar metric to measure bridges.

Highway Bridge over Waterway

Pedestrian Bridge over Highway

Highway Bridge over Valley

The LEED guidelines define sustainable buildings in five categories, and a comparable bridge metric according to these five categories is shown in Table 1.

Table 1: LEED Design Measurements vs. Sustainable Bridge

LEED Design	*Equivalent Bridge Design*
Location	Location
Water Efficiency	Water Use and Quality
Energy Use	Energy and Transportation
Materials and Resources	Materials and Resources
Indoor Climate	N/A

It is important to develop a useful framework to quantify sustainable bridges. More academic study, modeling and testing are needed in this emerging research area. Solid data should be obtained to answer the following important yet unanswered questions[1, 2, 5]:

- What is the sustainable bridge metric? The bridge metric should be meaningful and have a direct, positive environmental impact.
- How can the metric be measured? One of the challenges of developing the sustainable bridge metric is that the metric must be quantifiable based on qualitative concepts.
- What are the new materials available to be adopted in the sustainable bridge product or component?
- What are the critical components of sustainable bridges?
- How do technological innovations affect sustainable bridge design?

According to the equivalent measurements listed in Table 1, the potential critical components of sustainable bridges are listed in Table 2. The critical components may be identified based on environmental studies and assessment.

Table 2: Potential Critical Component of Sustainable Bridges

Sustainable Bridge Design Goal	*Critical Component*
Location	• Erosion and sedimentation control • Connection between two well-established developments • Economic and social value of the connected bodies • Preservation of greenfield, wetland, and/or farmland • Minimization of traffic delays • Existing bridge replacement or new bridge construction • Impact of footing and pier location • Reduction of traveling miles between the neighborhoods the bridge connects
Water Use and Quality	• Stormwater management • Impact of bridge on the flood performance • Non-potable water use during construction • Minimization of runoff from the bridge • Quality of runoff • Discharge location of runoff • Reduction of the need for treated water
Energy and Transportation	• Use of alternative transportation via High Occupancy Vehicles (HOVs) and transit • Consideration of future widening to add capacity • Installation of remote health monitoring system to reduce hands-on inspections • Use of Accelerated Bridge Construction to minimize construction time and energy consumption • Use of energy efficient electrical components on the bridge • Use of automated toll taking device to reduce traffic delay for toll roads • Sidewalks and bicycle lanes • Facilities to promote mass transit
Materials and Resources	• Use of recycled materials in the bridge • Use of easy recyclable materials in the structure • Reuse of material from old structures for rehabilitation • Use of local materials to reduce transportation • Use of high strength materials to reduce the total amount of materials • Use of industrial waste in bridge construction, such as fly ash, slag and etc. • Complete life cycle analysis

The other factors involved in bridge design and construction may include pollution, Carbon Dioxide emission, construction waste, biodiversity, re-usable structures, quality control, long-term performance monitoring, easy maintenance and social priorities etc. Among the difficulties in defining sustainable bridges is measuring and quantifying design goals. In order to make the sustainable bridge metric meaningful, a rating system needs to be developed with a proper weighting factor to each critical component, and a reference table may be set up to rank the bridge's level of sustainability according to the total points. The magnitude of the weight factor may be determined by the equivalent energy consumption. The total equivalent energy may be computed to provide an accurate, measurable approach to quantify the weighting factor, and thus the sustainable bridge metric.

There are many potential approaches to minimizing the non-renewable energy use during the bridge design and construction process. Because nearly all of the energy input for a bridge occurs during the initial construction, it is important to find new and novel methods of bridge design. Innovative design and construction methods may reduce traffic delays and on-site equipment use. Such design and construction methods will ultimately reduce labor, fuel costs, traveling time, construction waste, worker exposure to unhealthy emissions and so on. The innovative design and construction methods include adaptive design, structure reuse, rational phased construction, rapid construction, pre-fabrication, accelerated bridge construction, and innovative connections for simple deconstruction. Design strategies are being sought to facilitate structure rehabilitations due to natural disasters, climate change and human activities. These strategies should provide the flexibility to accommodate future changes caused by load capacity, deck geometry, pedestrian traffic and transit service.

Transportation is of crucial importance to economic growth. It is important to design bridges with high levels of sustainability to add to their durability with optimal use of resources and minimal disruption of the surrounding environment. It is time for the bridge engineering field to realize the great potential of sustainable design and build a framework to define and quantify sustainable bridges.

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