# TABLE OF CONTENTS ~ SUSTAINABLE BRIDGE DESIGN

2 Sustainability
2.1 Overview
2.1.1 Definition
2.1.2 Sustainability goals
2.1.3 Sustainability assessment tools
2.1.4 Water use and quality
2.1.5 Materials and resources
2.1.6 Potential benefits
2.2 Context sensitive design
2.2.1 Core principles of context sensitive solutions
2.3 Visualization
2.3.1 Uses and benefits of visualization
2.3.2 Visualization case studies
2.4 Bridge preservation
2.4.1 Introduction

# 2 Sustainability

## 2.1 Overview

The Bridges and Structures Bureau (BSB) follows established Iowa Department of Transportation (Iowa DOT) guidelines, in providing, promoting and using sustainable practices. The Iowa DOT has always been at the forefront of sustainable design and maintenance practices.

The use of these materials is intended as a policy guide for projects developed for the Iowa Department of Transportation, Bridges and Structures Bureau.

### 2.1.1 Definition

The United Nations World Commission on Environment and Development (WCED) in its 1987 report Our Common Future defined sustainable development as: ***"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs."***

The Federal Highway Administration (FHWA), which is actively promoting sustainability through their **Invest** – ***Sustainable Highways Initiative*** *(www.sustainablehighways.org)*, has the following mission statement:

> ***"The Sustainable Highways Initiative supports programs and activities conducted across the Federal Highway Administration to facilitate balanced decision making among environmental, economic, and social values — the triple bottom line of sustainability."***

Essentially, ***sustainability means balancing economic, environmental and community well-being in a manner that protects the needs of current and future generations.*** A sustainable transportation system provides people with vibrant transportation choices, while addressing environmental and community needs.

Sustainability is a concept that takes into account the long view of projects, considering costs and benefits over lifetimes rather than concentrating on a one or two year cost life cycle. Incorporating sustainability into decision-making can have positive effects for stakeholder relations, for the bottom line, and for the natural resources of the state.

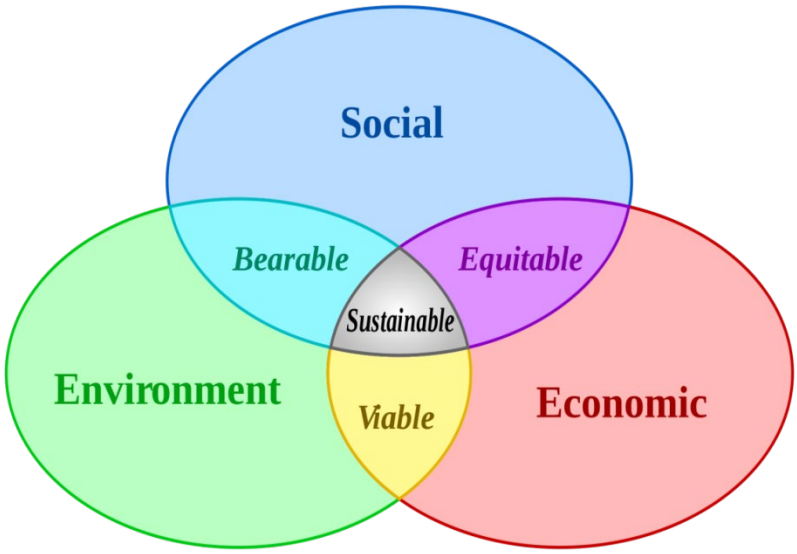


**Figure 2.1.1 Sustainable values**

Sustainable bridge design is concerned with questions, such as:

- 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?
- Will the bridge be constructed in such a fashion as to minimize delays to the general public?
- Does the bridge replace or improve an existing structure or is it a new structure?
- Are footings and piers required, and how does their placement impact the surrounding environment?
- Can a bridge in one location replace several smaller, possibly less functional bridges in disparate locations?

Additional State DOT Resources:

- Washington State Department of Transportation – Sustainable Transportation
- Minnesota Department of Transportation – Sustainability
- Oregon Department of transportation – Sustainability program
- Ohio Department of Transportation – Sustainable Initiatives
- New York State Department of Transportation - GreenLITES
- Colorado Department of Transportation – Sustainability
- Virginia Department of Transportation – Sustainable Building Practices
- North Carolina Department of transportation – Statewide Transportation Plan
- Iowa Department of Transportation - Sustainability & Resiliency

### 2.1.2 Sustainability goals

The goals of providing sustainable features in the design and construction of bridge projects are to:

- Minimize impacts to environmental resources
- Minimize consumption of material resources
- Minimize energy consumption
- Preserve or enhance the historic, scenic and aesthetic context of a bridge project
- Integrate bridge projects into the community in a way that helps to preserve and enhance community life
- Encourage community involvement in the transportation planning process
- Encourage integration of non-motorized means of transportation into a highway project

Sustainable bridge design should strive to find a balance between what is important:

- to the transportation function of the facility
- to the community
- to the natural environment, and is economically sound

While encouraging the use of new and innovative approaches in achieving these goals.

### 2.1.3 Sustainability assessment tools

Sustainable infrastructure is one of the keys to maintaining a thriving economic base in communities throughout the state.

Sustainable bridge design is concerned with new bridges but it is also about rehabilitation, reuse or the optimization of existing bridges.

This includes an economic analysis, the protection of existing bridges from environmental degradation, use of sustainable materials, minimizing waste and developing new strategies to improve the bridge design/construction process.

The main sustainability assessment tools for bridges are:

- **Economic** – cost/benefit analysis, modelling, regressions, scenarios
- **Environmental** – life-cycle analysis, material flows, resource accounting
- **Social** – sustainable livelihoods, human and social capital measurement, participatory processes

Infrastructure Rating Systems

Currently a number of programs, similar to the Leadership in Energy and Environmental Design (LEED) rating system for building have been developed for infrastructure.

The Federal Highway Administration, has developed the INVEST rating system.

> *"INVEST includes a collection of sustainability best practices, called criteria, intended to help transportation practitioners evaluate programs and projects in the area of sustainability. The goals of INVEST include identifying these criteria, assisting agencies in researching and applying the criteria, and establishing an evaluation method to measure the progress toward more sustainable highway projects."* (https://www.sustainablehighways.org)

The Illinois Department of Transportation has developed the I-LAST - Livable and Sustainable Transportation Rating System and Guide (https://idot.illinois.gov/content/dam/soi/en/web/idot/documents/transportation-system/reports/desenv/i-last-v-2-02.pdf)

From I-LAST:

> *The purpose of this guide is threefold:*
>
> - *Provide a list of practices that have the potential to bring sustainable results to highway projects.*
> - *Develop a simple and efficient method of evaluating transportation projects with respect to livability, sustainability, and effect on the natural environment.*
> - *Record and recognize the use of sustainable practices in the transportation industry.*

The American Society of Civil Engineers (ASCE) has developed a new rating system, similar to LEED, for infrastructure, Called ENVISION. (http://www.sustainableinfrastructure.org)

> *"**Envision**™ provides a holistic framework for evaluating and rating the community, environmental, and economic benefits of all types and sizes of infrastructure projects. It evaluates, grades, and gives recognition to infrastructure projects that use transformational, collaborative approaches to assess the sustainability indicators over the course of the project's life cycle."*

### 2.1.4 Water use and quality

The quality and quantity of water used in construction and that which runs off the structure after its installation should be considered:

- For water crossings, how does the proposed hydraulic opening impact the flood performance upstream and downstream?
- Was non-potable water used during the construction process? How much?
- What systems are in place to ensure that runoff from the bridge is minimized (grass swales along the curb, etc.)?
- What systems are in place to ensure runoff from the structure is of high quality?
- Where is the runoff from the bridge discharged?

(Sustainable Structures for the Bridge Engineer – Daniel Whittemore, P.E., LEED AP)

### 2.1.5 Materials and resources

Thinking about materials and resources ensures that the choice in bridge materials is appropriate for the site and the future maintenance and recycling of the structure.

Sustainable Material and Resource questions include:

- Are recycled materials used in the structure?
- Can the materials used in the structure be 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 mixes)?
- Is the bridge designed with a complete Life Cycle Analysis in place?

(Sustainable Structures for the Bridge Engineer – Daniel Whittemore, P.E., LEED AP)

### 2.1.6 Potential benefits

After sustainable bridges have been suitably 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 bridge design is an area that requires more real world examples, and both academic and field studies as have been done previously for buildings. However, from the above metrics, a list of proposed benefits for this type of design could include the following:

- 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 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 leading edge bridge design and materials
- Bridges that produce fewer upstream and downstream negative impacts to both the natural and developed communities
- Bridges that due to their certification could 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
- Bridges that are better planned and thought out with engineering judgment that can ultimately better serve the public

(Sustainable Structures for the Bridge Engineer – Daniel Whittemore, P.E., LEED AP)

## 2.2 Context sensitive design

The context sensitive solutions (CSS) approach is to combine the work of interdisciplinary teams with public and agency stakeholders to tailor solutions to the setting; preserve scenic, aesthetic, historic, and environmental resources; and maintain safety and mobility.

(https://www.fhwa.dot.gov/planning/css/index.cfm)

The goal of FHWA's CSS program is to deliver a program of transportation projects that is responsive to the unique character of the communities it serves.

In short, CSS supports livable communities and sustainable transportation.

### 2.2.1 Core principles of context sensitive solutions

These core CSS principles apply to transportation processes, outcomes, and decision-making.

1. Strive towards a shared stakeholder vision to provide a basis for decisions.
2. Demonstrate a comprehensive understanding of contexts.
3. Foster continuing communication and collaboration to achieve consensus.
4. Exercise flexibility and creativity to shape effective transportation solutions, while preserving and enhancing community and natural environments.

- Results of Joint AASHTO/FHWA Context Sensitive Solutions Strategic Planning Process Summary Report, March 2007

Context sensitive solutions is guided by a process which:

- Establishes an interdisciplinary team early, including a full range of stakeholders, with skills based on the needs of the transportation activity.
- Seeks to understand the landscape, the community, valued resources, and the role of all appropriate modes of transportation in each unique context before developing engineering solutions.
- Communicates early and continuously with all stakeholders in an open, honest, and respectful manner, and tailors public involvement to the context and phase.
- Utilizes a clearly defined decision-making process.
- Tracks and honors commitments through the life cycle of projects.
- Involves a full range of stakeholders (including transportation officials) in all phases of a transportation program.
- Clearly defines the purpose and seeks consensus on the shared stakeholder vision and scope of projects and activities, while incorporating transportation, community, and environmental elements.
- Secures commitments to the process from local leaders.
- Tailors the transportation development process to the circumstances and uses a process that examines multiple alternatives, including all appropriate modes of transportation, and results in consensus.
- Encourages agency and stakeholder participants to jointly monitor how well the agreed-upon process is working, to improve it as needed, and when completed, to identify any lessons learned.
- Encourages mutually supportive and coordinated multimodal transportation and land-use decisions.
- Draws upon a full range of communication and visualization tools to better inform stakeholders, encourage dialogue, and increase credibility of the process.

- Results of Joint AASHTO/FHWA Context Sensitive Solutions Strategic Planning Process Summary Report, March 2007

## 2.3 Visualization

The Visualization techniques provide valuable insights into design options which typically lead to better context sensitive solutions. Techniques from hand drawings to 3D animations are useful in explaining project requirements, location challenges, staging procedures and help the public understand the intent and impact of a construction project.

Resources:

Federal High Administration – Visualization in Planning
American Association of State Highway and Transportation Officials - Visualization in Transportation
Washington State Department of Transportation – Visual Engineering Resource Group

### 2.3.1 Uses and benefits of visualization

Visualization has a large number of uses, such as:

- Concept visualization which gives end users a realistic overview of the project parameters.
- Conflict visualization can show designers where complex project systems interact and help reduce construction errors in the office and the field.

- Building Information Modeling (BIM) or Bridge Information Modeling (BRIM) allows users to coordinate, simulate and communicate projects between designers in 3D.

**Benefits** (From AASHTO – Visualization in Transportation)

*With such a wide range of capabilities and techniques possible, visualization provides the design team (i.e., transportation staff, advisory groups, community leaders, and environmental resource agencies) with a valuable resource. The design team can review the visualization to ensure that they are in consensus with the improvement as planned. This is a valuable check in determining if the proposed improvement the design team anticipated is what is being provided.*

*Once consensus has been reached, the information can be shared with the public to convey, in an understandable way, what the improvement alternative entails. A typical public involvement workshop is shown in Figure 11. Consensus for the project can be sought and obtained, and the proposed improvement can proceed through design to construction. Visualization can contribute to significant time savings throughout this process.*

*Visualizations that are accepted by project stakeholders, the public, and those living and working adjacent to the project can also be effective in conveying the design intent to potential bidders as well as to the construction contractor. These individuals often do not participate in the project development process.*

- AASHTO - Visualization in Transportation

## 2.3.2 Visualization case studies

**Iowa Falls bridge replacement**
The US65 (Oak Street) bridge is one of a trio of open spandrel concrete arch bridges located within a stretch of the Iowa River as it meanders its way through the middle of scenic Iowa Falls. Built in 1928 and listed on the National Register of Historic Places, the existing bridge has served its purpose for over 80 years but has recently been showing its age and is in need of replacement.

The Iowa DOT sought input from the community during the planning stages of project development. The result was a local preference for the concrete arch bridge to be replaced with another arch structure, thus keeping the river free of supporting piers and maintaining the aesthetic appeal of the arch bridge theme prevalent at the two other nearby river crossings in town. An above-deck, steel through-arch bridge type was chosen as the final concept. The new bridge will feature a 42-foot roadway, a sidewalk and a bicycle trail.

**Figure 2.3.2-1 Original Concrete Arch Bridge**

**Figure 2.3.2-2 Replacement Steel Arch Bridge**

**Massena lateral bridge slide project**
The Massena Lateral Bridge Slide project consists of replacing the existing 40’ x 30’ steel I-beam bridge (FHWA #017840) that was constructed in 1930 and is currently classified as structurally deficient with a sufficiency rating of 38. The proposed bridge replacement is intended to increase the structural capacity of the bridge, improve roadway conditions, and enhance safety by providing a wider roadway.

Construction zone safety will be greatly improved due to the introduction of innovative accelerated bridge construction (ABC) methods (limit traffic interference to a period of nine days or less). Furthermore, by minimizing the need for future maintenance that interferes with traffic flow, congestion and crashes will be reduced.

A video showing the construction process was developed to aid contractors and is located here.
http://www.youtube.com/watch?v=NA-nhOMEn8s

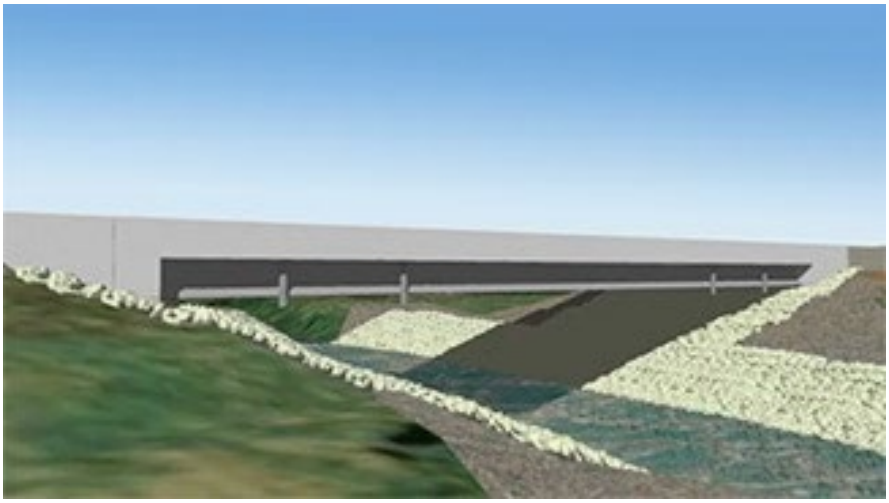

**Figure 2.3.3-3 Massena replacement bridge**

## 2.4 Bridge preservation

### 2.4.1 Introduction

State departments of transportation and other bridge owners are faced with significant challenges in addressing the Nation’s highway bridge preservation and replacement needs.

More than 25 percent of the Nation’s 600,000 bridges are rated as structurally deficient or functionally obsolete. More than 30 percent of existing bridges have exceeded their 50-year theoretical design life[1] and are in need of various levels of repairs, rehabilitation, or replacement. This issue is exacerbated by increasing travel demands, limited funding, and increasing costs of labor and materials. These circumstances have caused most bridge owners to become more reactive than proactive in their approach to managing and addressing their bridge program needs.

Bridge stewards and owners need to become, inevitably, more strategic by adopting and implementing systematic processes for bridge preservation as an integral component of their overall management of bridge assets.

A successful bridge program seeks a balanced approach to preservation and replacement. Focusing only on replacing deficient bridges while ignoring preservation needs will be inefficient and cost-prohibitive in the long term. Adopting a “worst first” approach to managing bridge assets may also yield ineffective results that allows bridges in good condition to deteriorate into the deficient category which generally is associated with higher costs and other challenges.

The objective of a good bridge preservation program is to employ cost effective strategies and actions to maximize the useful life of bridges. Applying the appropriate bridge preservation treatments and activities at the appropriate time can extend bridge useful life at lower lifetime cost.

Preservation activities often cost much less than major reconstruction or replacement activities. Delaying or forgoing warranted preservation treatments will result in worsening condition and can escalate the feasible treatment or activity from preservation to replacement. The latter will result in extensive work and higher cost. A viable alternative is timely and effective bridge preservation of sound bridges to assure their structural integrity and extend their useful life before they require replacement.

Source: FHWA Publication Number: FHWA-HIF-11042

**Bridge preservation - definition**
Bridge preservation is defined as actions or strategies that prevent, delay or reduce deterioration of bridges or bridge elements, restore the function of existing bridges, keep bridges in good condition and extend their life. Preservation actions may be preventive or condition-driven.

Source: FHWA Bridge Preservation Expert Task Group.3

**Bridge preservation - commentary**
Effective bridge preservation actions are intended to delay the need for costly reconstruction or replacement actions by applying preservation strategies and actions on bridges while they are still in good or fair condition and before the onset of serious deterioration. Bridge preservation encompasses preventive maintenance and rehabilitation activities (refer to figure 1).
An effective bridge preservation program:

1. Employs long-term strategies and practices at the network level to preserve the condition of bridges and to extend their useful life;
2. Has sustained and adequate resources and funding sources; and
3. Has adequate tools and processes to ensure that the appropriate cost effective treatments are applied at the appropriate time.

**Preventative maintenance - definition**
Preventive maintenance is a planned strategy of cost-effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system (without substantially increasing structural capacity). Source:

AASHTO Subcommittee on Maintenance.