A SHRP 2 Renewal Project Brief

Designing Bridges for Service Life

AUGUST 2013

Addressing service life during bridge design has the potential to significantly reduce the costs and risks that are associated with bridge maintenance and preservation activities. A systematic approach to designing bridges and their elements, components, systems, and subsystems for service life provides an array of options that can enhance service life and optimize the timing of interventions.

Design Guide for Bridges for Service Life (the Guide) was produced in Bridges for Service Life beyond 100 Years: Innovative Systems, Subsystems, and Components (SHRP 2 Project R19A). The main objective of the Guide is to provide information and define procedures for systematically designing for service life and durability for both new and existing bridges. It includes new concepts and approaches that offer improvements to current practice and have the potential to enhance the service life of bridges. The Guide is intended to equip users with the knowledge needed to develop specific optimal solutions for a bridge. The Guide's approach to designing for service life is based on a framework, outlined in 12 steps, that is applicable to all bridges and adaptable to specifics that vary from bridge to bridge. This project brief provides an overview of the Guide and its 12 steps.

Bridge Service Life-Related Terminology and Relationships

- **Service Life.** The time period during which the bridge element, component, subsystem, or system provides the desired level of performance or functionality, with any required level of repair and maintenance.
- **Target Design Service Life.** The time period during which the bridge element, component, subsystem, or system is expected to provide the desired function with a specified level of maintenance established at the design or retrofit stage.
- **Design Life.** The period of time on which the statistical derivation of transient loads is based—75 years according to the 2012 edition of *AASHTO LRFD Bridge Design Specifications,* hereafter referred to as Load and Resistance Factor Design (LRFD) Specifications.
- **Bridge Element.** Individual bridge members—including girder, floor beam, stringer, cap, bearing, expansion joint, and railing. When combined, these elements form subsystems and components, which together constitute a bridge system.
- **Bridge Component.** A combination of bridge elements forming one of the three major portions of a bridge that comprises the entire structure—substructure, superstructure, and deck.
- **Bridge Subsystem.** A combination of two or more bridge elements acting together to serve a common structural purpose. Examples include composite girder, which could consist of girder, reinforcement, and concrete.
- **Bridge System.** The three major components of the bridge—deck, substructure, and superstructure—combined to form a complete bridge.

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Several basic relationships exist between bridge design life and the service lives of bridge components, elements, subsystems, and systems:

- Predicting the service life of bridge systems is accomplished by predicting the service life of its elements, components, or subsystems.
- The design life of a bridge system is a target life in years, set at the initial design stage, and specified by the bridge owner.
- The service life of a given bridge element, component, subsystem, or system could be more than the target design service life of the bridge system.
- The end of service life for a bridge element, component, or subsystem does not necessarily signify the end of bridge system service life as long as the bridge element, component, or subsystem could be replaced or resume its function with retrofit.
- A given bridge element, component, or subsystem could be replaced or retrofitted, allowing the bridge as a system to continue providing the desired function.
- The service life of a bridge element, component, or subsystem ends when it is no longer economical or feasible to undergo repairs or retrofits, and replacement is the only remaining option.
- The service life of a bridge system ends when it is not possible to replace or retrofit one or more of its components, elements, or subsystems economically or because of other considerations.
- The service life of a bridge system is governed by the service life of its critical elements, components, and subsystems. The critical bridge elements, components, or subsystems are defined as those needed for the bridge as a system to provide its intended function.

Guide Approach to Design for Service Life

The Guide's approach to design for service life is to provide a body of knowledge relating to bridge durability under different exposure conditions and constraints, and to establish an array of options capable of enhancing service life. A solution for a particular service life issue is highly dependent on many factors that vary from location to location and state to state, because a solution depends on local practices and preferences. Consequently, use of the Guide is not intended to dictate a unique solution for any specific service life problem or to identify the "best and only" solution. Rather, it equips the reader with a body of knowledge for developing specific solutions best suited to stated conditions and constraints.

When applying the Guide framework to a particular bridge, including long-span bridges, an array of solutions can be identified for enhancing the service life of a bridge element, component, or subsystem, and an optimum solution can be identified through life-cycle cost analysis. The solutions can be based on data collected by local transportation agencies responsible for maintaining the bridge, and in order to be complete, the life-cycle cost analysis should include maintenance, retrofit, replacement, and user costs. It is important that the list of assumptions and feasible solutions considered for a particular bridge element, component, and subsystem be communicated and shared with the owner, especially with respect to the life-cycle cost analysis, so that the entire process is fully transparent.

The Guide recognizes that not all bridges can or need to have 100 years of service life. Therefore maintenance, rehabilitation, and replacement are part of the service life design process. The Guide provides the general framework to achieve this objective through a systematic approach that considers the entire bridge system and all project demands.

There are different methods of enhancing the service life of existing and new bridges. Examples include a) using improved, more durable materials and systems during original construction that will require minimal maintenance; and b) improving techniques and optimizing the timing of interventions, such as preventive maintenance actions. Interventions can be planned and carried out based on the assessment of individual bridge conditions and needs, or based on a program of preventive maintenance actions planned for similar elements on a group of bridges. A simple example of a preventive, planned maintenance program might include the following activities:

- Spot painting steel structures
- Sealing decks or superstructures in marine environments
- Sealing substructures on overpasses where deicing salts are used on the roadways below
- Washing deicing salts off bridge decks in the spring
- Cleaning debris from bridge deck expansion joints
- Cleaning debris from bearings and truss joints
- Cleaning drainage outlets

By acknowledging that service life can be extended either by using more durable, deterioration-resistant materials or by planned intervention, a cost comparison can be made to determine the most cost-effective approach for various environmental exposure levels and various levels of available maintenance and preservation actions.

12 Steps to Design Bridges for Service Life

The following section provides an overview of the general approach used in the Guide. The 12 steps were created for new bridges; however, the Guide's approach can be adapted for existing bridges by eliminating some of the steps. Because the descriptions are general and use very simple examples to demonstrate the point of discussion, many intermediate steps are eliminated for the sake of clarity.

Step 1

The design for service life begins by first considering all project demands set by the owner, including the service life requirements. The Guide provides examples of local operational and site requirements, as well as service life considerations that need attention.

Step 2

Develop all feasible and preliminary bridge alternatives that satisfy project demands. For example, one might want to consider steel, concrete, and segmental bridge alternates for a particular bridge. The development of the potential bridge systems is carried out in a conventional manner, meeting all the provisions of the LRFD Specifications. It is good practice to consider potential service life issues, even at this stage of the design process. It is also feasible to use bridge technologies that do not have a specific design guideline within the LRFD Specifications. In such cases, the best available design approach could be used, subject to owner approval.

Steps 3 and 4

Evaluate each bridge system alternate one at a time, considering service life issues related to each element, component, and subsystem of that bridge system. For each bridge element, component, and subsystem, the Guide provides a framework for incorporating the changes and modifications needed to meet service life requirements.

For example, assume that one of the bridge systems to be considered for a particular project is a steel bridge alternate. The designer will first develop the preliminary bridge configurations using the conventional approaches that meet all LRFD specifications. Then each element, component, or subsystem of the steel alternate will be checked against the service life requirements using the fault tree approach described in the Guide. An example of a fault tree can be seen in Figure 1. These evaluation requirements may lead to changes in the details of the element, component, or subsystem under consideration. For example, the preliminary deck configuration may indicate that use of 8-in. thick concrete is sufficient from a strength standpoint. Going through the fault tree corresponding to bridge deck, the designer may change the deck thickness to 9 in. to address potential overloads, or may specify sealing the bottom of the deck to protect it from salt spray if the bridge is located along the coastline. It should be noted that for major and complex bridges, most of these fault trees will need to be customized to meet specific needs and preferred practices. Examples of fault trees and how they work are provided in the Guide.

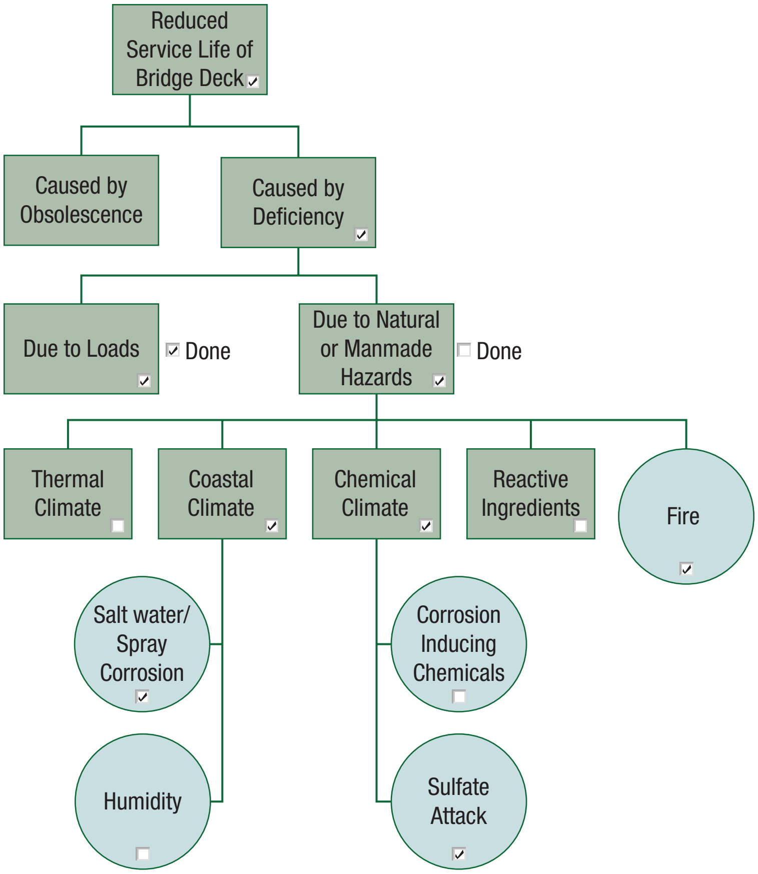
Table 1. 12 Steps to Design Bridges for Service Life

Step 1.	Identify the project requirements, particularly those that will influence the service life.
Step 2.	Identify feasible bridge systems capable of meeting the project demand.
Step 3.	Select each feasible bridge system and complete Steps 4 through 10.
Step 4.	Identify the factors that influence service life of bridge elements, components, and subsystems, such as traffic and environmental factors.
Step 5.	Identify modes of failures and consequences. For instance, the corrosion of reinforcement causing corrosion-induced cracking and loss of strength.
Step 6.	Identify suitable approaches for mitigating the failure modes or assessing risk of damage, through life-cycle cost analysis. For example, use better-performing materials for sliding surfaces in bearings.
Step 7.	Modify the element, component, or subsystem under consideration, using the selected strategy and ensure compatibility of different strategies used for various bridge elements, components, or subsystems. This step may involve the need to develop several alternatives.
Step 8.	For each modified alternative, estimate the service life of the bridge element, component, or subsystem using finite or target service life design approaches.
Step 9.	For each modified alternative, compare the service life of the bridge element, component, or subsystem to the service life of the bridge system and develop appropriate maintenance, retrofit, and/or replacement plan.
Step 10.	For each modified alternative, develop design, fabrication, construction, operation, maintenance, replacement, and management plans for achieving the specified design life for the bridge system.
Step 11.	For each modified alternative, conduct life-cycle cost analysis for each feasible bridge system meeting strength and service life requirements, and select the optimum bridge system.
Step 12.	When specified by the owner or in cases of major and complex bridges, document the entire design for service life process in a document called the Owner's Manual. Conduct an independent review of the document and provide it to the bridge owner at the time of opening the bridge to traffic.

Steps 5 through 8

At the end of Step 4 and after going through appropriate fault trees for various bridge elements, components, and subsystems, the designer will have developed a bridge system that meets both strength and service life requirements. To some extent, changes to configurations of various bridge elements, components, and subsystems are carried out separately. However, there is a need to ensure that these changes are compatible and not contradictory or overly conservative, and that is what happens in steps 6 and 7. For example, in the steel bridge example discussed previously, service life requirements may dictate the use of a jointless, integral abutment system and require metalizing the end of the girder. The designer may then want to consider not metalizing the end of the girder, since leaking joints would be eliminated. In Step 8 the designer develops

Figure 1. Example Segment of the Fault Tree.



a final configuration for the selected bridge system alternate under consideration that meets both strength and service life requirements.

Steps 9 through 12

In Step 9, the designer will evaluate the service life of the various bridge elements, components, and subsystems of the bridge alternate under consideration and compare it to the owner-specified target service design life of the bridge system. For example, the owner may require that the bridge provide 100 years of service life, whereas the life of a particular bridge element, such as the sliding surface for a bearing, may be limited to 20 years. This would require the designer to determine how to accommodate replacement of the sliding surfaces. This would also require the designer to develop a systematic maintenance plan that could include the identification of "hot areas" requiring more detailed inspection and maintenance. By Step 10, the designer should have a bridge system alternate that meets both strength and service life requirements with an associated maintenance and/or rehabilitation or replacement plan for the bridge. In Step 10 the designer has to carry out life-cycle cost analysis, considering the final configuration of the select bridge alternate and maintenance plan. The same steps are repeated for all bridge alternate systems in Step 11. After comparing all alternates, the designer can then recommend which alternate should be used, allowing the owner to make the final selection.

When specified by the owner or in cases of major and complex bridges, Step 12 requires the designer to document the entire design for service life processes in a document called the Owner's Manual. The designer would also conduct an independent review of the document and provide it to bridge owner at the time of opening the bridge to traffic.

Status

This project is complete. Design Guide for Bridges for Service Life is available at http://www.trb.org/Main/Blurbs/168760.aspx. The research report will be available on the TRB website in fall 2013.