GUIDELINES FOR HISTORIC BRIDGE REHABILITATION AND REPLACEMENT

Requested by:

American Association of State Highway
and Transportation Officials (AASHTO)

Standing Committee on the Environment

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ABSTRACT

This report presents a literature search, findings of a survey on the current state of historic bridge rehabilitation or replacement decision making by state and local transportation agencies, and nationally applicable decision-making guidelines for historic bridges. The guidelines are intended to be used as the protocol for defining when rehabilitation of historic bridges can be considered prudent and feasible and when it is not based on engineering and environmental data and judgments. The guidelines include identification of various approaches to bringing historic bridges into conformance with current design and safety guidelines/standards, and the effect or implications of remedial action on historical significance.

There are currently no such nationally applicable decision-making guidelines, but there are a variety of state and local processes and policies for managing historic bridges. Effective practices for the various processes inform the nationally applicable guidelines. The guidelines are in narrative and matrix format.

EXECUTIVE SUMMARY

While the National Historic Preservation Act of 1966 (amended) and Section 4(f) U.S. Department of Transportation Act of 1966 specify nationally applicable processes for considering preservation or replacement of historic bridges, there is no corresponding protocol that ensures a nationally consistent approach to determining which bridges should be rehabilitated or replaced. State and local transportation agencies have developed a wide variety of approaches for addressing historic bridges with each reflecting the priorities and culture of the particular agency as well as the bias, knowledge and expertise of the decision makers. Despite the federal legislation and proactive policies of many states, historic bridges continue to be lost for a variety of reasons. To ensure that rehabilitation versus replacement decision making is balanced and consistent among the states, nationally applicable guidance on historic bridge analysis is deemed by the American Association of State Highway and Transportation Officials Standing Committee on the Environment to be useful.

Research indicates that while many transportation agencies have processes for managing historic bridges, including some with well thought out treatments for preserving specific bridges, few have written protocols or guidelines that lead engineers and historians through the decision-making process. When is it not prudent to rehabilitate a substandard bridge? When is it prudent to upgrade the bridge to keep it in service? What work can be done without adversely affecting what makes the bridge historic? Has everything that could be done to preserve the bridge been considered? Research indicates that engineers believe that their agencies are proactive about historic bridge preservation while historians do not. So while there are stunning successes, like Vermont’s metal truss bridge preservation program or Oregon’s Coastal Highway bridge rehabilitations, the perception is that historic bridges that could be saved are not being saved because rehabilitation is not as consistently considered as it should be.

Guidelines have been developed based on effective practices, understanding of historic bridge types and appropriate methodologies for addressing deficient load capacity, geometry and safety features. These guidelines lead decision makers through considerations that define when rehabilitation is prudent and feasible and when it is not based on engineering judgments balanced with consideration of environmental issues.

CHAPTER 1

INTRODUCTION AND RESEARCH APPROACH

INTRODUCTION

While the National Historic Preservation Act of 1966 (amended) and Section 4(f) of the U.S. Department of Transportation Act of 1966 specify nationally applicable processes for considering preservation or replacement of historic bridges (defined as those that are listed in or have been determined eligible for inclusion in the National Register of Historic Places), there is no corresponding protocol that ensures a nationally consistent approach to determining when rehabilitation is the appropriate decision or when replacement is justified. State and local transportation agencies have developed a wide variety of approaches for managing historic bridges, and many of them proactively define treatments and uses after decisions about rehabilitation or replacement have been made. But few of the processes are founded on written protocols or guidelines that ensure balanced decision making that spells out to all stakeholders when rehabilitation is the prudent alternative.

When an engineer considers rehabilitation or replacement of a deficient, non-historic bridge, the engineer may not look very deeply into rehabilitation unless the bridge is of substantial length (at least a few hundred feet) or has multiple spans. For those bridges, whether they are historic or not, rehabilitation is nearly always considered because it is often less expensive than full replacement. This approach is sound and valid because ways to upgrade the bridge and keep it in service are fully considered. But the same approach is not consistently applied to shorter bridges. Owners and managers often decide to replace shorter bridges that have structural, functional and/or safety problems rather than consider rehabilitation based on the proven long-term cost effectiveness of replacement for short and single-span bridges. With so many shorter and less complicated bridges now identified as historic, and thus worthy of preservation under federal policy and statutes, the engineering approach to decision making needs to acknowledge the value of these bridges and to take their historic value into account in the decision-making process.

Those concerned about preservation of historic bridges acknowledge that there is a need for nationally applicable guidance on analysis and decision making that balances engineering judgment and environmental issues. There is also a need for definitions of when rehabilitation can be considered prudent and feasible and when it cannot. The guidelines need to address all of the issues associated with decision making, including thresholds that define such issues as when cost makes remedial work not prudent or when a context-based solution is appropriate.

Some deficiencies are easily corrected. Others may require so much effort to bring the bridge into conformance that rehabilitation may not be the prudent decision. Not all historic bridges can be saved, but many can. Preservability of a historic bridge, as with any bridge, is a factor of its ability to perform adequately, which is defined by engineers as meeting current minimum standards or guidelines in the areas of load capacity (structural), geometry (functional) and safety. The cost to achieve and maintain adequacy in these areas must also be factored into any definition of preservability.

Historical significance must also be a major factor in the decision-making process, including whether the bridge is of such significance that a higher level of effort to preserve it is warranted. If a bridge can be improved to an acceptable level in a prudent manner, within the limits of acceptable technology and without adversely affecting what it is that makes it historic, then the bridge is likely a viable candidate for rehabilitation.

RESEARCH APPROACH

The approach to research was to use existing information to the greatest extent possible and then synthesize it (1) to identify effective practices, (2) to provide an accurate assessment of the state of the practice of historic bridge "rehabilitation-versus-replacement" decision making among state and local transportation agencies, (3) to identify approaches for consistent and balanced decision making, and (4) to understand if historic bridge "issues" delay projects. The research was conducted by doing a literature search (see Appendix A) and a targeted questionnaire (see Appendix B). Both efforts were structured to identify effective practices and the issues that prevent consistent consideration of rehabilitation potential of all historic bridges. A great deal of anecdotal and empirical data is provided by the research team based on their years of experience assessing the rehabilitation potential of all types of historic bridges.

A questionnaire was developed to determine the current state of practice and decision-making processes that are being used by the states. The questionnaire was sent to 49 engineers and environmental specialists, including historians, preservationists, archaeologists, and managers, with county, state, and federal transportation agencies and state historic preservation offices (SHPOs).

The guidelines for historic bridge rehabilitation or replacement decision making represents the synthesis of the literature search, questionnaire responses and experience of the researchers.

CHAPTER 2

FINDINGS

LITERATURE SEARCH

The literature search (Appendix A) revealed that very little has been published (including the web) that addresses specific evaluation criteria or guidelines for historic bridge rehabilitation or replacement decision making. Rather, much of the existing body of literature describes particular rehabilitation projects or general approaches to decision making, particularly methods for expediting or streamlining consultation under the National Environmental Policy Act (NEPA), Section 106, and Section 4(f).

The literature search identified two previous NCHRP syntheses by William Chamberlin (1983, 1999) that do an excellent job of summarizing the issues faced and methods used by state highway departments. Chamberlin concludes that approaches and levels of historic bridge rehabilitation expertise vary greatly from state to state. Some states start with the mind set that historic bridges should be preserved unless thorough analysis proves that rehabilitation and preservation is not prudent and feasible; others assume deficient bridges should be replaced. In many cases, decisions whether to rehabilitate or replace are made based on very general guidance and assumptions. A 2004 national historic bridge workshop (DeLony and Klein) concluded that historic bridges remain a heritage at risk despite local, state and federal legislation to identify and protect historic bridges. The workshop recommended development of historic bridge management plans and a synthesis of rehabilitation-versus-replacement options.

Perhaps the most significant applicable guidance to appear in the past decade is the American Association of State Highway and Transportation Officials (AASHTO) *Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT<400)*, 2001. That guidance, which is now part of AASHTO's *A Policy on Geometric Design of Highways and Streets*, offers flexibility when considering width and safety performance and thus increases the likelihood that narrow bridges can remain in service on very low-volume local roads.

A number of state highway departments have preservation plans that are outgrowths of their historic bridge inventories, but the plans tend to be process oriented and offer a menu of possible treatments rather than a protocol or specific technical guidance for deciding when to rehabilitate and when to replace. Maine DOT's Historic Bridge Preservation Plan (2004) was the only one identified to have a specific quantifiable protocol for rehabilitation or replacement analysis and decision making.

The technical literature of journal articles, conference proceedings and briefs from such organizations as the American Concrete Institute, American Society of Civil Engineers, Association for Preservation Technology, and the National Park Service's Technical Preservation Services offer many historic bridge rehabilitation case studies and scholarship on properties, testing, and conservation of materials, like reinforced concrete or steel, but again with little synthesis of this information in a format that would offer broadly applicable guidance when deciding whether to rehabilitate or replace historic bridges.

FINDINGS FROM QUESTIONNAIRE ON CURRENT STATE OF DECISION-MAKING PRACTICE

A 16-question questionnaire was developed to research the current state of historic bridge rehabilitation-versus-replacement decision making. It was sent to 49 engineers, historians, archaeologists, and managers from state departments of transportation (DOTs), counties, SHPOs and the Federal Highway Administration (FHWA). Twenty-one respondents from 17 states replied. The goal was to elicit responses that might help the research team to identify useful resources or specific problem areas.

About half of the respondents felt that their agencies were proactive in terms of rehabilitation decision making. Of these respondents, nine identified their agency as either having a written procedure that defines the process related to historic bridge treatments, or identified their agency as currently working on a written procedure. Of the nine, five of them have (or will have) a procedure/process that addresses all bridge types, whereas the rest have written processes that address specific bridge types, like metal or wood trusses. Three respondents indicated that their agency consistently follows an unwritten approach. However, only one of these three found their agency to be acting in a proactive manner regarding historic bridges.

Determining factors that affect rehabilitation versus replacement decision-making included cost, community input, Section 106 and Section 4(f) findings, engineering needs, future traffic, safety issues, historic significance, structural condition and geometric issues such as roadway width, lane width, and vertical clearance. Only eight respondents, all of whom felt their agency to be proactive, also felt their agency achieved a balance between engineering and historic preservation issues. Only one of these eight respondents represents an agency that does not have an established written procedure or a consistent unwritten approach.

The respondents' suggestions on how to achieve a consistent national approach dealt with either including specific information in the analysis process, or accessing information to inform decision making. Information identified as useful to the decision-making process included clearer guidelines defining rehabilitation potential; design exceptions and options other than replacement, like relocation and bypassing; guidance on what makes a bridge historically significant and valuable; and consideration of rehabilitation occurring earlier in the decision-making process before replacement funds have been allocated.

The survey findings confirmed the dearth of general information about historic bridge analysis and decision making. Suggestions for disseminating useful information included setting up an easily accessible "permanent record" of related research and case studies that would include successes and failures, effective practices, and the latest technology used for bridge rehabilitation and preservation. Other suggestions included establishment of closer coordination between cultural resources staff, engineers and owners and for more engineering expertise at the SHPO staff level. There was also a suggestion for information on how to address substandard features on low-volume roads, which to a large extent has already been accomplished with AASHTO's *Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT<400)*, but which may not have been known or useful enough to the respondent.

Over half of the respondents identified delays and other problems as common to projects involving historic bridges. These delays and problems typically arose from issues associated with completing the Section 106 and Section 4(f) processes and the additional public involvement necessary to accommodate all interested and consulting parties. Interestingly, the respondents who did not identify delays or problems felt that their agencies had a streamlined process already in place with FHWA and SHPO and/or that the "rehabilitation-versus-replacement" decision-making process was so well-established that all parties knew how to advance projects. One respondent stated that there was no delay or problem because their state agency was unwilling to accept rehabilitation as an option.

Issues identified as important in the decision-making process are functionality, public opinion, initial cost, life-cycle cost differences between rehabilitated and new bridges, concerns with safety, bridge location, historic significance, difficulty identifying parties to accept ownership and liability for a bypassed bridge, and traffic volumes. That engineers would rank achieving structural and geometric functionality as the highest priority is not surprising, nor is the finding that public opinion is a very strong factor in decision making or that initial and life-cycle costs matter greatly.

A detailed discussion of the questionnaire and responses is included in Appendix B.

CHAPTER 3

HISTORIC BRIDGE REHABILITATION/REPLACEMENT DECISION-MAKING GUIDELINES

THE NEED FOR DECISION-MAKING GUIDELINES

The National Historic Preservation Act (NHPA) of 1966, the US Department of Transportation (US DOT) Act of 1966, and the National Environmental Policy Act (NEPA) of 1969 specify nationally applicable processes for considering preservation of historic bridges, but there is no corresponding guidance to ensure a nationally consistent approach for determining when they should be rehabilitated or replaced. Many state and local transportation agencies have developed approaches for managing historic bridges, including some well thought-out treatments for preserving specific bridges. Most of the approaches reflect the culture of each agency, as well as the knowledge and preferences of the individuals making decisions, rather than written step-by-step protocols that lead engineers, managers and environmentalists, including historians and preservationists, through a process to achieve consistently balanced and well-founded decisions.

While there are stunning historic bridge preservation successes, like Vermont's metal truss bridge preservation program or Oregon's Coastal Highway bridge rehabilitations, the perception is that historic bridges that could be saved are not being saved because rehabilitation is not as fairly and consistently considered as it could be. Additionally, a need to better integrate historic bridge rehabilitation or replacement decision making into the NEPA process has been identified. To that end, step-by-step guidelines have been developed to address historic preservation and engineering issues in a manner that reflects the appropriate balance between the two seemingly divergent objectives – preserving old bridges and maintaining a safe, efficient transportation system. These guidelines will lead decision makers through considerations that will define when rehabilitation is feasible and prudent, and when it is not, based on engineering judgments balanced with consideration of environmental issues.

HOW TO USE THE DECISION-MAKING GUIDELINES

The guidelines focus on the initial decision related to keeping a historic bridge in service and on-system, not whether it has potential for adaptive use. They are more than a reiteration of environmental review processes or identification of preferred treatments for historic bridges. Their purpose is to lead decision makers step-by-step through a series of relevant questions that, when answered using a balanced approach based on readily available data sets and effective-practice techniques, will define when a bridge can be made adequate and when it cannot. The guidance is also intended to demonstrate to owners and managers that, while there are more issues with old bridges than those designed to meet current codes, there is a great deal of flexibility available to make them adequate and safe while maintaining their historic significance.

Since conditions vary from bridge to bridge, the amount of analysis needed to support a balanced decision will vary. Some deficiencies are easily corrected while others require more effort to bring a historic bridge into conformance with engineering standards. Some deficiencies or site limitations are so severe that a bridge cannot be retained in service. Other factors, like initial and life-cycle costs and the inherent perception that a new bridge is better than an old one, affect decisions. What will not vary, however, is the relevance of certain data to define when rehabilitation is warranted and when it is not.

Those involved with keeping historic bridges in service have struggled to codify or quantify a threshold or rule for when rehabilitation is feasible and prudent and when it is not. Ultimately, the rehabilitation or replacement decision, as with any bridge, is based on the cost and level of effort needed to make it safe and adequate. If a bridge can be improved to an acceptable level in a feasible and prudent manner without destroying what makes it historic, then it is generally a viable candidate for rehabilitation. These guidelines are based on using three key aspects of adequacy that, when balanced with environmental issues, can serve as thresholds defining when rehabilitation of historic bridges is feasible and prudent and when it is not. The three aspects of adequacy are (1) superstructure and substructure condition, including scour and waterway adequacy, (2) geometry and safety, and (3) load-carrying capacity. While the thresholds are applicable in most instances, there may also be other issues, including NEPA-related issues that will affect the decision.

The guidelines lead decision makers through four steps that will result in balanced and appropriate decisions. Each step integrates engineering and historic preservation considerations and is intended to achieve iterated assessments.

Step 1, *Understanding What Makes a Bridge Historic*, provides an understanding of the historical significance of the bridge and its components.

Step 2, *Applying Structural and Functional Considerations*, discusses how to balance considerations addressing functional and operational inadequacy with historical and environmental issues.

Step 3, *Historical and Environmental Considerations*, addresses any historical and environmental issues not addressed in step 2.

Step 4, *Applying the Decision-Making Thresholds*, explains how to use the information from steps 1 through 3 to define and support when rehabilitation of a historic bridge is feasible and prudent and when it is not.

STEP 1: UNDERSTANDING WHAT MAKES A BRIDGE HISTORIC

What Makes the Bridge Historic?

The first step, and the one that will underlie all planning and preliminary engineering assessments, is to understand why a bridge is historic.[1] Bridges meet the National Register Criteria For Evaluation and are determined to be historic for many reasons, including the fact that they have integrity of workmanship, design, and materials. Significance can range from being a rare example of an arcane bridge type, like a pin-connected truss, to a common bridge type located in an architectural, commercial or rural historic district where scale rather than technology is the primary issue. When the reason for eligibility is not well-articulated and understood, it is difficult to make appropriate decisions about how to preserve or maintain what makes a bridge significant or ensuring that all possible planning has been done to avoid or minimize harm.

By understanding what makes a bridge historic, decision makers can proceed to consideration of feasible and prudent ways to preserve significant features without having an adverse effect. This is often done by upgrading or even replacing features of lesser importance. Integrating this assessment of effect of any proposed actions on the historic bridge is at the heart of meeting the federal regulatory processes required under Section 106 of the NHPA, Section 4(f) of the US DOT Act and NEPA. The clearer the understanding of significant features, the more successful the selected alternative will be, whether a historic bridge is rehabilitated or replaced. The understanding will also inform appropriate mitigation measures when they are required.

Is the Bridge of Average or High Historical Significance?

All bridges that meet the federal definition of historic are afforded equal consideration under federal laws and procedures, but not all historic bridges are equally significant. Those that are important on the state or local level are generally considered to be of average significance, like common bridge types located in and contributing to a historic district. Other bridges of greater importance at the state or at the national level are generally considered to be of high historical significance, for example a rare survivor of certain important bridge types or early applications of a technology that goes on to have a tremendous influence on bridge building, such as an early prestressed concrete bridge.

Understanding the level of significance is particularly important in light of FHWA's and NEPA's emphasis on the holistic approach to decision making. That guidance seeks to balance environmental and engineering issues based on the relative significance of affected Section 4(f) properties. Bridges of high significance should be afforded greater effort to preserve them, while average bridges may not merit a similar effort. This does not imply lessening the test for prudence and feasibility of rehabilitation for average-significance bridges; it does mean that some bridges deserve greater effort to rehabilitate than others.

Public interest and other circumstances may raise the level of consideration that an average preservation priority bridge receives, but a lack of interest or public opinion should not lessen the level of consideration. It is acknowledged that bridges for which there is a constituency are more likely to be rehabilitated than those for which there are no advocates. If the bridge is historic, federal laws and processes still require that it be fairly assessed for its rehabilitation potential. The issue of education is an extremely important factor in decision making, not just for owners and engineers but also for politicians and the public, who often drive the decision-making process.

Can Members Be Changed Without Adversely Affecting Historic Significance?

Not all bridge members or components are equally significant; the relative importance of components varies among the bridge types and associative historic contexts. Understanding which members are vital to maintaining historical significance and which are not frequently provides ways to upgrade the structure without adversely affecting it. For an early reinforced concrete arch bridge that is technologically significant, for instance, it is the arch ring that is important, not the standard-design railings or the roadway width. For another arch bridge that was designed to reflect the aesthetic tenets of the City Beautiful movement, it may be that all of the features, including the railings, are important and thus worthy of preservation in order to maintain historical significance.

This understanding of which members contribute to the significance of a particular historic bridge should be used during engineering analysis and evaluation phases to assess whether the proposed work has an adverse effect or not. For example, whether the floorbeams of a pin-connected pony truss bridge are original or not does not affect historical significance, but retention of the pinned connections certainly does. Can floorbeams and stringers be replaced in kind? Yes, if they are pin connected thus maintaining integrity of original design, materials and workmanship. Similarly, can a technologically significant arch bridge that is too narrow be widened without an adverse effect? Since the arch alone makes the bridge historic, widening it with a cantilevered deck section and appropriate railings/barriers without dramatically changing the overall scale can preserve the historic arch and achieve the project goals (Figure 1).

Knowledgeable historians and preservationists are responsible for understanding and articulating which members are historically important and should be retained whenever possible, and which can be modified without having an adverse effect. It is also their responsibility to be reasonable and exercise good judgment that facilitates rather than hinders rehabilitation.

Members/Components That Generally Have Historical Significance

The following is a list of bridge members and components that are generally considered significant features of historic bridges. The list is not intended to be comprehensive as significance and importance can vary depending on the bridge type and design and why it is historic.

- Technologically significant components or details. This addresses a wide variety of items from panel point connections on metal truss bridges to early reinforcing designs for concrete to continuous beams and suspended section connections (Figure 1, Figure 2).
- Particular configurations of truss design, such as Pratt, Warren, Whipple, etc.
- Completeness of early examples of common bridge types.
- Stone masonry bond patterns. Mortar joint types and compositions.
- Arch rings and related spandrel walls.
- Aesthetic railings. This does not include standard-design railings, which are rarely aesthetic.
- Scale of bridges located in historic districts.

Members/Components That Generally Are Not Vital to Retain

The following is a list of bridge members and components that are generally not considered significant features. The list is not intended to be comprehensive as significance and importance can vary depending on the bridge type and design and why it is historic.

- Decks, unless they are an early or rare example of significant design, such as a brick jack arch or composite.
- Standard-design railings unless they are an integral component of a significant standard design (Figure 2).
- Substructure units unless they are historically or technologically significant or an integral part of significant design (Figure 2).
- Stringers and floorbeams, unless the deck is significant.
- Rivets (Figure 3).
- Exact dimension and strength of structural steel (Figure 3).
- Existing railings when replaced with compatible ones that meet safety considerations and reflect the original design. (Figure 4, Figure 5).
- Location of metal truss bridges. Truss bridges have historically been relocated and reused.
- Bearings.

Figure 1. Bankhead Highway over Proctor Creek Bridge in Atlanta, GA. The 1908 bridge is historically and technologically significant because it is one of the oldest reinforced concrete arch bridges in the state. It is the arch itself, not the original railings (removed ca. 1955 when the steel stringer-supported sidewalks were added) that makes this bridge eligible for the National Register. The significant element is below the deck. Photograph by Lichtenstein Consulting Engineers, Inc.

Figure 2. Standard-design 2-span continuous bridge in Georgia. Understanding what makes this seemingly ordinary, 2-span continuous steel stringer bridge significant is crucial to assessing rehabilitation or replacement options. Built in 1931 by the Georgia Highway Department, it represents state standard design that was both innovative and important to modernization of the state highway system. Technically the bridge represents an early national application of continuous beams, which were selected because of the economy. The timber pile bent substructure, cantilevered deck sections, and one-rail high concrete railings also reflect economy of design, making all of the elements part of what makes this particular bridge type and design historic. This means that even the substructure units and the standard-design railings, which are generally not significant features, are in fact significant. Changing them, even if reusing the 2-span continuous beams, would be an adverse effect. Photograph by Lichtenstein Consulting Engineers, Inc.

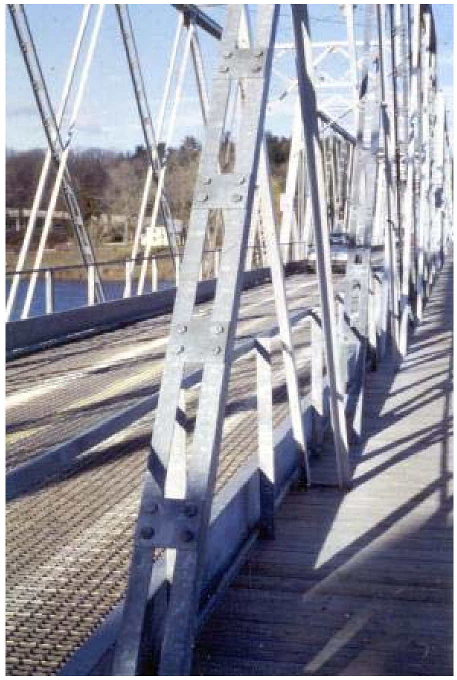

Figure 3. Detail of Delaware River Bridge at Washington Crossing, NJ. Undersized and deteriorated truss members of the 1904 bridge were replaced in kind with higher strength steel to increase the load carrying capacity. Note that the new built up members have high-strength bolts instead of the original rivets. The wood deck was replaced with an open steel grid deck, which also increased load capacity. Photograph by Lichtenstein Consulting Engineers, Inc.

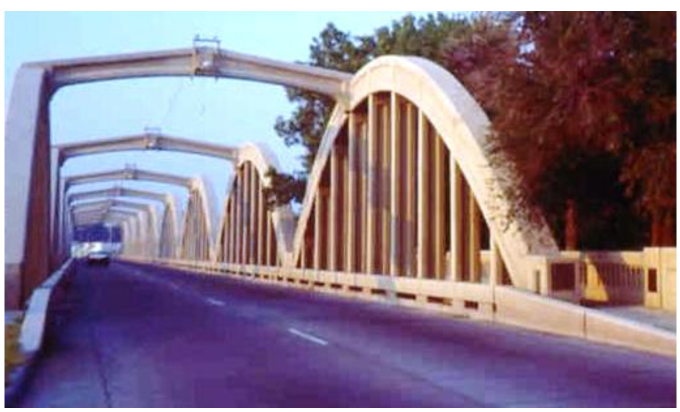

Figure 4. Kansas Corral railings on John Mack Bridge at Wichita, KS. The crash-tested Kansas Corral railings were placed in front of the superstructure on the 1931 bridge as part of the early 1990s rehabilitation. Note how the simple design blends appropriately with the original design of the historic bridge. The original bridge is a Marsh-design steel through arch with a reinforced concrete flooring system and is listed in the National Register of Historic Places. Photograph by Lichtenstein Consulting Engineers, Inc.

5a – Elevation.

5b. Through view showing modern railings.

Figure 5. Partridge Bridge at Whitefield, ME. The historical significance of Maine's earliest reinforced concrete rigid frame bridge, built in 1935, was not lost when an appropriate new railing that is sufficiently stiff was placed. The design defers to the original but addresses current safety concerns, including how approach guide rail is attached to the end posts. The railing was designed by the bridge maintenance division of the Maine Department of Transportation. Photograph by Lichtenstein Consulting Engineers, Inc.

Upgrading That Generally Has No Adverse Effect

The following is a list of some activities that generally do not have an adverse effect on historic bridges. It is important to consider the reversibility of actions. A general rule is that it is better to add than to take away. The list is not intended to be comprehensive as significance and importance can vary depending on the bridge type and design and why it is historic.

- Adding guide rails when done in a manner that is reversible and does not damage historic fabric.
- Addition of strengthening members if accomplished in a sensitive manner (Figure 6).
- Raising overhead members to increase vertical clearance when increase is proportional and appropriate to overall dimensions.
- Material added to “harden” bridges against extraordinary events when the work is done in a reversible manner and does not affect original design or how components work, such as suspender covers on suspension bridges or adding plate to built-up members.
- In kind replacement of selected members using similar shapes and dimensions.

6a. Post-tensioned diagonal.

6b. Post-tensioned lower chord.

Figure 6. Walnut Street Bridge at Chattanooga, TN. The 1891 pin-connected bridge was strengthened by post-tensioning the diagonals and the lower chords. Post-tensioning strands can be seen between the eye bars of the diagonals in the foreground of 6a and in a lower chord detail in 6b. Note the original built up floorbeam and cantilever bracket. Photograph by Lichtenstein Consulting Engineers, Inc.

Completion of Step 1

When step 1 has been completed, decision makers should have a clear understanding of why the bridge is historic, which members or components should be retained if possible, and which members or components could be used to upgrade the bridge in an appropriate manner. This information should be used as guidance for issues to address in steps 2 through 4 and to achieve balanced judgments in evaluating the effects of proposed actions on the historic bridge.

STEP 2: APPLYING STRUCTURAL AND FUNCTIONAL CONSIDERATIONS

Once the significance of the bridge is understood, the next step is to determine if the engineering objectives can be achieved while preserving what makes the bridge historic. As stated previously, the engineering decision whether to rehabilitate or replace a historic bridge, as with any bridge, is driven primarily by the ability to improve it to an acceptable level. This decision generally means addressing three areas of functional and operational adequacy: superstructure and substructure condition – scour and waterway adequacy, load-carrying capacity, and geometry and safety features. Step 2 takes those three aspects of adequacy and balances their consideration with historic preservation issues. The three aspects of functional and operational adequacy will come into play again in step 4 as the thresholds for defining when rehabilitation is feasible and prudent and when it is not, but only after historical and environmental considerations have been integrated into the analysis.

Analysis of Structure Condition and Waterway Adequacy

This section provides guidance on how structural condition and waterway data needs to be analyzed to determine if deficiencies can be brought into conformance with current standards in a feasible and prudent manner without adversely affecting what makes a bridge historic.

The convention for defining superstructure and substructure adequacy is the National Bridge Inspection Standards (NBIS) condition rating code (Table 1). Values from 0 to 9 are linked to definitions that characterize the overall physical condition, not localized deterioration or disrepair. These guidelines are based on using a condition rating of 4 (poor condition) as the qualifier for when a bridge may have rehabilitation potential. Experience has demonstrated time and again that a condition rating of 4 or higher suggests that structural condition is conducive to rehabilitation. This does not mean that a current condition rating of less than 4 is reason to replace a historic bridge since many bridges with this condition rating can be improved at a reasonable cost. Condition ratings should be based on a current, in-depth, hands-on inspection and any test results.

The adequacy of the waterway opening and any scour potential must be considered. Scouring due to normal flows or flooding may cause undermining of foundations and put the entire structure at risk. Where data indicates that flood elevations have increased over time, low superstructure members may now be located below the flood-plain elevation, affecting the adequacy of the waterway opening or rendering the superstructure susceptible to damage. Bends in waterways may direct water flows at bridge abutments or piers causing scour. The number of piers may cause an increase in water velocity due to a reduction in the waterway cross section.

Historic bridges, depending upon their age, may or may not have had substructures sized to account for any scour effects. Additionally, they may not meet current design guidelines, which are based on a 100-year flood event.

Code	Description
N	NOT APPLICABLE
9	EXCELLENT CONDITION
8	VERY GOOD CONDITION - no problems noted.
7	GOOD CONDITION - some minor problems.
6	SATISFACTORY CONDITION - structural elements show some minor deterioration.
5	FAIR CONDITION - all primary structural elements are sound but may have minor section loss, cracking, spalling or scour.
4	POOR CONDITION - advanced section loss, deterioration, spalling or scour.
3	SERIOUS CONDITION - loss of section, deterioration, spalling or scour have seriously affected primary structural components. Local failures are possible. Fatigue cracks in steel or shear cracks in concrete may be present.
2	CRITICAL CONDITION - advanced deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present or scour may have removed substructure support. Unless closely monitored it may be necessary to close the bridge until corrective action is taken.
1	"IMMINENT" FAILURE CONDITION - major deterioration or section loss present in critical structural components or obvious vertical or horizontal movement affecting structure stability. Bridge is closed to traffic but corrective action may put back in light service.
0	FAILED CONDITION - out of service - beyond corrective action.

Table 1. Condition rating descriptions. From *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges*, Federal Highway Administration, Report No. FHWA-PD-96-001, December 1995, p. 38.

The crucial first step in analysis of the structural condition adequacy is to understand the cause and effect of any deterioration. This means that an in-depth, hands-on inspection needs to be conducted to document the nature and extent of the deterioration. Previous inspection and maintenance reports can provide information on any progression of deterioration or efficacy of remedial actions. Gathering needed baseline information may require specialized tests for accurate strength and condition data. With a full understanding of the deficiencies, all appropriate treatments to make the structural condition adequate should be considered. This includes defining and supporting the level of effort required to bring the bridge into conformance and the associated costs. This analysis may indicate that the level of effort is much too costly even though it is feasible to do the work. At that point, it may be possible to support a conclusion that the bridge does not have rehabilitation potential based on its current condition.

Considerations for Correcting Structural and Waterway Deficiencies

Methods to correct deficiencies and make historic bridges adequate vary greatly depending on bridge and material type. Successful techniques common to particular bridge types, designs and/or materials should be considered. Additionally, new methodologies are continuously being developed and thinking "outside the box" is recommended. At a minimum, the following approaches to addressing structural deficiencies should be considered, at least summarily, before a decision to replace a historic bridge is made based on its structural condition.

Plain, Reinforced and Prestressed Concrete

Common problems: cracking, corrosion that results in spalling, cyclic freezing, shrinkage and creep, moisture penetration, and poor coverage of reinforcing.

- Can deteriorated/failed material be removed and replaced in kind to match the existing appearance?
- In a salt-water environment, can cathodic protection be installed?
- Can protective jackets be added to a substructure unit?
- Can piles be added around or within a footing to increase strength?
- Can a deteriorated deck be removed and replaced?
- Can a new waterproofing and/or drainage system, including clean fill, be installed?
- Can a relieving member be installed on arch bridges?
- Can broken prestressing strands be replaced?

Iron and Steel

Common problems: rust/corrosion resulting in section loss.

- Can a deteriorated or cracked member be replaced in kind?
- Can a deteriorated or cracked member be repaired with additional material bolted to it?
- Can members be added to supplement deteriorated or undersized ones?
- Will applying a coating system arrest corrosion?
- Can an auxiliary structural system, like post-tensioning, be installed (Figure 6)?

Stone and Brick Masonry

Common problems: cracking, cyclic freezing, moisture penetration and resulting movement, vegetation resulting in movement of units, acid attack, and mortar joint failure. Additionally, bricks are subject to spalling and efflorescence.

- Can stone arch spandrel walls and/or arch ring be disassembled and rebuilt?
- Can proper waterproofing and drainage be installed?
- Can masonry be repointed in an appropriate manner?
- Can a relieving member be installed over an existing arch?

Wood

Common problems: fire, decay, insect damage, and degradation of lignin.

- Can deteriorated or decayed members be replaced in kind or with a compatible material?
- Can an effective drainage system be installed?
- Can a preservative treatment be applied?

Waterway Adequacy and Scour

Common problems: scouring of the channel bottom due to normal flows and flooding that put the entire structure at risk of failure.

- Can the superstructure be raised and substructure units capped?
- Can material be pumped into voids under piers?
- Can channel bottom protection be placed?
- Can concrete underpinning at abutments be installed?
- Can foundations be strengthened by the installation of piles around or within a footing?
- Can the channel be redirected?

In general, if the waterway opening is not adequate and cannot be adapted as noted above, the bridge may not be a candidate for rehabilitation.

Analysis of Load-Carrying Capacity

This step provides guidance on how load-carrying capacity data needs to be analyzed to determine if deficiencies can be brought into conformance with current standards/guidelines in a feasible and prudent manner without adversely affecting what makes the bridge historic.

All in-service bridges, regardless of original design capacity or date of construction, are required to carry a load based on a specified design vehicle. The load-carrying capacity is determined using reduced section properties, where applicable, to account for deterioration of the main load-carrying members and appropriate allowable stresses due to the age of the material. Based on this analysis, the existing capacity of the structure is then compared to the capacity that would be required to support the design vehicle. State DOTs have discretion in what trucks are used for analysis and can use vehicles that are representative of usage in their state.

Understanding the actual load capacity is a critical first step and one that requires a concerted effort to ensure that the analysis is fair to the historic bridge. In order to accurately determine allowable stresses, material strength tests may be needed. Test results provide solid, scientific data that bring credibility to the decision-making process. On larger bridges, using three-dimensional finite element analysis coupled with load-testing and strain-gauging often results in a finding that the bridge is capable of supporting more load than was computed using conventional methods.

Every bridge needs to have a structural capacity that is consistent with the road network it services, and how that is achieved must be well thought-out. When a bridge enters an agency's work program, an analysis is made to determine if it can support legal loads, which in many cases is HS20 or HS25 depending on the roadway classification. The NBI ratings (inventory and operating) can be used as a starting point, but an independent analysis must be made. At this time appropriate or perhaps innovative methods to reduce dead load should also be considered and evaluated. Under some circumstances, it may be appropriate to consider a lesser design vehicle, such as an H15 vehicle for county and municipal routes not subjected to significant truck traffic.

Many historic bridges have low load-carrying capacity because they either have deterioration or were designed for lighter vehicles than current standards. There are several common methods to address load-carrying deficiencies. One involves increasing the live-load capacity of the members either by strengthening individual members or member replacement using higher strength material. Another is to reduce dead load by replacing the existing deck with a new, lighter-weight deck. In other instances, consideration of a lower structural capacity may be warranted. The bridge could be located on a very low-volume local road where it only needs to carry lighter vehicles, or there is a higher-capacity bridge nearby that can service heavier loads.

Considerations for Improving Load-Carrying Capacity By Bridge Type

Common problems associated with inadequate load-carrying capacity are deteriorated members, particularly controlling members, inadequate load capacity of the original design to meet current requirements, too much dead load, simplistic analysis that does not reflect the true capacity of a bridge, and roadway classification.

At a minimum, the following approaches to addressing load-carrying capacity deficiencies should be analyzed.

Remedial Methodologies Common to Multiple Bridge Types:

- Can dead load be reduced by replacing the deck with a lighter one?
- Can carbon-fiber reinforcing polymer wrapping be used to strengthen concrete components?

- Can material be added to individual members to increase capacity? This includes installing high-strength rods as well as plates.
- Can deteriorated members or sections of members be replaced in kind to restore structural integrity and/or increase capacity?
- Can a parallel bridge be constructed to create a one-way pair and thus reduce the live load? If so, any visual changes should not be considered adverse when the historic bridge is preserved.
- Can use of the bridge be restricted? Is there a full-capacity crossing nearby?
- Can the roadway be reclassified? This could result in a different definition of adequate.

Arch Bridges

- Can existing fill material be replaced with lighter-weight fill or engineered fill to decrease dead load?
- Can a relieving slab or auxiliary member be placed to carry some or all of the live loads?

Truss and Girder-Floorbeam Bridges

- Can the flooring system be replaced in kind with higher capacity members? Upgrading floorbeams and stringers can increase load-carrying capacity significantly.
- Can the truss lines or girders be used to support themselves and any sidewalks as part of a new superstructure? The usefulness of this alternative is predicated on many factors including original dimensions and how much the bridge can be widened so that scale of the bridge is not compromised (Figure 7).

Analysis of Geometry and Safety Features

This step provides guidance on how geometric and safety-feature data needs to be analyzed to determine if deficiencies can be brought into conformance with current standards/guidelines in a feasible and prudent manner without adversely affecting what makes the bridge historic. When working with historic bridges, geometry and safety-feature deficiencies often prove to be the most challenging to solve.

For a bridge to continue in use, it must be geometrically (functionally) adequate and safe. Geometric adequacy includes consideration of the number of travel lanes, roadway width, shoulder width, approach roadway width, vertical clearance over the roadway, underclearances, horizontal clearances, sight distances across the bridge and at the approaches, proximity to intersections and the functional classification of roadways carried and any crossed. Safety features include the crashworthiness of guide rail and railing systems based on their capability to effectively redirect an errant vehicle and to safely stop it in a controlled manner.

Two parameters that are used to evaluate the geometric adequacy of a bridge are the functional classification of the roadway, which is based on whether it serves as an arterial, collector or local road and whether the setting is urban or rural, and the average daily traffic (ADT) count. The ADT also considers the percentage of that count that is truck traffic. Traffic volume affects historic bridges because they are often geometrically inadequate for today's usage demands. Since geometric adequacy is defined by the characteristics of the traffic serviced, ADT is an important consideration affecting the required number and width of lanes, shoulder widths, and roadway alignment. These parameters are often used together to set minimum acceptable geometric guidelines and standards.

Bridges with geometry or safety features that do not meet current design standards are classified as functionally obsolete. However, a bridge classified as functionally obsolete because it does not meet current guidelines should not automatically be considered unsafe and in need of replacement. Many functionally obsolete bridges perform adequately. For those instances, a design exception for width should be considered and used if it is appropriate. Design exceptions are based on in-depth studies that include data such as accident history, travel speed, etc., to support using a lesser design criteria. Under certain conditions, a reduced roadway width can be justified.

Figure 7. Truss Bridge at Califon, NJ. One of the first truss widening projects in the mid-Atlantic region, the historic 1887 pin-connected through truss bridge located in the Califon historic district was widened from 17' to 24' between the truss lines in 1985 by cutting the trusses and attaching them to the fascia stringers of the new superstructure. While the original flooring system, and thus how the truss bridge worked has been lost, the truss lines support themselves and the original cantilevered sidewalks. The widening was successful because of the original scale of the 100’-long bridge. A 10' widening would not be successful on a 60'-long pony truss bridge. Note how the widening is appropriately expressed in the portal brace. Photograph by Lichtenstein Consulting Engineers, Inc.

Geometry on Very Low Volume Local Roads

To account for the correlation between lower traffic volume and lack of accidents caused by substandard geometry, AASHTO in its 2001 *Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT <400)* established geometric guidelines that are now part of its *A Policy on Geometric Design of Highways and Streets* (5th edition, 2004). The very low-volume local road guidance uses risk assessment in determining roadway and bridge width adequacy by weighing the cost effectiveness of the work against "substantial safety improvements." The AASHTO guidelines state that "existing bridges can remain in place without widening unless there is evidence of site-specific safety problems related to the width of the bridge." Based on this guidance, if the bridge is on a local road, is performing well, and is structurally adequate, it probably has rehabilitation potential. This policy supports and reinforces earlier guidance from AASHTO that a certain level of flexibility, when applied to bridges on low-volume roads, would allow lesser design values based on specific, minimal, "tolerable" criteria. Bridges that are functioning adequately now, and can be considered to do the same into the future with appropriate maintenance, are considered to have rehabilitation potential even though they do not meet current standards.

Many states have adopted their own bridge and roadway geometric policies for various classifications of highways. These policies are considered to be a starting point for bridge widths. Additionally, width of the approach roadways and their continuity with the bridge roadway width can be an important consideration that may affect the definition of "tolerable" and thus rehabilitation potential. If the bridge roadway width is equal to that of the approaches and neither the bridge roadway width or approach roadway width meet current design requirements, the bridge may still be a candidate for rehabilitation until such time as the approach roads are also upgraded and as long as other considerations, like accident history, demonstrate adequate safety performance. This concept is being used increasingly by state DOTs to "right-size" projects.

Using Accident History to Understand Deficiencies

Accident reports are an extremely useful source of specific information about what geometric features of the bridge, if any, are problematic. It is important to review specific accident reports to determine what types of accidents are attributable to the bridge itself, including its geometric characteristics and its safety features. The reports are generally compiled by highway segment, not for a bridge alone, so accidents may not be related to bridge deficiencies. A nearby intersection, for instance, may have turning movement-related accidents. Since the intersection and bridge share a common highway segment, all accidents will be reported with the bridge, which may in fact be functioning adequately. The review of accident reports will also assist with assessing risk management.

Considerations for Improving Geometry and Safety Problems

Common problems associated with geometry and safety are many and include bridge width, shoulder width, clearances, stopping sight distances (or vertical and horizontal alignment of the approaches that results in insufficient stopping sight distances), superelevation, proximity to intersections, and railing/barrier design. Additionally, there can be safety problems related to substandard geometry and roadside features at the ends of the bridge, like the blunt ends of superstructures above the roadway, lack of a proper barrier system (length, inadequate transition, inadequate attachment to the bridge railing), and crashworthiness of bridge railings.

While not comprehensive, the following are important questions to consider. The relevance of particular questions will vary depending on site constraints.

- Can a bridge be widened without adversely affecting its scale (Figure 7)?
- Can the vertical clearance be increased to remain in scale with the bridge and not have an adverse effect?
- Does the original design make it possible to consider adding cantilevered deck sections (Figure 1)? Can sidewalks be cantilevered from the superstructure?
- Can substandard approaches be improved to an acceptable level using techniques like adding shoulders, flattening curves, flattening side slopes, adding superelevation, removing hazardous features, etc.?
- Likewise, can sight distance be improved?
- Can any sidewalks be eliminated to provide more roadway width?
- Can signals or signage be installed to control alternating flow of traffic on a low-volume road?
- When the proposed improvement is for a highway or street that is already substandard, can minimally acceptable standards/guidelines be used?
- Would a design exception result in maintaining the historic bridge and meeting the project goals?
- Can the roadway be reclassified?
- Can custom or context-based railings appropriate for the bridge type and setting be used (Figure 4)?
- Can a crashworthy traffic barrier be placed at the curb line, and the historic railing retained?
- Can the historic bridge be retained and used for pedestrian sidewalks/bikeway in combination with a new vehicular bridge using a funding source other than the Highway Bridge Replacement and Rehabilitation Program (HBRRP)? Using the historic bridge to maintain some of the functionality of the upgraded crossing may result in being able to keep it on-system and thus eligible for future maintenance funds.
- Can a parallel bridge be constructed to create a one-way pair? If so, visual changes should not be considered adverse when the historic bridge is preserved.
- Can the scale and proportions of a bridge contributing to a historic district be maintained by a new, replacement bridge and have no adverse affect to the district?
- Is it prudent to avoid use by constructing a bypass? This frequently means that the historic bridge will not remain on-system and will require a new owner.

Railings

Many railing systems and traffic barriers on historic bridges do not meet current safety standards for crashworthiness, minimum height, and adequacy of guardrails at the approaches, or the transition between the two systems. They are therefore evaluated as substandard and obsolete. Additionally, older railings may be deteriorated due to normal deterioration and deferred maintenance. On some, the opening size between individual rail components can create snagging hazards and pocketing problems that can result in unacceptable vehicular deceleration.

Crashworthiness is based on a railing's capability to effectively redirect an errant vehicle and to safely stop it in a controlled manner, and it is determined by conducting crash tests on full-scale railings in accordance with established guidelines. The AASHTO *LRFD Bridge Design Standards* have adopted the test levels specified in NCHRP Report 350, *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, which requires that railings on new bridges be crash tested. The test levels range from TL-1 for low volume, low speed local streets to TL-6 for heavy trucks with high centers of gravity and unfavorable site conditions.

Replication of historic railings to meet crash test requirements is difficult because the older railings were not designed for modern design impact loads. One approach is to find a crash-tested barrier, like the open balustrade Texas railing (T411) that can be modified to recreate the appearance of a historic design. Many configurations of railings have been crash tested, and approved railings can be found at the FHWA Safety Web site *http://safety.fhwa.dot.gov/roadway_dept/road_hardware/bridgerailings.htm* (Figure 5).

Some state agencies take a different approach to defining safe bridge railings by using the AASHTO *Standard Specifications for Highway Bridges, 17th Edition*. Deficient railings on existing bridges can be replaced using designs that defer to the historic shape while meeting safety and load requirements specified in the *Standard Specifications*. States like Oregon use this approach to construct new reinforced concrete railings that resist snagging and are capable of withstanding a 10,000 pound horizontal force and look like the historic railings they replaced. This approach, which is used with FHWA and SHPO concurrence, provides the opportunity to design new railings that are visually historic while meeting the design load requirements for railing strength. When railings are truly an important part of the historic value of a bridge, this approach should be considered.

Considerations for Improving Bridge Railings. Providing adequate traffic railings or barriers on historic bridges is a common problem. There are many effective practices for addressing substandard railings, including placing approved traffic railings in front of substandard ones or placing a traffic railing at the roadway curb line. Substandard historic railings can also be replaced with new, compatible designs that meet current safety standards. Whenever possible, new railings that defer to the original design should be determined to have no adverse effect on the historic bridge.

Some railing-related questions to consider are as follows:

- Can deficient railings be replaced "in kind" with no adverse effect, i.e., with a design that incorporates modern load and safety features with the historic design?
- Can an aesthetic, crash-tested design be used as an in-kind replacement (Figure 5)?

- Can crashworthy traffic railings be installed at the roadway, leaving the historic railings in place?
- Can an adequate guide rail system be placed in front of historic railings, which will be left in place?
- Can a stone parapet be rebuilt in reinforced concrete capable of meeting current codes and faced with a stone veneer that matches the historic pattern?
- Can members be added to increase height or reduce opening size?

Completion of Step 2

When the step 2 analysis of the engineering objectives has been completed, specific condition, load-carrying capacity, and geometry/safety deficiencies will have been identified. Methodologies for addressing the deficiencies will be fully understood as will their efficacy to meet the project need and purpose.

The next step is to evaluate the proposed actions against historical and any other environmental considerations. The engineering judgments will be balanced with historical and any other environmental considerations as well as costs, both initial and life cycle, to support the appropriate decision.

STEP 3: HISTORICAL AND ENVIRONMENTAL CONSIDERATIONS

While engineering issues and costs often drive the decision to rehabilitate or replace a historic bridge, they are not the only factors involved in the analysis and selection of the preferred alternative. Since passage of the NHPA and the US DOT Act in 1966 and NEPA in 1969, the federal government has established procedures affording those concerned with historic preservation opportunities to be a meaningful part of the analysis and decision-making process when historic properties are involved. This means that for projects to have credibility with multiple perspectives, it must be demonstrated that preservation and/or avoidance of an adverse effect has been fairly considered as part of the scoping and preliminary engineering studies, and that all possible planning to minimize harm to historic properties was done. This integration of historical and environmental issues has the greatest efficacy when it is done from the outset of the project.

Common Problems

There are many common problems associated with historical and environmental issues related to making decisions about historic bridge rehabilitation or replacement. They include, but are not limited to, the following:

- Not clearly understanding the historical significance of a bridge.
- Failure of preliminary scoping, preliminary engineering, and/or the NEPA process to incorporate federally required activities to assess effect or to demonstrate that there is no feasible and prudent alternative that does not involve using the historic bridge.
- Failure to demonstrate that all possible planning to minimize harm has been done.
- Failure to adequately consider the views of the public.

- Failure to match project need and purpose with actual conditions of the setting (context-sensitive-based).
- Inability to apply flexibility when it may be appropriate to achieve a balanced solution.
- Engineering prejudice against certain historic bridge types.

Approaches for Addressing Historic and Environmental Considerations

Since these guidelines are intended to balance historic preservation with engineering issues throughout the decision-making process, there is likely to be some overlap between steps 2 and 3 as consideration of some historical issues will have already been integrated into the analysis of the engineering data in step 2. Given the breadth and variety of historical and environmental issues, there may well be other factors that must be taken into account. This could include looking at engineering judgments from the environmental perspective, particularly non-construction methodologies. Considerations will vary from project to project depending on factors like bridge type, severity of deficiencies, setting or historic context, and other environmental issues.

The following are some of the commonly applicable historical and environmental considerations that, at a minimum, should be considered. This could include looking at selected engineering judgments from the environmental perspective:

- Are there additional environmental constraints like wetlands, historic archaeological sites, takings, or other NEPA issues that must be considered? If so, do they affect the feasibility of particular methods to rehabilitate or replace the bridge?
- Does the required work to address deficiencies exceed what is generally considered to be prudent? This includes cost and other effects to non-4(f) resources like communities or natural resources.
- Can the project goal be achieved without an adverse effect to historic properties?
- Is the SHPO placing too much emphasis on visual effect of proposed modifications at the expense of losing an opportunity to otherwise retain a historic bridge?
- With the understanding that safety cannot be compromised is rehabilitation possible using *de minimis* impacts or a design exception?
- Does the project meet the regulatory definition of adverse effect but still preserve what makes the bridge historic? In this instance it may be the feasible and prudent alternative even though it is determined to have an adverse effect.
- Is required work so extensive that, while feasible, it is not prudent given the initial cost and effect on a historic bridge?
- Are the engineering conclusions well supported? Was avoiding or not using the historic bridge considered?
- Can the project goal be achieved using minimally acceptable or tolerable design criteria?
- Can the roadway be reclassified to lower the definition of what is structurally and geometrically adequate?
- Is the project need and purpose statement appropriate to the setting? For example, is a 40'-wide bridge scoped for a project that has a lengthy 24'-wide approach roadway with no improved shoulders?
- Have non-construction alternatives to meeting the project goal been explored?

- Have the views and values of the community been appropriately addressed?
- Is preservation being used as the reason to resolve land use and zoning issues thus skewing the importance of the bridge to the detriment of sound engineering and/or safety?

Completion of Step 3

Completing step 3 will result in tempering engineering data and analysis with historical and environmental considerations and offer a clear understanding of the effect of any action on the historic bridge or other environmental considerations. It also results in knowing which methodologies will achieve the project goals of providing a safe and adequate facility while preserving what makes the bridge historic.

The next step is to determine the feasibility and prudence of the alternatives.

STEP 4: APPLYING THE DECISION-MAKING THRESHOLDS

Step 4 uses the aspects of adequacy – the structural and functional/safety factors – tempered with historic considerations to define when rehabilitation of a historic bridge can be considered feasible and prudent and when it can not. This is where the decision to rehabilitate or replace a historic bridge is supported and justified by applying the decision-making thresholds to the findings and conclusions from steps 1 through 3. Step 4 starts with understanding the meaning of prudent and feasible and moves to applying that understanding to the thresholds of adequacy to support the decision to rehabilitate or replace the historic bridge.

Defining Feasible and Prudent

The measure of the viability of any proposed alternative is whether it is feasible and prudent. What does feasible and prudent mean? From the engineering perspective, the technology exists to do almost anything given unlimited resources. Thus, much is possible or technically feasible, but is that action prudent? Resources are not unlimited, and there are other engineering and environmental concerns that affect decision making, like initial cost, life-cycle costs, and any additional environmental issues, from the presence of other historic properties or wetlands to extraordinary disruptions.

There is no inclusive definition of what is prudent and what is not; it varies from project to project based on its need and purpose and existing conditions. It is useful, however, to think of prudent as tempering feasibility with common sense and realistic constraints. Is it feasible, for example, to spend $5,000,000 to paint a long historic through truss bridge that is functionally and structurally inadequate and cannot be brought into conformance? Yes, it certainly is, but is it prudent to do so when the bridge will remain substandard? Does that judgement change when there are no long-range plans to replace the substandard bridge with one that meets current design and safety criteria? Is it then prudent to paint the bridge and do all that can be done using both construction and non-construction techniques to make it as adequate as possible?

To facilitate advancing projects through the NEPA process using a holistic approach, FHWA has defined a feasible and prudent alternative as one that "avoids using Section 4(f) property [like a historic bridge] and does not cause other severe problems of a magnitude that outweighs the importance of protecting the Section 4(f) property. In assessing the importance of protecting the Section 4(f) property, it is appropriate to consider the relative value of the resource to the preservation goals of the statute [23 U.S.C. 138 and 49 U.S.C. 303 and known as Section 4(f)]." Through codification (CFR 774.17(h)(1-5)), which at this writing is in the comment phase, FHWA provides six instances of when an alternative is not feasible and prudent:

1. It cannot be built as a matter of sound engineering judgment;
2. It compromises the project to a degree that it is unreasonable to proceed with the project in light of its stated purpose and need;
3. It results in severe safety or operational problems;
4. After reasonable mitigation, it causes severe impacts or disruptions to other resources, groups, communities or the environment;
5. Extraordinary initial and/or life cycle costs; and/or
6. Causes unique problems or other factors.

Life-cycle costs are one of the most frequently used factors in decision making. Agencies have limited resources, and choices must continually be made whether to utilize them on old bridges. There are some historic bridges where cost clearly is not an issue, like our landmark bridges or long bridges that will be rehabilitated without being considered for replacement. But those instances are few and far removed from the problems of allocating resources among the much more common shorter and average significance bridges. It is for these structures where initial construction and long-term maintenance costs are vitally important and often the deciding factor. Additionally, a bias that new is better than old often factors into decisions.

Once the issues related to load capacity, functional adequacy and environmental concerns have been addressed, the remaining question is "How much do initial cost (cost of rehabilitation) and life-cycle costs differ from that of a new bridge?" There are no hard and fast rules to answer that question, but it can be said with certainty that if the cost of rehabilitation is less than the cost of replacement, if the life-cycle costs are approximately equal to that of a new bridge, and if the life of the rehabilitation is on the order of 25 years, then rehabilitation can be easily justified even though a new bridge may have a life of 50 years or more. Experience shows that even if the cost of rehabilitation approaches the cost of replacement, as long as the cost of maintenance and the rehabilitation life remains reasonable, rehabilitation of the historic bridge is justified. Rehabilitation should not be considered if the maintenance costs are extremely high and if major work will be required in less than 25 years.

An important point to remember is that rehabilitation must correct the deficient features using methods that do not require constant maintenance. Selected materials and methods should be the best available and in conformance with generally accepted preservation and conservation guidance, even when cheaper and less long-lived methods are available. The prudent approach is to rehabilitate well so that the work does not need to be done again anytime soon and that maintenance costs are not abnormal.

Because existing conditions and the level of effort to make a historic bridge adequate vary from bridge to bridge, it is not possible to prescribe hard and quantitative rules as to when rehabilitation is feasible and prudent and when it is not. Decision making needs to be founded on a reasoned understanding of when the work needed to make a bridge adequate exceeds the benefits of such work. This includes balancing the cost and effect(s) with the historical and cultural significance of the bridge itself and the impact of the bridge work on other environmental considerations. The consideration of other environmental factors in a holistic manner may result in a sound and balanced decision that those other factors are more important than preservation of the historic bridge. Even though the bridge work is feasible, from the holistic perspective, it may not be prudent.

Application of Thresholds Based on Aspects of Adequacy

This step explains how to use the aspects of adequacy – the structural and functional/safety factors – to determine when rehabilitation of a historic bridge is feasible and prudent and when it is not. It is acknowledged that rehabilitation or replacement decisions are largely founded on the ability of a bridge to perform adequately based on aspects of functional and operational adequacy. At the same time, it must also be acknowledged that the adequacy thresholds are not the stand-alone definition of when replacement is the right decision. It is not appropriate to decide to replace a deficient, historic bridge unless all feasible and prudent means to address the deficiencies without adversely affecting what makes the bridge historic, as well as any other environmental constraints, have been fully analyzed and fairly evaluated in accordance with these guidelines.

Since rehabilitation or replacement decisions are largely founded on the feasibility and prudence of making the superstructure and substructure condition, load-carrying capacity, and geometry/safety features adequate, the thresholds defining when rehabilitation is the appropriate decision and when it is not are based on placing the bridge into one of six groups. These groups are derived from probable combinations of the three aspects of adequacy. Combinations that include bridges with inadequate superstructure and substructure condition and adequate load-carrying capacity are not included because it is unlikely that bridges with poor condition ratings would have an adequate load-carrying capacity. Within each of the six groups is guidance on when rehabilitation may be the appropriate decision and when it may not.

Group I.	Adequate:	Superstructure/Substructure Condition Load-Carrying Capacity Geometry
Group II.	Inadequate:	Geometry
	Adequate:	Superstructure/Substructure Condition Load-Carrying Capacity
Group III.	Inadequate:	Load-Carrying Capacity
	Adequate:	Superstructure/Substructure Condition Geometry

Group IV.	Inadequate:	Load-Carrying Capacity Geometry
	Adequate:	Superstructure/Substructure Condition
Group V.	Inadequate:	Load-Carrying Capacity Superstructure/Substructure Condition
	Adequate:	Geometry
Group VI.	Inadequate:	Load-Carrying Capacity Superstructure/Substructure Condition Geometry

From the engineering perspective, the threshold for defining when rehabilitation is the appropriate decision is a structural condition code value of 4 (Table 1). A condition code value of 4 (poor) will require further study to determine if there are feasible and prudent options for rehabilitation. Bridges with a code value of 5 (fair) or greater generally have rehabilitation potential.

A condition code value of 3 (serious) is unacceptable when and if the controlling member(s) cannot be sufficiently improved. If the controlling member(s) can be improved, then the bridge is considered to have rehabilitation potential despite its 3 or below rating. If the controlling member(s) cannot be improved without destroying what it is that makes the bridge historic, or if it is not feasible and prudent to do so, then the bridge is evaluated as not having rehabilitation potential for remaining in service.

Bridges with high and exceptional historical significance should be considered for rehabilitation based on a greater level of effort (level of engineering required, cost, etc.) because of their overriding historical significance. Even with more effort, some may not have rehabilitation potential. When there is no prudent or feasible way to keep a historic bridge in service without destroying what it is that makes it significant or finding an adaptive use, even at the higher level of effort, the bridge will not have preservation potential.

The thresholds described below have been presented in matrix form in Table 2.

Group I. Superstructure/Substructure Condition, Geometry, and Load-Carrying Capacity are Adequate

These bridges are generally in poor (4), fair (5), or satisfactory (6) structural condition and have adequate travelway width and alignment matching or exceeding that of the approaches. All bridges in this group have rehabilitation potential.

Group II. Geometry is Inadequate; Superstructure/Substructure Condition and Load-Carrying Capacity are Adequate

Many historic bridges are in this group because they were designed as one-lane or narrow, two-lane bridges, often without shoulders, and are not adequate by today's standards. In addition to being narrow, some are located on horizontal curves that cause sight distance and alignment problems. They may also have inadequate safety features like railings or barriers.

A bridge may be a good candidate for rehabilitation if widening and improving the deficiencies can be accomplished without destroying what makes the bridge historic in a manner that is feasible and prudent and without adversely affecting other environmental concerns like wetlands, historic districts, and/or archaeological resources.

Older bridges often have no shoulders carried through from the approaches. The bridge roadway width may or may not conform to the approaches. If the bridge lane width is equal to that of the approaches and neither meets design requirements, the bridge would be a candidate for preservation until such time as the approaches are upgraded and it can be demonstrated that accident data is low, sight distance is good, and speed is low.

The AASHTO green book, which serves as a design standard in many states, allows bridges to remain in place on local rural and rural collector roads and streets after an approach roadway improvement if they meet certain "tolerable" criteria. AASHTO's 2001 *Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT <400)* states that "existing bridges can remain in place without widening unless there is evidence of site-specific safety problems related to the width of the bridge." Bridges that meet a state's bridge roadway width standards and/or the AASHTO guidelines may have rehabilitation potential.

Based on supporting analysis and an evaluation that balances engineering with other environmental issues like historic preservation, bridges with inadequate geometry can be determined to have no rehabilitation potential under the following circumstances:

1. A bridge that has previously been widened or already has a cantilevered deck section and has no capacity for further widening to improve the substandard geometry.
2. A bridge that is too narrow for its current usage, has inadequate approach geometry (such as being on a sharp curve), and cannot be improved cost effectively.
3. A bridge that cannot be made geometrically adequate without destroying what it is that makes it historic.

Group III. Load-Carrying Capacity is Inadequate: Superstructure/Substructure Condition and Geometry are Adequate

Bridges that are in this group were originally designed for lighter loads than are currently acceptable. The superstructure and substructure may be in fair or better condition (condition rating of 5 or greater), but the bridge is simply not strong enough to support today's heavier vehicles. Those bridges that can be strengthened to increase load-carrying capacity without destroying what it is that makes it historic in a manner that is feasible and prudent have preservation potential. This includes using generally accepted methodologies for strengthening in a sensitive manner that does not alter the integrity of the original design of the bridge.

Local bridges that have or can be strengthened to an H15 load-carrying capacity and are on very low volume (<400 ADT) and low volume roads (less than 1000 ADT) with a low percentage of truck traffic (5% or less) and for which there is an appropriate bypass may have preservation potential.

If the reason for a low load-carrying capacity is not clear, the bridge should be considered to have rehabilitation potential until more in-depth evaluation into the deficiencies and specific analysis can be completed. Decisions need to be based on actual conditions, not assumptions, particularly when there are methodologies to determine these conditions.

Based on supporting analysis and evaluation that balances engineering with other environmental issues like historic preservation, bridges with inadequate load-carrying capacity can be determined to have no rehabilitation potential under the following circumstances:

1. A bridge that has no capacity to be strengthened or cannot be strengthened in a cost-effective manner.
2. A bridge with a high percentage of truck traffic that cannot be made adequate.

Group IV. Load-Carrying Capacity and Geometry are Inadequate; Superstructure/Substructure Condition is Adequate

Bridges in this group generally were originally designed for lighter loads and smaller vehicles with lower ADTs. In analyzing the bridges within this group, group II criteria should be used for geometry, and group III criteria should be used for load-carrying capacity. If the analysis of conditions of either or both groups indicates that a bridge cannot be made adequate without destroying its historical value or other environmental concerns, then rehabilitation may not be the feasible and prudent decision. Bridges that cannot be improved in a manner that is feasible and prudent so that both the geometry and the load-carrying capacity are adequate may be considered as not having rehabilitation potential.

Group V. Load-Carrying Capacity and Superstructure/Substructure Condition are Inadequate; Geometry is Adequate

Bridges that are in this group were originally designed for lighter load requirements (load-carrying capacity) and are deteriorated due to age or poor maintenance practice. These bridges will typically require some level of structural rehabilitation to improve their condition and load-carrying capacity. Sometimes the amount of work required is too great or the bridge type is one that cannot readily be repaired and/or strengthened, like reinforced concrete rigid frame and T-beam bridges. In analyzing the bridges within this group, group III criteria should be used for load-carrying capacity.

Bridges that cannot be improved in a feasible and prudent manner so that both the condition and the load-carrying capacity are adequate may be considered to not have rehabilitation potential.

Group VI. Superstructure/Substructure Condition, Geometry, and Load-Carrying Capacity are Inadequate

Bridges in this group are severely deteriorated and severely deficient. When a bridge is deficient in all categories and those deficiencies cannot be corrected in a feasible and prudent manner, it is very unlikely to have rehabilitation potential. The problems may be too great for keeping it on-system.

Superstructure / Substructure Condition	Load-Carrying Capacity	Geometry	Rehabilitation Potential
NBI Ratings ≥ 5	Capacity ≥ design requirements ***or*** Capacity sufficient to meet acceptable lower design requirements	Bridge can be widened ***or*** Approach deficiencies can be improved without destroying what makes bridge significant	Bridge **has** potential
		Bridge roadway width equal to approaches but does not meet design requirements ***or*** No site specific safety problems	Bridge **may** have potential
		Bridge has no ability to be widened or substandard geometry cannot be improved ***or*** Bridge is too narrow for current use, has inadequate approach geometry and cannot be improved in cost effective manner ***or*** Bridge cannot be made adequate without destroying what makes bridge significant	Bridge is **unlikely** to have potential
	Capacity < design requirements ***but*** Able to meet a lower capacity requirement in a cost effective manner	Bridge can be widened ***or*** Approach deficiences can be improved without destroying what makes bridge significant	Bridge **may** have potential
		Bridge roadway width equal to approaches but does not meet design requirements ***or*** No site specific safety problems	
		Bridge has no ability to be widened or substandard geometry cannot be improved ***or*** Bridge is too narrow for current use, has inadequate approach geometry and cannot be improved in cost effective manner ***or*** Bridge cannot be made adequate without destroying what makes bridge significant	Bridge is **unlikely** to have potential
	Capacity < design requirements ***and*** Unable to meet capacity requirements in a cost effective manner	Bridge can be widened ***or*** Approach deficiencies can be improved without destroying what makes bridge significant	Bridge is **unlikely** to have potential
		Bridge roadway width equal to approaches but does not meet design requirements ***or*** No site specific safety problems	
		Bridge has no ability to be widened or substandard geometry cannot be improved ***or*** Bridge is too narrow for current use, has inadequate approach geometry and cannot be improved in cost effective manner ***or*** Bridge cannot be made adequate without destroying what makes bridge significant	

2a. Rehabilitation potential for structures with NBI Ratings ≥ 5.

Table 2. Rehabilitation/Replacement Thresholds Based on Aspects of Adequacy. Table by Lichtenstein Consulting Engineers, Inc.

<table>
<tr><th>Superstructure / Substructure Condition</th><th>Load-Carrying Capacity</th><th>Geometry</th><th>Rehabilitation Potential</th></tr>
<tr><td rowspan="9">NBI Ratings = 3 or 4</td><td rowspan="3">Capacity ≥ design requirements
or
Capacity sufficient to meet acceptable lower design requirements</td><td>Bridge can be widened or
Approach deficiencies can be improved without destroying what makes bridge significant</td><td rowspan="2">Bridge <u>may</u> have potential</td></tr>
<tr><td>Bridge roadway width equal to approaches but does not meet design requirements or
No site specific safety problems</td></tr>
<tr><td>Bridge has no ability to be widened or substandard geometry cannot be improved
or
Bridge is too narrow for current use, has inadequate approach geometry and cannot be improved in cost effective manner or
Bridge cannot be made adequate without destroying what makes bridge significant</td><td>Bridge is <u>unlikely</u> to have potential</td></tr>
<tr><td rowspan="3">Capacity < design requirements
but
Able to meet a lower capacity requirement
in a cost effective manner</td><td>Bridge can be widened or
Approach deficiencies can be improved without destroying what makes bridge significant</td><td rowspan="2">Bridge <u>may</u> have potential</td></tr>
<tr><td>Bridge roadway width equal to approaches but does not meet design requirements or
No site specific safety problems</td></tr>
<tr><td>Bridge has no ability to be widened or substandard geometry cannot be improved
or
Bridge is too narrow for current use, has inadequate approach geometry and cannot be improved in cost effective manner or
Bridge cannot be made adequate without destroying what makes bridge significant</td><td>Bridge is <u>unlikely</u> to have potential</td></tr>
<tr><td rowspan="3">Capacity < design requirements
and
Unable to meet capacity requirements
in a cost effective manner</td><td>Bridge can be widened or
Approach deficiencies can be improved without destroying what makes bridge significant</td><td rowspan="3">Bridge is <u>unlikely</u> to have potential</td></tr>
<tr><td>Bridge roadway width equal to approaches but does not meet design requirements or
No site specific safety problems</td></tr>
<tr><td>Bridge has no ability to be widened or substandard geometry cannot be improved
or
Bridge is too narrow for current use, has inadequate approach geometry and cannot be improved in cost effective manner or
Bridge cannot be made adequate without destroying what makes bridge significant</td></tr>
</table>

2b. Rehabilitation potential for structures with NBI Ratings = 3 or 4.

Table 2. Rehabilitation/Replacement Thresholds Based on Aspects of Adequacy. Table by Lichtenstein Consulting Engineers, Inc.

Superstructure / Substructure Condition	Rehabilitation Potential
NBI Ratings ≤ 2	Bridge is **unlikely** to have potential unless controlling members can be upgraded in a cost effective manner. If controlling members can be upgraded cost effectively, rehabilitation potential should be considered as described for NBI ratings of 3 or 4 with regard to load-carrying capacity and geometry impacts.

2c. Rehabilitation potential for structures with NBI Ratings ≤ 2.

Table 2. Rehabilitation/Replacement Thresholds Based on Aspects of Adequacy. Table by Lichtenstein Consulting Engineers, Inc.

Endnote

1. Guidance on historical significance is generally part of states' historic bridge inventories and/or updates. The historic context narratives will explain why some bridges in statewide populations are significant. Additionally, individual bridge inventory forms or reports may address specific features for particular bridges as should any National Register of Historic Places nomination. NCHRP Project 25-25, Task 15 *A Context for Common Historic Bridge Types* (October, 2005) is useful as is Carl W. Condit's seminal two-volume work *American Building Art* published in 1961 by the Oxford University Press. For prestressed concrete, the Prestressed Concrete Institute's 1981 *Reflections on the Beginnings of Prestressed Concrete in America* is a good source.

APPENDIX A

LITERATURE SEARCH

The purpose of the literature search was to identify and critically review the professional literature and current practice, including those web sites, manuals, reports and protocols prepared by state departments of transportation, useful in the development of nationally applicable guidance for historic bridge rehabilitation analysis. Significantly, no literature was identified that systematically and scientifically addresses national guidance for deciding when to rehabilitate or replace historic bridges as a class.

Following is an annotated list summarizing the literature that was found to have the greatest general applicability to the development of guidelines for historic bridge rehabilitation analysis.

GENERAL OVERVIEW AND GUIDANCE

American Association of State Highway and Transportation *Officials, Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT<400).* Washington, DC (2001) 96 pp.

Now incorporated into AASHTO's *A Policy on Geometric Design of Highways and Streets,* also known as the *Green Book,* the guidance addressed the unique needs of very low-volume local roads and the geometric designs appropriate to meet those needs. The guidelines recommend an approach for both rehabilitation and new construction using safety risk assessment and design flexibility based on the experience of engineering professionals familiar with site conditions and local experience. The key elements in selecting an appropriate bridge width are width of the approach roadway (traveled way and shoulder widths) and safety performance of the existing bridge. The guidance states that a one-lane bridge is acceptable on a road with ADT<100 when the bridge can operate effectively.

Chamberlin, W. P., "Historic Bridges – Criteria for Decision Making." *NCHRP Synthesis of Highway Practice No. 101*, Transportation Research Board, National Research Council, Washington, DC (1983) 77 pp.

Establishment of National Bridge Inspection Standards and the Highway Bridge Replacement and Rehabilitation Program to upgrade bridges with sufficiency ratings of less than 50% placed old and historic bridges at risk because they are the ones most likely to have substandard geometry and/or load-carrying capacity. This pioneering synthesis examined state highway agencies' efforts to identify historic bridges and approaches to resolving inherent issues to preserve them. The conclusion of the 1983 study was that both identification and preservation of historic bridges varied greatly from state to state and few states had even considered a consistent approach for managing them.

Chamberlin, W. P., “Historic Highway Bridge Preservation Practices.” *NCHRP Synthesis of Highway Practice No. 275*, Transportation Research Board, National Research Council, Washington, DC (1999) 64 pp.

William Chamberlin’s excellent research and synthesis that summarizes the variety of methods state highway agencies use to manage their historic bridges remains definitive. It makes clear that addressing historic bridges is done to satisfy federal laws, but how historic bridges are managed and decisions are made is a state issue; there is not a national approach. In addition to explaining the laws and issues associated with preserving or replacing historic bridges, Chamberlin provides specific examples of various state approaches to bridge preservation, which illustrate superbly his point that methods vary greatly from formal, stand-alone documents to memoranda of agreement, protocols that outline a hierarchy of treatments to be considered, and unwritten but spoken understandings of how decisions will be made.

DeLony, E. and Klein, T. H., “Historic Bridges: A Heritage at Risk. A Report on a Workshop on the Preservation and Management of Historic Bridges. Washington, DC December 3-4, 2003.” SRI Foundation, Preservation Conference Series 1 (June 2004) 32 pp.

Report is a summary of the issues, initiatives and recommendations identified by a national panel of experts who gathered at a two-day workshop to define the issues confronting historic bridges. The goal of the workshop was to consider possible solutions for preserving “this heritage at risk.” The group produced ten specific recommendations to “streamline and enhance historic bridge preservation and management nationwide,” and those recommendations range from mandating states to do bridge-specific management plans to an NCHRP synthesis on rehabilitation verses replacement decision making. The report also includes synthesis of a 15-question survey sent to a variety of historic bridge stakeholders.

STATE TRANSPORTATION DEPARTMENTS – PLANS, PROGRAMS, AND MANUALS

Connecticut Department of Transportation, Office of Environmental Planning. “Connecticut Historic Bridge Inventory. Final Report: Preservation Plan.” Hartford, CT (1991) 206 pp.

As an outgrowth of the state’s historic highway bridge inventory, Connecticut’s preservation plan was designed to provide decision makers with a menu of options (no action, posting, by-pass, selective rehabilitation, major structural rehabilitation, relocation, replacement) with applicability to various historic bridge types and contexts, like bridges on the Merritt Parkway. While the plan does not establish specific decision-making criteria, it does provide rehabilitation guidance and preservation considerations applied individually to each of the 120 historic bridges in the state inventory.

Maine Department of Transportation, “Historic Bridge Management Plan.” 2 vols. (2004).

MDOT’s comprehensive management plan consists of several supporting work products including a report on appropriate treatments for historic bridge types and materials, a protocol for establishing level of significance (average, high, exceptional), a protocol for determining when

bridges have preservation potential and when they do not, and bridge specific plans that balance historic/environmental considerations with ability of the bridge to provide or be improved to meet current standards and design criteria. Engineering judgments are used to assess ability to achieve adequate level of service, geometry, capacity, condition, and long-term maintenance impacting the feasibility of preservation and rehabilitation.

Miller, A. B., Clark, K. M., and Grimes, M. C., "A Management Plan for Historic Bridges in Virginia." Virginia Transportation Research Council, Charlottesville, VA (2001) 127 pp.

The plan addresses the legal, engineering, regulatory, financial, and political issues that arise concerning the management of historic bridges and evaluates treatment and management options geared toward eliminating "...eliminates the need for costly and time-consuming bridges studies that can unnecessarily slow planning, construction, and rehabilitation projects." A bridge management database was developed with a system for rating significance levels and a matrix of possible treatments including repair and maintain for vehicular use, structural upgrade to VDOT standards, repair and maintain for adaptive use, transfer ownership, preventive maintenance, discontinue use, abandon, document and dismantle for future use, and document and demolish. The matrix was used to develop an individual management plan for approximately fifty state-owned historic bridges. The plan recommends the establishment of a historic bridge management fund and regularly scheduled updates to the management plan.

Ohio Department of Transportation, "Historic Bridges." Web site address: http://www.dot.state.oh.us/oes/hist_bridges.htm (As of March 16, 2007).

The website provides access to documents and data from ODOT's historic bridge program including programmatic agreements, preservation plans for truss and arch bridge types, a clearinghouse list of truss bridges available for relocation and adaptive re-use, state funding options for bridge rehabilitation, and a comprehensive list of the state's historic highway bridges, particularly useful to Ohio's many county and municipal bridge owners.

Texas Department of Transportation, Bridge Division, "Historic Bridge Manual." Revised (April 2006) 42 pp.

The manual "provides guidance on TxDOT-required coordination activities, funding restrictions, and reuse options to be considered when preserving historic bridges in the course of bridge replacement and rehabilitation projects." It contains minimum design criteria or thresholds for load and width for off-system bridges with ADT <251. Note that this is more stringent than AASHTO policy for the same classification of highway. Web site address: http://manuals/dot.state.tx.us (As of March 16, 2007).

Sparks, Patrick, P.E. "Guide to Evaluating Historic Iron & Steel Bridges." Prepared for the Texas Department of Transportation (December 2004).

The guide presents a nondestructive approach to evaluating metal truss bridges based on visual inspection, materials identification/characterization, and nondestructive testing and is intended to supplement other guides and standards. It also includes guidance on structural

analysis and a bibliography that is strong on metallurgy.

Vermont Agency of Transportation, "Vermont Historic Bridge Program." Web site address: http://www.aot.state.vt.us/progdev/Sections/LTF/VermontHistoricBridgeProgram/HBP00VermontHistoricBridgeProgram.htm (As of March 17, 2006).

The web site contains all of the pieces for this state's comprehensive approach to preservation and maintenance of historic bridges. It includes programmatic agreements defining how the program will work, development of bridge-specific studies to identify preservation potential, uses and treatments, and state design standards that balance engineering and impacts on natural resources, historic, scenic or other community values. The goal of each truss bridge plan is/was to identify preservation use and treatments, so there are no specific decision-making criteria or protocol. The Vermont program represents an exemplary agency commitment to rehabilitation being the rule rather than the exception with all of the pieces in place, from state design standards that tolerate "reasonable" widths and sight distances to financial incentives for towns. Consequently, its guidance is more process rather than rehab versus replacement decision making oriented. Their update of the approach to evolving plans for covered bridges represents an important movement to applying a holistic approach with emphasis on public education and involvement.

TECHNICAL LITERATURE

The technical papers published by professional societies, institutes, and agencies represent the largest body of detailed information on specific strategies for historic bridge rehabilitation. The available data tends to be project specific or specific to the study of particular bridge materials. It is often derived from conferences and designed to communicate the experiences and findings of practitioners to other practitioners, thus building up the professional knowledge base.

The technical literature is an important resource to inform the development of specific rehabilitation protocols as applied to specific bridge types, designs, and materials. The following are a list of some organizations that have published technical papers related to historic bridge rehabilitation, but it is not an exhaustive list.

American Concrete Institute (ACI)

The ACI publishes two journals (*ACI Materials Journal* and *ACI Structural Journal*) and a magazine (*Concrete International*) that feature research, analysis, and projects related to the development of the professional knowledge and application of concrete, including occasional papers on maintenance, repair, and historic analysis. Most of the information presented is project specific but there are some synopses of issues facing the rehabilitation of historic reinforced concrete. The ACI journals and magazine are indexed and abstracted. Web site address: http://www.concrete.org (As of March 16, 2007).

Examples:

Kemp, E. L., "An Introduction to the Structural Evaluation of Historic Reinforced Concrete Structures." *Concrete International*, Vol.1, No. 10 (Oct. 1979).

O'Connor, J. P., Cutts, J. M., Yates, G. R., and Olson, Carlton A., "Evaluation of Historic Concrete Structures." *Concrete International*, Vol.19, No. 8 (Aug. 1997).

American Society of Civil Engineers (ASCE)

Among the many useful ASCE publications are its *Conference Proceedings*, *Transactions*, *Journal of Bridge Engineering*, and *Journal of Materials in Civil Engineering*. Articles are abstracted and searchable on-line. Web site address: http://ascelibrary.aip.org (As of March 16, 2007). The application of the ASCE literature to specific bridge rehabilitation solutions is wide ranging and offers a body of professional experience treating most historic bridge types and materials. Articles offer strategies for addressing issues of structural analysis, load-carrying capacity, and rehabilitation techniques. Data is offered that has potential use in the establishment of specific rehabilitation protocols, e.g. reliable and proven methods of testing the strength of wrought-iron truss members, often resulting in higher than assumed strength.

Examples:

Gordon, R. and Knopf, R., "Evaluation of Wrought Iron for Continued Service in Historic Bridges." *Journal of Materials in Civil Engineering*, Vol. 17, No. 4 (July/August 2005), pp. 393-399.

Green, P. S., "Rehabilitation of a Nineteenth Century Cast and Wrought Iron Bridge." ASCE Structures Congress, Proceedings (1999), pp. 259-262.

Lamar, D. M. and Schafer, B. W., "Structural Analysis of Two Historic Covered Wooden Bridges." *Journal of Bridge Engineering*, Vol. 9, No. 6 (November/December 2004), pp. 623-633.

Pullaro, J., "Restoring Historic Bridges Using Modern Methods." ASCE Structures Congress, Proceedings (1999), pp. 263-267.

Association for Preservation Technology (APT)

The *APT Bulletin* publishes case studies and technical information in the field of historic preservation, including the history of building materials and state-of-the-art technical information for preservation. Many of the articles are derived from papers presented at the annual APT conference.

Examples:

Fischetti, D. C., “Conservation Case Study of the Cornish-Windsor Covered Bridge.” *APT Bulletin*, Vol. 23, No. 1 (1991), pp. 22-28.

Simpson, L., Guadette, P., and Slaton, D., “Centre Street Bridge Lions: Rehabilitation and Replication of Historic Concrete Sculpture.” *APT Bulletin*, Vol. 32, Nos. 2/3 (2001), pp. 13-20.

Sparks, S. P. and Badoux, M. E., “Non-destructive Evaluation of Historic Wrought-Iron Truss Bridge in New Braunfels, Texas.” *APT Bulletin*, Vol. 29, No. 1 (1998), pp. 5-10.

National Park Service. Technical Preservation Services. *Preservation Briefs*.

The National Park Service’s *Preservation Briefs* series offers general guidance on preserving, rehabilitating, and restoring historic buildings and structures. The briefs synthesize important and widely accepted professional guidance on the treatment of historic materials, much of it applicable to bridge rehabilitation approaches that meet the *Secretary of the Interior’s Standards*. Web site address: http://www.cr.nps.gov/hps/TPS/briefs/presbhom.htm (As of March 16, 2007).

Examples:

Coney, W. B., “Preservation of Historic Concrete, Problems and General Approaches.” Preservation Brief No. 15, National Park Service, Technical Preservation Services, Washington, DC (1987), 11 pp.

Mack, R. C. and Grimmer, A., “Assessing Cleaning and Water-Repellent Treatments for Historic Masonry Buildings.” Preservation Brief No. 1, National Park Service, Technical Preservation Services, Washington, DC (Revised, 2000), 17 pp.

Mack, R. C. and Speweik, J. P., “Repointing Mortar Joints in Historic Masonry Buildings.” Preservation Brief No. 2, National Park Service, Technical Preservation Services, Washington, DC (Revised, 1988), 21 pp.

Waite, J. G., “The Maintenance and Repair of Architectural Cast Iron.” Preservation Brief No. 27, National Park Service, Technical Preservation Services, Washington, DC (1991), 17 pp.

Weaver, M. E., “Removing Graffiti from Historic Masonry.” Preservation Brief No. 38, National Park Service, Technical Preservation Services, Washington, DC (1995), 15 pp.

APPENDIX B

SUMMARY OF RESPONSES TO QUESTIONNAIRE

Two questionnaires were developed to solicit information on the current state of practice regarding whether to rehabilitate or replace a historic bridge. One questionnaire was for historic bridge owners and state agencies, and the other for state historic preservation office (SHPO) personnel. They were sent to 49 engineers and environmentalists, including historians, preservationists, archaeologists, and managers, with county, state, federal transportation agencies and to SHPO offices. The purpose of the questionnaires was threefold: (1) to assess how decisions are made related to rehabilitation versus replacement of historic bridges, (2) to solicit suggestions on how to improve the process, and (3) to solicit data about decision-making that could inform the guidelines.

Twenty-one respondents from 17 states responded to the questionnaire. Three responses were from SHPOs, 17 responses were from state departments of transportation, and one response was from a county. Because of the small number of responses from SHPOs and the similarity in the questions asked in the two questionnaires, the results have been combined into a single discussion of each question. Where responses from SHPOs differ significantly from other responses, they have been specifically called out in the summaries below.

QUESTIONS AND RESPONSES

1. Do you consider your agency to be proactive in rehabilitation of historic bridges? If not, why not?

Ten of the respondents (roughly half) considered their agency to be proactive in rehabilitation of historic bridges. Reasons given for this included:

- the existence of multiple programs aimed at historic bridge preservation,
- pride in state heritage resulting in concentrated efforts to avoid replacement of historic bridges,
- state encouragement to consider rehabilitation and relocation of historic bridges,
- subprograms for historic bridges in condition assessment done as part of study to determine rehabilitation or replacement,
- active consideration for replacement if upgrading of historic bridge not feasible,
- the number of historic bridges that have been successfully rehabilitated, and
- transportation enhancement funds set aside to assist local governments in the rehabilitation of historic bridges.

Of the remaining respondents who did not identify their agency as proactive in rehabilitation of historic bridges, reasons given included:

- agency considers replacement to be better,
- not many rehabilitations have been done and agency has only recently begun to consider rehabilitation a viable option,
- rehabilitation is not the primary mission of the agency,
- financial considerations,

- engineering dominated decision making,
- rehabilitation is only considered when public input demands it,
- rehabilitation is considered a “last option,” and
- rehabilitation only considered if SHPO rules “No Adverse Affect”.

It is interesting to note that all of the engineers who responded as part of the survey considered their agency to be proactive, while only two of the ten historians who responded considered their agency to be proactive.

2. Do you have a written process/protocol that defines the decision-making process related to historic bridge treatments? Does it address all types of bridges or certain types like arches or trusses? Explain how it has or has not been successful.

Six respondents identified that their agency has a written process/protocol that defines the decision-making process. Three respondents indicated that their agency is currently working on a written process/protocol. Five of the nine respondents answered that their written process addresses all types of bridges, whereas the remaining three addressed covered bridges and metal truss bridges.

Of the nine respondents who currently have or are working on a written process, all thought that their agencies are or may be proactive.

3. If you do not have a written protocol, do you have an unwritten but spoken approach and is it consistently followed?

Three respondents indicated that their agency had an unwritten but spoken approach consistently followed. Of these three, only one considered their agency to be proactive.

4. How does your process decide one way or another between rehabilitation or replacement? What are the deciding factors? Is there a fair balance between historic preservation issues/ NEPA/Section 4(f) considerations and sound engineering or does one perspective dominate?

Eight respondents described the decision as a process specific to each bridge, usually dependent on structural condition and geometrics, as well as rehabilitation costs.

Seven respondents stated that the decision to rehabilitate or replace an historic bridge is based upon the results of NEPA, Section 106 and 4(f) processes and a finding of No Adverse Affect from the SHPO, with input from engineers regarding structure condition.

Only three respondents stated that the process followed a plan. Plans included a multi-variable ranking process and prescribed treatments for certain bridge types or specific bridges. In the case of one respondent, the process is plan specific for certain bridges, with the remainder of structures being decided on a case-by-case basis.

Two respondents described the process as decided on an individual basis, where rehabilitation usually is selected when the structure has an advocate or advocacy group pushing for rehabilitation.

Two respondents stated that the decision is based on structural condition and the ability to rehabilitate the bridge.

Identified deciding factors include (with number of times listed by respondents):

- cost (6)
- community input (5)
- SHPO/NEPA/Section 106/4(f) determination (4)
- engineering needs, such as ability to rehabilitate or maintenance of traffic (4)
- anticipated traffic (3)
- accident rates and other safety issues (3)
- historic significance (3)
- structural condition (2)
- geometrics (2)
- hazardous materials (1)

Eight respondents felt that there was a balance between historic preservation issues and sound engineering. It is interesting to note that all those who felt there was a balance were also those who thought their agency was proactive in rehabilitation of historic bridges. Only one of the respondents who felt there was a balance was part of an agency who did not have either a written or unwritten approach consistently followed.

Of those who felt that there is not a balance, engineering was always considered to dominate the situation.

5. Are you satisfied with the process in your state? How could it be improved?

Ten respondents were satisfied with the process in their state. Eight of the ten also had responded that their agency was either proactive or were not sure whether the agency was proactive as far as rehabilitating historic bridges. Of the ten respondents, all but two either have a written process or have an unwritten process consistently followed.

Eight respondents were not satisfied with the process in their state. Only two of these eight felt that their agency was proactive regarding rehabilitation of historic bridges.

Suggested improvements to the process included:

- integrate rehabilitation or replacement decision into the process at an earlier stage, not just at final design, so that there is more time to explore options,
- closer coordination between cultural resources staff, engineers and owners,
- evaluate all bridges for rehabilitation potential, not just the top tier or highest profile structures, based on either past historic bridge survey or in addition to the condition report, historic and engineering significance,
- examine structures on an individual basis, not as a group,

- publish a historic inventory on the web,
- engineering background in SHPO,
- provide more consistent SHPO review without subjective interpretations,
- create a dedicated fund for historic bridge management and rehabilitation,
- provide a clear-cut process with a formula to make the decision,
- provide more predictability through use of a management plan, and
- include preservation recommendations in the historic survey.

Several respondents believed that a centralized formulation for deciding the feasibility of rehab would promote preservation.

6. What information/methodology would be most helpful to making rehabilitation a more viable alternate and facilitate the decision-making process?

Seven respondents suggested a permanent record of research and case studies that would present successes and failures, the best practices and latest technology used in rehabilitation and preservation. Safety railings were singled out by some respondents as a component that should be particularly addressed.

Four respondents suggested that clearer guidelines regarding design exceptions and options other than replacement would be helpful.

Other suggestions included:

- provide a method that would allow for earlier evaluation of a structure's potential for rehabilitation prior to assignment of funding to replace the structure,
- publicize the presence of federal funding sources for rehabilitation, in addition to making more of these funds available,
- provide additional guidance regarding relocation, stabilization, and abandonment of structures,
- provide better definitions of what makes a bridge or bridge type historically significant and valuable,
- relax SHPO interpretations of Secretary of the Interior standards for preservation to consider rehabilitation not an adverse affect as long as the basic design and geometry is not altered, and
- provide policy guidance that is more forgiving of substandard features on low volume roads.

7. Does lack of designated funds or incentives outside the highway bridge rehabilitation replacement program factor into decision-making? If such assistance were available, would that likely change decisions?

Sixteen of 19 respondents felt that the lack of designated funds does factor into decision making. However, in light of this, only ten of fifteen respondents felt that additional assistance would change decisions. It would appear that the decision to rehabilitate historic bridges is in large part related to cost, but that cost is not the overriding factor.

8. Do projects involving historic bridges cause delays or other problems? Explain.

Twelve of 20 respondents felt that historic bridge projects do cause delays or other problems. Explanations given included:

- extensive coordination required between the public, the agency and the engineering consultant,
- the process is time consuming and has inconsistent review,
- repair options require historical assessment,
- section 106 and 4(f) processes,
- community objections to preservation treatments, and
- relocation of structures cause delays.

The eight respondents who felt that historic bridge project did not cause delays or other problems offered the following as explanations:

- Their agency has a streamlined process with FHWA and SHPO already on-board,
- Survey, review and management process is proactive in identifying historic bridges for rehabilitation,
- Agency is not willing to accept rehabilitation as an option, and
- Teams usually understand the scope of the project so that time delays are usually avoided

9. Are staff (consultants) encouraged to consider lesser or minimal acceptable criteria in order to accommodate rehabilitation rather than replacement or a context sensitive solution?

Respondents from proactive agencies or non-proactive agencies were evenly split regarding this question.

10. Are you comfortable with design flexibility? Why or why not?

Thirteen of 18 respondents felt comfortable with design flexibility. Reasons for this comfort included:

- some decisions are better based on subjective issues,
- design standards for their agency recognizes the need for flexibility,
- agency in-house expertise,
- strong dichotomy between modern requirements and service a rehabilitated historic bridge can provide, and
- guidelines have been set by state agency and AASHTO.

Reasons given by those not comfortable with design flexibility included:

- no clear guidance or precedents to compare or gauge decisions,
- structure must be able to meet an acceptable level regarding safety issues, weight limits and future development,
- flexibility not accepted by engineers within the agency,
- reluctance by agency to try solutions that have not been tested within the state, and

- liability-conscious agency.

11. Has FHWA's emphasis on context sensitive solutions and/or AASHTO's recent guidelines on geometric design of very low volume local roads affected bridge rehab or replacement decisions?

Thirteen of 19 respondents did not feel that the FHWA emphasis has affected decisions regarding rehabilitation or replacement.

12. Does your staff (consultants) have the knowledge and understanding to fairly assess rehabilitation potential?

Thirteen of 20 respondents believe their staff or consultants have the knowledge and understanding to fairly assess rehabilitation potential. Interestingly, for three states in which there were two respondents from different agencies within the state, the respondents did not feel the same way about this issue.

13. Which bridge deficiencies have proven to be the most difficult to address through rehabilitation? Please be specific.

The responses have been tabulated and are listed below, with the number of times mentioned by respondents in parentheses):

- Geometrics, such as roadway width, horizontal clearance, overhead clearances, lane widths and sight distance (17 respondents)
- Load capacity (10)
- Safety railings (7)
- Fatigue or fracture critical details (3)
- Waterway considerations (3)
- Material integrity due to deterioration (2)
- Replacement of substandard elements that cannot be replaced in kind (1)
- Lead paint abatement (1)
- Long term durability (1)
- Seismic retrofit (1)

14. What issues are important in determining whether a historic bridge is rehabilitated or replaced? Grade the following from a 1-5 with 5 being very important and 1 being least important: Cost, Functionality, Life cycle cost/long term maintenance of new vs. rehabilitated, Feeling that new is better than rehabilitated, Lack of confidence in staff or consultants being able to rehabilitate bridges, Public opinion, Other: please specify.

Among the six items requested for grading in the question, the average score (in order of most important to least important) was as follows:

- functionality (average score 4.33)
- public opinion (4.06)
- cost (3.75)

- life cycle cost/long term maintenance of new vs. rehabilitated (3.67)
- feeling that new is better than rehabilitated (2.82)
- lack of confidence in staff or consultants being able to rehabilitate bridges (1.88)

Several respondents listed additional items they considered important. These items are as follows (listed by one respondent unless otherwise noted), along with rating scores:

- Safety – listed by three respondents, with average rating 5.00
- Location – listed by three respondents, with average rating 3.33
- Historic Significance –rating 5.0
- Willingness for an entity to accept ownership and liability for bypassed or "orphaned" bridges – rating 5.0
- Traffic Volume – rating 4.0
- Environmental impact – rating 3.0
- Clear waterway of piers – rating 1.0

15. Do you have a bridge specific-historic bridge management plan that evaluates which historic bridges have preservation potential and which do not? If yes, has it been effective? Does it address all historic bridges or certain ones (type, condition, etc)? If no, is one being considered?

Six of 18 respondents do have a bridge-specific historic bridge management plan that evaluates the preservation potential of historic bridges. All six find the plan to be effective. Two of the six respondents identified their plan as addressing all bridge types, with the remaining four identifying specific structures or structure types. Structure types listed by the four respondents included covered bridges and metal truss bridges.

Of the twelve respondents that do not have a historic bridge management plan, seven are currently considering creating a plan.

16. Please provide additional comments that you would like to offer. A copy of any written procedure or protocol or a link to an electronic version would be greatly appreciated.

Aside from some web-based links where various agency documents could be found, few additional comments were received. However, two comments were received related to costs and funding. One respondent stated that making more funding available to local agencies for rehabilitation and maintenance of historic bridges would make a huge difference in retaining locally-owned historic bridges. The other respondent stated that monies for continued preservation needs must be redistributed to state and federal reserves so that they do not have to compete for funds with new construction projects.

A third respondent stated that saving bridges is unlikely unless there is local advocacy for the rehabilitation of an historic bridge.