A COMPREHENSIVE BRIDGE PRESERVATION PROGRAM TO EXTEND SERVICE LIFE

Bruce Johnson[1]

Abstract

Bridges represent a large investment in highway systems. As highway systems age, agencies should optimize the methods used to preserve this high value portion of the infrastructure and extend its useful life. In the US funding for highway preservation and modernization is decreasing at a time when the largest age group of bridges is nearing the end of their expected service life. The cost of replacement and major rehabilitation with modern traffic mobility issues and environmental mitigation is excessive. Most agency budgets are insufficient to maintain service levels without a major shift in management to a preservation focus that maximizes the useful service life of highway infrastructure. This paper presents the key elements of a comprehensive preservation program and provides an introduction to tools used to assess, evaluate, prioritize, and carry out actions that can be shown to be cost effective methods to extend service life.

Introduction

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

Bridge Preservation is a strategy which is intended to aid highway agencies in managing their bridge inventories at a critical stage where bridge needs are increasing and available funding is decreasing. In pavements, for example, a preservation strategy has been used which focuses on maintaining surface treatments in good condition in order to protect the highway substructure from costly damage. While bridges are more complex structures with greater variation in design- and damage can often result from conditions under the bridge as well as on upper surfaces- the intention of a well-managed and comprehensive bridge preservation program is both sound and timely.

Given that adopting a comprehensive bridge preservation program to extend service life to existing bridge inventory, much of which is close in age to its original design life is not without significant challenges and some limitations, it is possible to identify the components of an ideal system, while addressing the complications posed

[1] State Bridge Engineer, Oregon DOT (ODOT), Salem, Oregon, USA

by the "as is" conditions.

Even under ideal circumstances (e.g. starting with a new, rather than existing, bridge inventory), bridge preservation is just one component of successful bridge inventory management. Bridges will eventually require replacement and along the way, conditions may also necessitate major rehabilitation to address functional problems or deterioration based needs beyond what can be expected with typical preservation actions. However, even under less than ideal circumstances (e.g., existing inventory of predominantly advanced age), a comprehensive bridge preservation program has much to offer agencies in increasing the cost effectiveness of their bridge investments, maximizing the number of bridge needs addressed with a given level of investment and in prolonging the service life of the bridge inventory.

Bridge Preservation –Definition

Bridge preservation is defined as actions or strategies that prevent, delay or reduce deterioration of bridges or bridge elements, restore the function of existing bridges, keep bridges in good condition and extend their life. Preservation actions may be preventive or condition-driven.[2]

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

An effective bridge preservation program:

1) Employs long-term strategies and practices at the network level to preserve the condition of bridges and to extend their useful life;

2) Has sustained and adequate resources and funding sources; and

3) Has adequate tools and processes to ensure that the appropriate cost effective treatments are identified and applied at the appropriate time.

2 Ahmad, Anwar, 2012

FIGURE 1, BRIDGE ACTION CATEGORIES, PRESERVATION ALTERNATIVES

Comprehensive bridge preservation program

One of the challenges facing many bridge program managers is transitioning existing bridge management organizational structures currently in use within agencies to align successfully with a new model in which bridge preservation plays a prominent role in bridge inventory management.

A successful bridge program seeks a balanced approach to preservation and replacement. A focus only on replacing deficient bridges, while ignoring preservation needs, will be inefficient and cost-prohibitive in the long term. A traditional "worst first" approach to managing bridge assets may result in lower performance measures. A "worst first" approach allows bridges in good condition to deteriorate into the deficient category, which generally is associated with higher costs and more complex projects.

Organizationally, the "worst first" model is fairly simple- a staff of bridge designers is focused primarily on bridge replacement and a relatively small, and often independent, bridge maintenance function takes care of the routine maintenance needs of the bridge inventory. Successful adoption of a comprehensive bridge preservation program will require a new organizational paradigm- one in which bridge staff of all disciplines- inspection, design, maintenance and programming, are more highly integrated and focused on bridge preservation. In addition to organizational staffing issues; existing funding categories, performance measurement systems and program decision making processing may all be affected by an increased focus on bridge preservation.

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

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

FIGURE 2 *illustrates the difference between the hypothetical deterioration of bridge with and without preservation actions*. Physical deterioration of an element is a gradual process as illustrated by the curve A-B. Timely application of preservation actions, perhaps even shortly after the element is put into service, can extend the life of some elements as illustrated by the curve A-C. If preservation action occurs after some deterioration as indicated by curve A-D, improvement in condition may occur (D-E) followed by subsequent deterioration as illustrated by E-F. It is often possible to apply multiple cycles of preservation action in extending the life of an element, timely painting and subsequent repainting of steel being a good example.

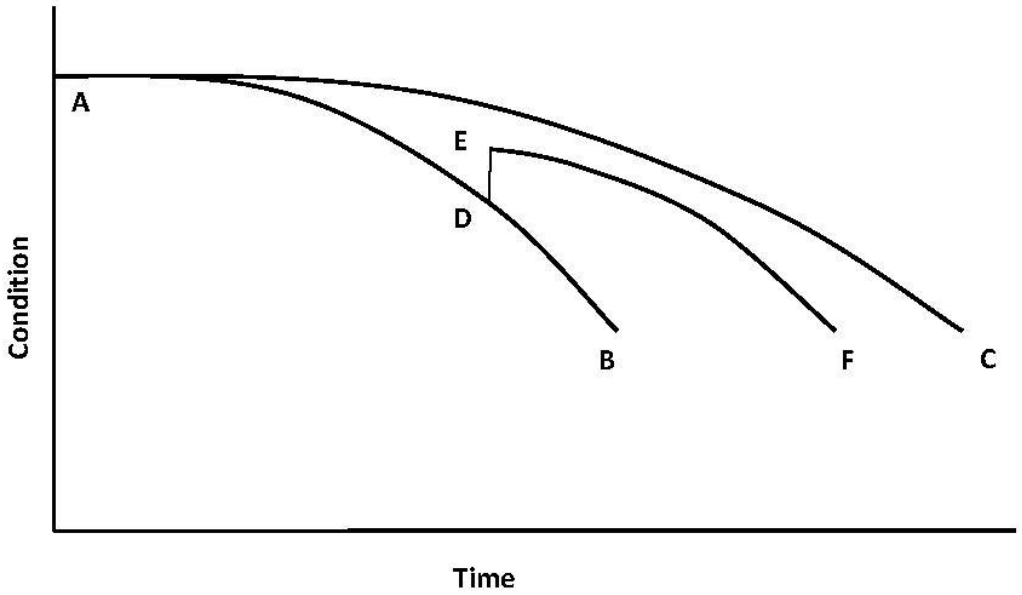

FIGURE 2, EFFECT OF PRESERVATION ON IDEALIZED CONDITION OVER TIME[3]

A successful bridge program is based on a strategic, systematic, and balanced approach to managing bridge preservation and replacement needs.

3 Johnston, David, 2013

Systematic Preventive Maintenance Program[4]

A systematic preventive maintenance program (SPMP) is one of the key processes in a comprehensive bridge preservation program. The following are features included in the SPMP.

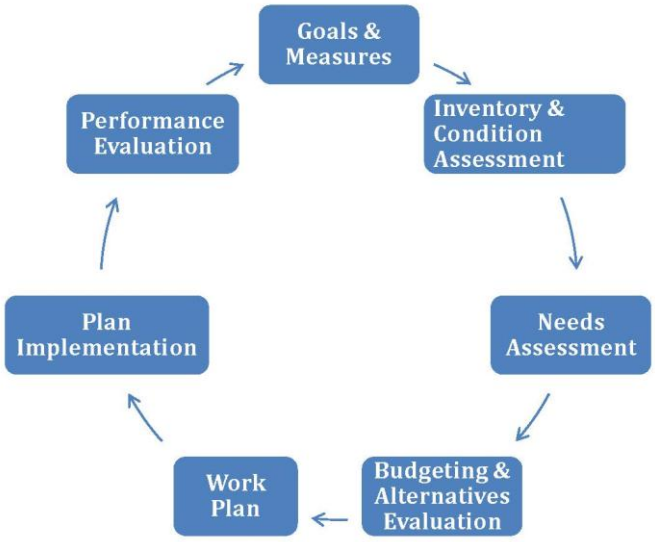

FIGURE 3, THE SYSTEMATIC PREVENTIVE MAINTENANCE PROCESS[5]

Systematic Preventive Maintenance Programs include both cyclic and event-driven activities. Examples of cyclic activities are shown in TABLE 1.

Cyclical PM Activity Examples	Commonly Used Frequencies (Years)[4]
Wash/clean bridge decks or entire bridge	1 to 2
Install deck overlay on concrete decks such as: - Thin bonded polymer system overlays - Asphalt overlays with waterproof membrane - Rigid overlays such as silica fume and latex modified	 10 to 15 10 to 15 20 to 25
Seal concrete decks with waterproofing penetrating sealant	3 to 5
Zone coat steel beam/girder ends	10 to 15
Lubricate bearing devices	2 to 4

TABLE 1, EXAMPLES OF CYCLIC PREVENTIVE MAINTENANCE ACTIONS[6]

4 Ahmad, Anwar, 2012
5 Ahmad, Anwar, 2012
6 Ahmad, Anwar, 2012

Oregon Example Bridge Program Strategy and Management

In Oregon, bridge conditions are projected to significantly deteriorate over the next several decades because of a combination of factors including reduced funding for preserving state bridges and a significant number of bridges reaching the end of their service life. The largest portion of the existing inventory was built prior to 1970; 1,500 bridges will reach the end of their design life by 2020. Of these "end of design life" bridges, approximately 27% are currently just one point away from structural deficiency as defined by FHWA. In 2011, ODOT leadership recognized that alternative bridge management strategies was be necessary to manage the deterioration while maintaining public safety and preserving as much of the public's investment as possible. The consequences of reduced bridge funding were identified as including potential condition and weight restriction levels that are route based, and a shift away from bridge replacements. Preparation of ODOT's maintenance staff for additional responsibilities would also be needed.

Initially, bridge service life was analyzed using three categories of bridges, based on the period of construction and importance to the highway network. These categories are: 1) high value coastal, historic and major river crossings, and border bridges; 2) bridges built during the 1950s and 60s and 3) all others. The second group of bridges were typically designed with very low safety factors and for loads much less than allowed by state law since the mid-1980s. It is not cost effective to preserve this group of bridges because of their weak elements, but neither is there funding to replace them. More recent service life analysis in Oregon has begun to refine bridge categories by material, design and environment.

FIGURE 4, OREGON DOT BRIDGE NEEDS BY DECADE

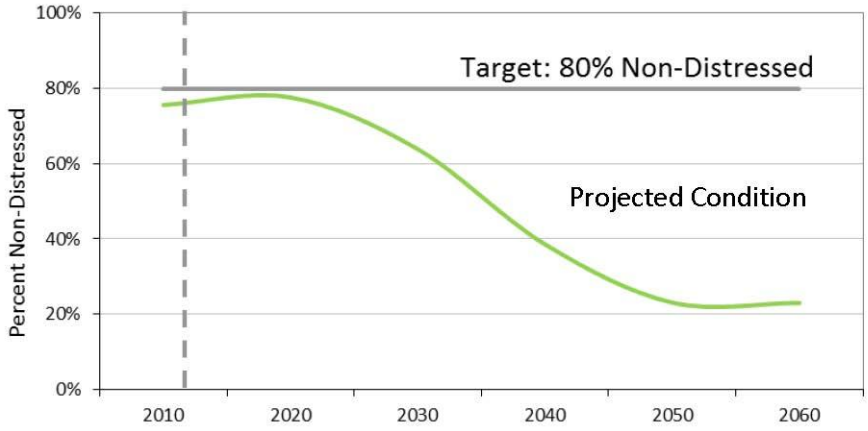

FIGURE 9, OREGON DOT PROJECTED BRIDGE CONDITION OVER 50 YEARS

ODOT adopted a bridge preservation strategy with seven goals. Chief among these are the following:

- Ensure the protection of high value coastal, historic and major river crossings, and border structures using timely preservation actions before cost becomes prohibitive.
- Give next priority to maintaining the highest priority freight corridors to ensure efficient freight movement.
- Develop a preventive maintenance program that will extend the service life of the deck and other structural components.
- Bring lower priority structurally deficient structures currently in Poor condition to Fair condition using a partial rehab scope of work.
- Use bridge inspection, health monitoring and improved deterioration prediction methods to anticipate future bridge conditions.

Although much work remains in Oregon to develop a comprehensive bridge preservation program, the groundwork has been laid. Most the rehabilitation work on the high value structures is being accomplished within our Statewide Transportation Improvement Program (STIP) using federal funds. Urgent and critical maintenance recommendations and work on low priority bridges in Poor condition are mainly addressed through Oregon's Major Bridge Maintenance (MBM) program, which is a smaller state-funded program. Other preservation activities, such as deck overlays, have been funded by both programs.

Current Research on Decision-Making for Bridge Preservation (NCHRP 14-23)

This promising research project seeks to begin to address many of the questions that arise in the implementation stage of a comprehensive bridge preservation program. It takes a pragmatic view of the key components that are needed to link existing systems and processes to the requirements of a successful bridge preservation program. The objective of the research under NCHRP Project 14-23 is to develop a handbook for possible adoption by AASHTO that will: 1) assemble a catalog of bridge element preservation actions; 2) quantify the benefits of bridge preservation actions; 3) provide decision-making tools to optimize bridge preservation actions; and 4) develop a method to determine appropriate levels of funding to achieve bridge agency selected goals and performance measure.

Current Research on Bridges for 100-Year Life (SHRP2 R19A)[7]

This long term study is already producing useful systems that will aid in the design for service life for a particular bridge element, system or subsystems. It suggests selecting feasible bridge systems and provides a method for analyzing these systems one at a time to identify the factors that influence the service life of bridge elements; identify failure modes and consequences; mitigation measures and assessment of risk

7 Azzizinamini, Atorod, 2013

through life cycle analysis. As an example TABLE 2 below shows the summary results of LCCA for four deck durability alternatives in an area of deicing salt use.

Alternative	Main Feature to address corrosion	Initial cost	Life cycle cost
AASHTO Base Design	N/A	$37,215	$774,676
1	Impermeable concrete using silica fume	$44,645	$277,550
2	Use of 316-stainless steel	$152,753	$152,753
3	Increasing concrete cover	$46,519	$691,114
4	Using membrane and overlay	$109,541	$172,252

TABLE 2, ALTERNATE DECK STRATEGIES FOR SERVICE LIFE SUMMARY[8]

Bridge Preservation Performance Measures

New performance measures are needed to support comprehensive bridge preservation programs. AASHTO and SCOPM have recognized the need for standard and consistent measures nationwide, but that provide adequate flexibility to states, local agencies and MPOs in setting performance targets and supporting the goals and communication needs of their own programs. As the sources of standard bridge data currently available are limited to NBI data, this data is the recommended source. Using NBI data to develop a "needs based" performance measure has been challenging due both to a lack of granularity and, in some cases, different divisions used as break points between categories. Below is an example of an NBI "needs based" performance measures illustrating the potential for target setting.

8 Azzizinamini, Arorod, 2013

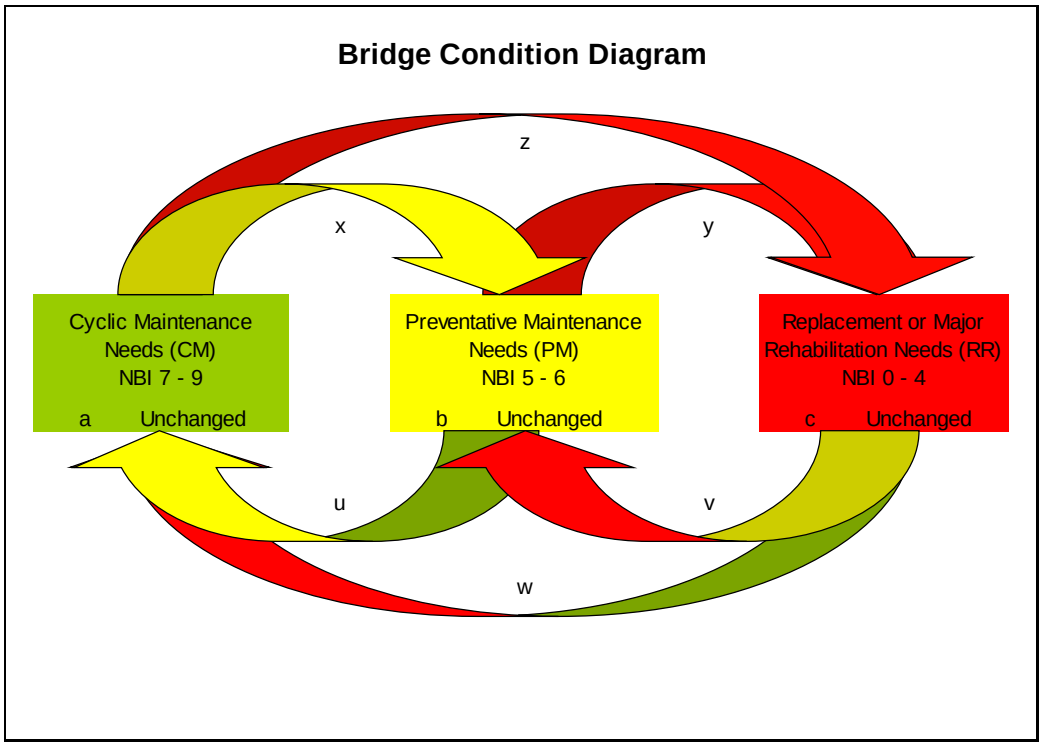

FIGURE 5, Measures can track for movement of bridge condition annually

Conclusions

A comprehensive systematic process is necessary to manage a large bridge inventory and to take full advantage of the service life extension potential of modern structures. Tools are currently available or are being developed to facilitate inspection, evaluation, selection of cost-effective preservation actions and monitoring performance of bridges and bridge elements. Tools are also available to estimate overall program funding levels to achieve a desired service level of highway bridges. Nevertheless, considerable challenge remains to bridge managers seeking to adopt a comprehensive bridge preservation program to achieve a best fit within an agency's overall bridge management system.

References

1. AASHTO, "Bridge Element Inspection Guide", 2013
2. Ahmad, Anwar, PE, FHWA "Bridge Preservation Guidelines", 2012
3. Azzizinamini, Atorod, PE, PhD, SRHP2 Project 19A Report and "Guidelines Design of Bridges for 100-year Life"
4. Bowling, Gary, PE, PLS, et al, "ODOT Inspection Manual", 2013
5. Bowling, Gary, PE, PLS, et al, "ODOT Bridge Inspection Coding Guide", 2013
6. Johnston, David, PhD, Michigan State University, personal communications and research in progress, 2013