Benefit-Cost Analysis: Showing the Value of Bridge Preservation

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As the nation once again debates a new national transportation bill, the condition of our highway bridges enters center stage. We all know that bridges are vital to our transportation networks, and we are challenged to manage them using the concepts of sound asset management. In Section 515.5 of Title 23, Highways, the Code of Federal Regulations (CFR)[1] defines asset management as follows:

> *A strategic and systematic process of operating, maintaining, and improving physical assets, with a focus on both engineering and economic analysis based upon quality information, to identify a structured sequence of maintenance, preservation, repair, rehabilitation, and replacement actions that will achieve and sustain a desired state of good repair over the life cycle of the assets at minimum practicable cost.*

The Federal Highway Administration's (FHWA's) *Bridge Preservation Guide*[2] defines maintenance, preservation, rehabilitation, and replacement actions. **Figure 1** lists the National Bridge Inventory (NBI)[3] condition-rating ranges and the terms associated with them for main bridge components. Bridge replacement includes the total replacement of a bridge. Bridge rehabilitation involves major work required to restore the structural integrity of a bridge, including partial or complete deck replacement, superstructure replacement, or major substructure repairs or partial replacement. Replacement and rehabilitation actions are typically done to bridges in poor condition, and the result is a bridge in good or fair condition.

	NBI Rating Scale (from 0 – 9)	9 8 7 Good	6 5 Fair	4 3 2 1 0 Poor
Bridge	Deck (Item 58)	≥7	5 or 6	≤4
Bridge	Superstructure (Item 59)	≥ 7	5 or 6	≤ 4
Bridge	Substructure (Item 60)	≥ 7	5 or 6	≤ 4
	Culvert (Item 62)	≥ 7	5 or 6	≤ 4

Figure 1. National Bridge Inventory (NBI) condition-rating categories for main components. Figure: Dave Juntunen.

Preservation actions are cost-effective means of extending the service life of a bridge, typically keeping a good bridge in good condition, and a fair bridge in fair condition. There are many examples of bridge preservation actions, including deck overlay, deck expansion joint replacement, deck patching, structural steel cleaning and coating, and sealing concrete superstructures. (See the Spring 2021 issue of *ASPIRE*® for a Perspective article on two forthcoming guides on bridge preservation from the American Association of State Highway and Transportation Officials.)

Figure 2 shows the bridge action categories available for bridge asset management. So, what is the best combination of these actions over the life of a bridge? This can be answered using a bridge management system (BMS). The FHWA Minimum Standards for Developing a Bridge Management System[4] state that a BMS for National Highway System pavement and bridge assets shall include documented procedures for the following:

- Collecting, processing, storing, and updating inventory and condition data
- Forecasting deterioration
- Determining the benefit-cost over the life cycle of assets to evaluate alternative actions
- Identifying short- and long-term budget needs for managing the condition of bridge assets
- Determining the strategies for identifying potential projects that maximize overall program benefits within the financial constraints
- Recommending programs and implementation schedules to manage the condition of bridge assets within policy and budget constraints

At the heart of an advanced BMS is benefit-cost analysis, where all possible combinations of actions

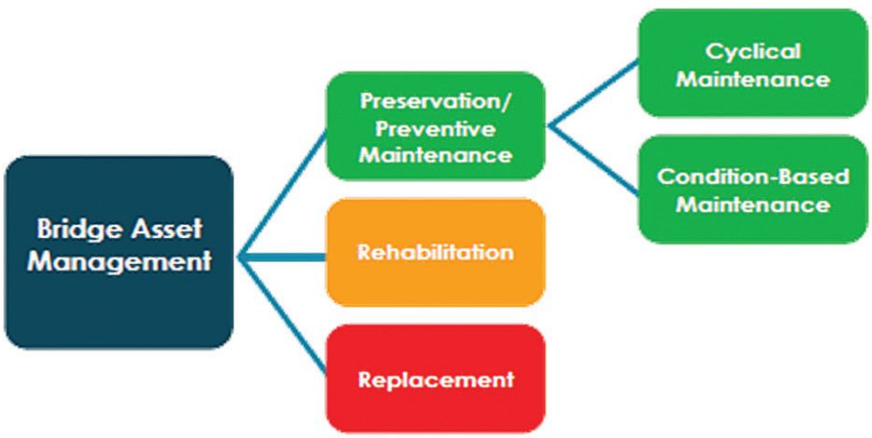

Figure 2. Effective bridge asset management includes a combination of the different types of bridge action categories. Source: Federal Highway Administration, 2018,[2] p. 3.

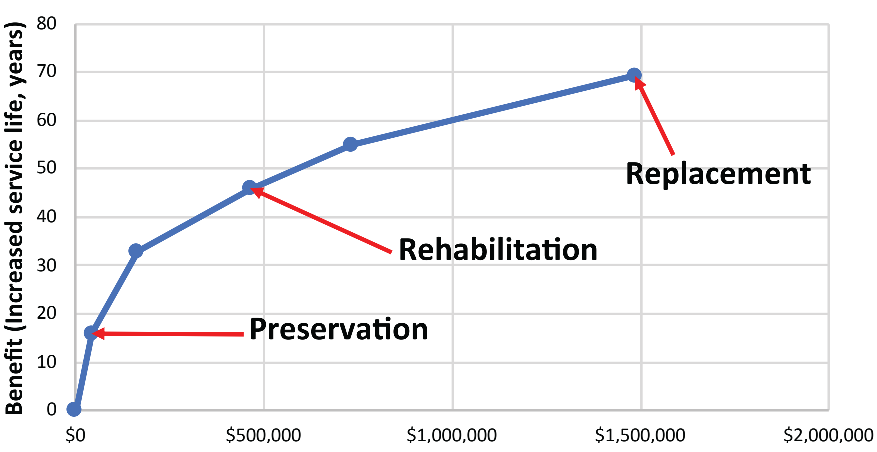

Figure 3. A benefit-cost comparison shows that well-chosen preservation actions can yield significant benefit at relatively low cost compared with rehabilitation or replacement projects. In this example, the benefit is measured in years of increased service life. Figure: Dave Juntunen.

(including no action) that can be taken for an individual bridge, or an entire network of bridges, can be compared over an analysis period to find the optimum treatment selections (actions). Proprietary software for BMSs, such as AASHTOWare Bridge Management, AgileAssets STRUCTURES ANALYST, and Deighton dTIMS, use concepts of benefit-cost analysis to optimize bridge asset management and strategic investment planning. Simply, this analysis begins by calculating the benefit-cost ratio for each possible action.

Any bridge manager can tell you that bridge preservation actions have an intrinsic value; however, it is not always obvious how to show this analytically. Fortunately, the tools available in BMSs and benefit-cost analysis can be used to show the value of bridge preservation. This is demonstrated in the following simple example, where we calculate and compare the benefit-cost ratio for a bridge replacement action and a bridge preservation action. BMSs have different methods to calculate benefit, which can be complex. For this example, we will simply measure benefit as added service life to the bridge and then use this measurement to calculate the benefit cost ratio ($\frac{B}{C}$) for two common bridge actions.

- Bridge replacement
  Added service life = 75 years
  Cost = $1.5 million

$$\frac{B}{C} = \frac{75}{1.5 \text{ million}} = 50 \text{ years per \$1 million}$$

- Bridge preservation action
  Deck overlay
  Added service life = 15 years
  Cost = $50,000

$$\frac{B}{C} = \frac{15}{0.05 \text{ million}} = 300 \text{ years per \$1 million}$$

We can see that the deck overlay action has a much higher benefit-cost ratio, which makes it the preferred action. When this type of analysis is done for all possible actions to all bridges in a network, mathematical procedures, such as incremental benefit-cost analysis or integer linear programming, can then be used to find the best combination of actions to maximize benefits given certain constraints, such as annual budget.

When benefit-cost analysis is done for a network of bridges, many owners have observed that well-chosen preservation actions frequently have higher benefit-cost ratios than rehabilitation or replacement projects, as shown in **Fig. 3**. A BMS can help determine the optimum portfolio of actions with the highest expected benefit within financial or other constraints.

BMSs and benefit-cost analyses are being used more frequently by state departments of transportation. Municipalities are also seeing the value of this type of management, which is not only limited to bridges. Agencies are starting to integrate bridge, pavement, sidewalk, stormwater, and other assets for overall infrastructure management. It is a great time to become familiar or reacquainted with benefit-cost analysis!

References

1. "Definitions." 2020. *Code of Federal Regulations* Title 23 Part 505.15.
2. U.S. Department of Transportation, Federal Highway Administration (FHWA). 2018. *Bridge Preservation Guide: Maintaining a Resilient Infrastructure to Preserve Mobility*. FHWA-HIF-18-022. Washington, DC: FHWA. https://www.fhwa.dot.gov/bridge/preservation/guide/guide.pdf.
3. FHWA. 2021. "National Bridge Inventory (NBI)." https://www.fhwa.dot.gov/bridge/nbi.cfm.
4. "Minimum Standards for Developing a Bridge Management System." 2020. *Code of Federal Regulations* Title 23 Part 515.17.