

# Bridge Management Systems and Performance Measures

Bridge management turns inspection data into investment decisions. This course explains the federal framework that now governs that process for National Highway System (NHS) bridges: the minimum standards for bridge management systems and the risk-based Transportation Asset Management Plan (TAMP) in 23 CFR Part 515, and the national bridge condition measures, targets, significant progress determinations and structurally deficient deck-area minimum in 23 CFR Part 490. It shows how element condition data and deterioration forecasting feed life-cycle planning, how FHWA's Bridge Preservation Guide connects preservation work types to condition, and how the bridge engineer's ratings ultimately become a state's reported Good and Poor percentages.

## Learning objectives

- Explain BMS components
- Use element data in deterioration models
- Link to asset management plans
- Apply federal bridge measures

## From worst-first to asset management

FHWA's 2018 *Bridge Preservation Guide: Maintaining a Resilient Infrastructure to Preserve Mobility* (FHWA-HIF-18-022) opens with the core problem of bridge management: owners face aging infrastructure, limited funds and increasing competition among highway assets. It states that a "worst-first" approach, focusing only on replacing poor bridges while ignoring the maintenance needs of good and fair bridges, is inefficient and cost-prohibitive in the long term. A successful program instead seeks a balanced approach to preservation and rehabilitation or replacement, adopted through systematic processes as part of overall asset management.

**The statutory shift.** The guide explains that for decades the Highway Bridge Replacement and Rehabilitation Program, later the Highway Bridge Program, was the primary federal bridge funding source, and that owners used its flexibility to fund preventive maintenance as well as rehabilitation and replacement. MAP-21 and the FAST Act recognized preservation as vital to achieving and sustaining a state of good repair; MAP-21 Section 1103 added preservation to the definition of construction in 23 U.S.C. 101, making it eligible for federal funds. Routine maintenance is not eligible (23 U.S.C. 116).

MAP-21 also brought, in the guide's words, transformative performance management and asset management requirements, codified in 23 U.S.C. 150 and 119. FHWA implemented them in two regulations that frame this course:

- **23 CFR Part 515, Asset Management Plans** (81 FR 73263, Oct. 24, 2016), which sets the processes and minimum content for each state's risk-based asset management plan and the minimum standards for bridge and pavement management systems.
- **23 CFR Part 490**, whose Subpart A sets target-setting, reporting and significant progress rules, and whose Subpart D (82 FR 5968, Jan. 18, 2017) defines the national measures for NHS bridge condition and the structurally deficient deck-area minimum.

**Definition of asset management.** Both the guide and 23 CFR 515.5 quote the statutory definition in 23 U.S.C. 101(a)(2): asset management is "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."

Every phrase matters to bridge engineers. "Quality information" means inspection data, which is why inspection accuracy (BR-I04, BR-I05, BR-I10) is an asset management issue. "Structured sequence" of actions means planning work types over time, not one project at a time. "Life cycle" and "minimum practicable cost" (defined in 515.5 as the lowest feasible cost to achieve the objective) mean the comparison is total cost over the asset's life, not first cost.

**What this course covers.** The components of a bridge management system and the federal minimum standards; element data and deterioration forecasting; the TAMP processes (performance gap analysis, life-cycle planning, risk management, financial plan, investment strategies); the national bridge measures and how they are computed; target setting and significant progress; the deck-area minimum and its penalty; and how preservation programs connect it all. Preservation programs are treated in depth in BR-DP01 and the SNBI data that will feed these systems in BR-S01 and BR-S02.

## What a bridge management system must do

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**Minimum standards.** 23 CFR 515.17 implements 23 U.S.C. 150(c)(3)(A)(i) by setting minimum standards for state bridge and pavement management systems. It states that these systems are not subject to FHWA certification under 515.13, but they must include, at a minimum, documented procedures for:

1. Collecting, processing, storing and updating inventory and condition data for all NHS pavement and bridge assets;
2. Forecasting deterioration for all NHS pavement and bridge assets;
3. Determining the benefit-cost over the life cycle of assets to evaluate alternative actions, *including no action decisions*, for managing condition;
4. Identifying short- and long-term budget needs;
5. Determining the strategies for identifying potential projects that maximize overall program benefits within the financial constraints; and
6. Recommending programs and implementation schedules to manage condition within policy and budget constraints.

These six procedures are, in effect, the functional definition of a BMS: *data, forecast, evaluate, budget, optimize and program*.

**Required use.** 515.7(g) requires states to use the best available data and, pursuant to 23 U.S.C. 150(c)(3)(A)(i), to use bridge and pavement management systems meeting 515.17 to analyze the condition of NHS pavements and bridges for developing and implementing the asset management plan. Management systems for other assets, such as signs, are optional.

**Scope of assets.** 515.5 defines "NHS pavements and bridges" to include NHS bridges carrying the NHS, including bridges that are part of ramps connecting to the NHS. "Bridge" takes the NBIS definition in 23 CFR 650.305. 515.9(b) requires the plan to include a summary listing of NHS pavement and bridge assets, *regardless of ownership*; 515.7(f) requires a process to obtain necessary data from other NHS owners in a collaborative and coordinated effort. That means local and toll-authority bridges on the NHS are in the state's plan even if the state does not own them.

**Data layer.** The inventory and condition data come from NBIS inspections. FHWA's Bridge Preservation Guide describes the two condition data types a BMS uses. NBI general condition ratings (GCRs) describe the in-place deck (Item 58), superstructure (59), substructure (60) and culvert (62) on a 0 (failed) to 9 (excellent) scale. Element condition states, from the AASHTO Manual for Bridge Element Inspection, assign each element's total quantity to four condition states (CS1 good, CS2

fair, CS3 poor, CS4 severe). The guide notes GCRs are too broad for determining specific activities on a bridge; if only GCRs are available, detailed scopes are needed to determine work and estimate cost. Element data are what allow a BMS to recommend specific actions such as recoating, joint seal replacement or deck patching.

**Elements.** The guide defines three element categories. National Bridge Elements (NBEs) are primary structural components needed to determine overall condition and safety: decks and slabs, railings, superstructures, substructures, bearings and culverts. Bridge Management Elements (BMEs) are components that support preservation of NBEs and the bridge: joints, approach slabs, wearing surfaces and protective systems. Agency Developed Elements (ADEs) are custom elements, either sub-elements of NBEs or BMEs or stand-alone. The guide's examples: a steel beam end ADE under an expansion joint, and a deck drain ADE to monitor scuppers and downspouts. It notes diaphragms in straight steel bridges are not NBEs, because they are not primary load-carrying elements, but can be added as ADEs.

**Why BMEs matter to management.** The guide emphasizes that in preservation, BMEs are maintained, repaired, replaced or retrofit to protect NBEs, and illustrates one BME protecting one NBE (a coating protecting a steel beam) and one BME protecting three (a joint protecting the deck, bearing and substructure). A BMS that tracks joint condition can trigger joint work before the beam ends and bearings beneath deteriorate. Element inspection is covered in BR-I04.

## Deterioration forecasting and benefit-cost

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**Requirement.** 515.17(b) requires documented procedures for forecasting deterioration of all NHS bridge assets, and 515.7(b)(2) requires the life-cycle planning process to identify deterioration models for each asset class or sub-group (optional for assets other than NHS pavements and bridges). Part 515 does not prescribe a modeling method.

**What a deterioration model does.** Conceptually, a deterioration model predicts how condition changes over time if no action is taken, and how actions change that trajectory. FHWA's Bridge Preservation Guide illustrates this with its "bridge condition over time" curve: preventive maintenance applied while a bridge is good or fair extends service life, achieving the greatest value from original construction by delaying rehabilitation or replacement; typically, once a component enters poor condition, preservation ends until it is rehabilitated back to good or fair, or replaced. A second figure compares a bridge without preservation, where debris and chemicals attack elements and shorten service life, to the same bridge with cyclical and condition-based maintenance, which lasts longer.

**Element data and models.** Because element data record the quantity in each condition state, a model can forecast how quantities migrate from CS1 toward CS4 over time. A widely used approach in bridge management software is probabilistic, estimating each year the fraction of an element's quantity that moves to a worse state. That is described here only as a general concept; agencies calibrate their own models from their inspection histories, and this course does not cite a specific model.

**Illustrative example.** As an illustration only, suppose an agency's data indicate that, with no action, roughly 10% of a steel protective coating's CS1 quantity moves to CS2 each year, and 5% of CS2 moves to CS3. A 10,000 sq ft coating that is all CS1 today would, under those assumed rates, have about 6,500 sq ft still in CS1 after four years, with the rest mostly in CS2 and a small amount in CS3. Spot painting the CS2 and CS3 areas resets them; doing nothing allows growing CS3 and CS4 quantities that eventually drive steel section loss and an NBE condition change. The numbers are invented; the point is that element-level forecasting connects specific actions to future condition.

**Benefit-cost including no action.** 515.17(c) requires procedures for determining benefit-cost over the life cycle to evaluate alternative actions, including no action. The Bridge Preservation Guide frames the benefit of preservation the same way: the goal is to slow deterioration and extend service life; longer life means lower annualized costs of rehabilitation or replacement;

preservation incurs costs, but lower annualized costs over the life of the structure are the monetized benefits, and programs are adopted and adjusted based on net benefits.

**Illustrative annualized comparison.** As an illustration with invented numbers: if a deck replaced for \$1,000,000 lasts 40 years without preservation, the simple annualized cost is \$25,000/year. If \$150,000 of sealing and overlays over its life extends it to 55 years, total cost is \$1,150,000 over 55 years, about \$20,900/year. A real analysis would discount future costs and include user costs, but the logic is the guide's: preservation is justified when it lowers life-cycle cost.

**Forecast quality depends on inspection quality.** A model calibrated on inconsistent ratings will forecast inconsistently. When one inspector codes CS2 what another codes CS3, apparent deterioration rates change. That is why the federal rules connect asset management to inspection quality, and why inspector training and QC (BR-I10) are management issues, not just inspection issues.

**Needs and optimization.** The remaining 515.17 procedures use the forecasts. Short- and long-term budget needs (d) are the cost of the actions the system recommends. Optimization (e) selects projects that maximize overall program benefits within the financial constraint. Programming (f) produces schedules within policy and budget constraints. The guide notes a BMS can run an unconstrained funding scenario, whose results, alongside actual work completed, can support maintaining or requesting funding.

## The TAMP: purpose, scope and required content

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**What it is.** 23 CFR 515.5 defines an asset management plan as a document describing how a state DOT will carry out asset management, including how it will make risk-based decisions from a long-term assessment of the NHS and lay out investment strategies to address condition and performance gaps, managing the network to achieve state targets for asset condition and system performance while managing risks, in a financially responsible manner, at minimum practicable cost over the life cycle. It is the risk-based plan required under 23 U.S.C. 119(e).

### Key definitions from 515.5.

- *Asset*: all physical highway infrastructure within the right-of-way, including pavements, bridges, tunnels, signs and ancillary structures.
- *Asset class and sub-group*: assets with the same characteristics and function (e.g., bridges), and specialized groups within a class.
- *Life-cycle cost*: cost of managing an asset class or sub-group for its whole life, from initial construction to replacement.
- *Performance gap*: gaps between current asset condition and state targets, and gaps in system performance best addressed by improving physical assets.
- *Risk*: "the positive or negative effects of uncertainty or variability upon agency objectives."
- *Work type*: initial construction, maintenance, preservation, rehabilitation and reconstruction.
- *Financial plan*: a long-term plan of 10 years or more estimating resources and expenditures.

### Minimum content (515.9(d)). The plan must discuss:

1. Asset management objectives, aligned with the agency mission and consistent with achieving a state of good repair at minimum practicable cost;
2. Measures and state targets for asset condition, including the 23 U.S.C. 150 measures for NHS pavements and bridges established in Part 490 (states may add supplemental measures);

3. A summary description of NHS pavement and bridge condition, regardless of ownership, based on the Part 490 measures and informed by Part 667 evaluations of facilities repeatedly damaged by emergency events;
4. Performance gap identification;
5. Life-cycle planning;
6. Risk management analysis, including Part 667 results;
7. Financial plan; and
8. Investment strategies.

**Other requirements.** The plan covers at least 10 years (515.9(e)). It must explain how investment strategies collectively support progress toward a state of good repair, improving or preserving condition and NHS performance, achieving the state's targets, and the national goals in 23 U.S.C. 150(b) (515.9(f)). It must describe how the analyses support the strategies (515.9(g)). It must be integrated into the transportation planning processes leading to the STIP (515.9(h)), made available to the public (515.9(i)), and approved by the head of the state DOT (515.9(k)). States may include other assets and other public roads; if they do, 515.9(l) requires a minimum level of analysis for those assets. The plan may consider critical infrastructure (515.9(m)), defined in 515.5 as facilities whose failure would debilitate economic security, energy security or public health or safety.

**Deadlines and updates.** 515.11 required an initial plan by April 30, 2018 and a complete plan with implementation documentation by June 30, 2019. 515.13(c) requires the plan and its development processes to be updated at least every 4 years. FHWA certifies the processes (within 90 days of submission, with a 90-day cure period for deficiencies) and makes an annual consistency determination, by July 31 each year after 2019, of whether the state has developed and implemented a plan consistent with 23 U.S.C. 119.

**Implementation evidence.** 515.13(b)(2)(i) states that FHWA considers the best evidence of implementation to be that, for the 12 months preceding the determination, the state's funding allocations are reasonably consistent with the plan's investment strategies, considering alignment between actual and planned investment by work type. Deviation may be accepted if due to extenuating circumstances beyond the state's reasonable control. In plain terms, if the TAMP says preservation, the state should be spending on preservation.

**Penalties.** Under 515.15, beginning October 1, 2019, if a state has not developed and implemented a consistent plan, the maximum federal share for National Highway Performance Program (NHPP) projects that fiscal year is reduced to 65 percent. Under 515.15(b), FHWA will not approve further NHPP-funded projects if the plan and the NHS pavement and bridge targets were not in place within 18 months after the effective date of the Part 490 pavement and bridge rule, with limited exceptions.

## The five TAMP processes

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23 CFR 515.7 requires each state to develop and use, at a minimum, five processes to prepare the plan. FHWA certifies these processes. Each has a direct bridge-engineering component.

**1. Performance gap analysis (515.7(a)).** Identifies deficiencies hindering progress toward improving or preserving the NHS and a state of good repair. It must address the state's condition targets for NHS pavements and bridges, gaps in NHS performance that affect pavements and bridges regardless of condition, and alternative strategies to close the gaps. For bridges, performance gaps regardless of condition might include load-posted or vertically restricted bridges that limit freight, which good condition ratings would not reveal.

**2. Life-cycle planning (515.7(b)).** Conducted at the network level for each asset class or sub-group. The regulation states the process should consider future changes in demand, current and future environmental conditions including extreme weather, climate change and seismic activity, and other factors affecting whole-of-life costs. It must include, at minimum: the condition targets; deterioration models for each class or sub-group (required for NHS pavements and bridges); potential work types across the whole life with relative unit costs; and a strategy for managing each class by minimizing life-cycle costs while achieving the targets. A state may propose excluding a sub-group if it can show no material adverse effect, for example because of few assets or low cost. The Bridge Preservation Guide describes life-cycle planning as evaluating different preservation actions and timing; different proportions of preservation, rehabilitation and replacement spending; and different funding levels, leading to a long-term strategy that minimizes life-cycle cost while maintaining desired condition.

**3. Risk management (515.7(c)).** Must produce: identification of risks to NHS pavement and bridge condition and NHS performance, including environmental risks (extreme weather, climate change, seismic activity) and recurring damage identified through Part 667 evaluations; assessment of likelihood and consequence; evaluation and prioritization; a mitigation plan for top risks; a monitoring approach; and a summary of Part 667 evaluations for NHS pavements and bridges. The regulation's examples of other risk categories are financial (budget uncertainty), operational (asset failure) and strategic (environmental compliance). For bridges, risks commonly considered include scour (BR-H01, BR-H02), seismic vulnerability (BR-E02), fracture-critical or nonredundant members (BR-F02), overheight impacts and funding uncertainty. The specific list is each state's choice.

**4. Financial plan (515.7(d)).** Identifies annual costs over at least 10 years and must produce: estimated cost of future work by state fiscal year and work type; estimated reasonably available funding by year (historical values may be used where uncertain); anticipated funding sources; and an estimate of the value of NHS pavement and bridge assets and the annual investment needed to maintain that value. The last item, asset valuation, ties bridge condition to an economic measure.

**5. Investment strategies (515.7(e)).** Must describe how strategies are influenced by the gap analysis, life-cycle planning, risk analysis and the financial plan. The strategies are what the state commits to fund, and what FHWA checks implementation against.

**Data and collaboration.** 515.7(f) requires obtaining data from other NHS owners; 515.7(g) requires best available data and use of 515.17-compliant management systems.

**Organizational integration.** 515.19 describes, as non-mandatory practices, integrating asset management into the agency's goals, conducting periodic self-assessments of capability (strategic goals, consideration in STIP planning, program delivery and cost tracking, data collection and analysis), and conducting a gap analysis of organizational performance with strategies and timelines to close gaps.

**Where the bridge engineer fits.** The bridge unit typically supplies inventory and condition data, deterioration assumptions, work-type definitions and unit costs, bridge risks, and project-level scopes that implement the strategies. Inaccurate unit costs or unrealistic deterioration assumptions propagate directly into the plan's investment strategies and financial plan.

## National bridge condition measures

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**Applicability.** 23 CFR 490 Subpart D implements 23 U.S.C. 150(c)(3)(A)(ii)(III), requiring measures for states and metropolitan planning organizations (MPOs) to assess the condition of bridges carrying the NHS, including on- and off-ramps connected to the NHS (490.401, 490.403). Bridges over the NHS but not carrying it are not covered.

**Three classifications, two measures.** 490.407(a) establishes three classifications: percentage of NHS bridges in Good, Fair and Poor condition. Under 490.407(c), two are the performance measures used to carry out the NHPP: **percentage in Good condition** and **percentage in Poor condition**. Fair is computed but is not a target measure.

**Classification rule (490.409(b)).** Classification is based on condition ratings for NBI Items 58 Deck, 59 Superstructure, 60 Substructure and 62 Culverts, using the minimum-of-condition-ratings method:

- **Good:** the lowest of Items 58, 59 and 60 is 7, 8 or 9 (or Item 62 is 7, 8 or 9 for a culvert).
- **Fair:** the lowest is 5 or 6.
- **Poor:** the lowest is 4 or below.

FHWA's Bridge Preservation Guide restates these same classifications.

**Deck-area weighting.** The measures are not bridge counts. 490.409(c) computes each percentage, reported to one tenth of a percent, as the sum of deck areas (NBI Item 49 Structure Length times Item 52 Deck Width) of bridges in that class divided by the total deck area of applicable bridges. For culverts where the roadway is on fill and headwalls do not affect traffic, Item 32 Approach Roadway Width is used in place of deck width. A single large Poor bridge can move a state's Poor percentage more than many small ones.

**Illustrative calculation.** As an illustration with invented numbers, a state has NHS bridges totaling 50,000,000 sq ft of deck. Bridges classified Good total 22,500,000 sq ft and Poor total 2,000,000 sq ft. The Good measure is 45.0% and Poor is 4.0%; Fair, by difference, is 51.0%. If a single 600,000 sq ft river crossing drops from a superstructure rating of 5 to 4, Poor rises to 5.2%, an increase of 1.2 points from one bridge.

**Why minimum-of-ratings matters.** Because the lowest component governs, a bridge with a deck rated 4 and superstructure and substructure rated 7 is Poor. Deck replacement alone would move it to Good if the deck is then rated 7 or better. This makes deck condition a powerful lever in state measures, and is one reason deck preservation (BR-DP02) gets attention in TAMPs.

**Inspector consequences.** The rating an inspector assigns to Items 58, 59, 60 or 62 directly sets the bridge's national classification. The boundary ratings, 7 versus 6 and 5 versus 4, are especially consequential. Consistent application of rating definitions (BR-I05) is therefore essential not only for safety but for accurate federal reporting. Ratings must reflect condition, never targets; BR-X01 discusses the ethical side of pressure on ratings.

**Data source.** 490.409(e) states the items are those in the Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges, incorporated by reference. With the transition to the Specifications for the National Bridge Inventory (BR-S01, BR-S02), engineers should confirm how the current regulation maps to SNBI data items; the eCFR text obtained for this course still references Coding Guide item numbers.

## Targets, reporting and significant progress

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**Who sets targets.** Under 23 CFR 490.105(c)(3), states and MPOs whose boundaries include NHS bridges must establish targets for both bridge measures in 490.407(c). Under 490.105(d), targets must represent the network regardless of ownership, including bridges crossing state borders. State targets are statewide; MPO targets cover the metropolitan planning area.

**Performance periods.** Per 490.105(e)(4), for the bridge measures a performance period begins January 1 of the year the Baseline Performance Period Report is due and lasts 4 years. The midpoint is 2 years in. States set **2-year targets** reflecting

anticipated condition at the midpoint and **4-year targets** for the end of the period.

**Biennial reporting.** 490.107(b) requires states to report baseline condition at the beginning of a period and progress at the midpoint and end, an ongoing 2-year frequency, using an FHWA electronic template. The Baseline Performance Period Report is due October 1 of the first year of a period; the first was due October 1, 2018, with subsequent baseline reports every 4 years thereafter. It must include the 2- and 4-year targets with the basis for each, baseline condition, and a discussion of how targets support longer-range plans, such as the asset management plan and the long-range statewide transportation plan.

**Significant progress.** Under 490.109, FHWA determines at the midpoint and end of each period whether a state has made significant progress toward each target, separately. For NHS bridge measures, it uses NBI data as of June 15 of the determination year. Per 490.109(e)(2), a state makes significant progress on a target if either the actual condition is better than the baseline, or the actual condition is equal to or better than the target. A state is deemed not to have made progress if it fails to submit required reports or targets or if its data are not cleared in the NBI by the extraction date. FHWA considers documented extenuating circumstances.

**Consequence.** Under 490.109(f)(1)(iii), if significant progress is not made for either NHS bridge target, the state must document in its next Biennial Performance Report the actions it will take to achieve the bridge targets.

**Illustrative interpretation.** As an illustration with invented numbers, a state's baseline Poor percentage is 4.0% and its 4-year target is 5.0%, reflecting expected deterioration under available funding. At the end of the period Poor is 4.6%. That is worse than baseline but better than the target, so the state has made significant progress on that measure. If Poor were 5.3%, worse than both, the state would have to document actions to achieve the target. Note that "better" for Poor means lower and for Good means higher.

**Targets and the TAMP.** 515.9(d)(2) requires the TAMP to include the Part 490 measures and targets, and 515.9(j) clarifies that including them does not relieve the state of Part 490 reporting. The life-cycle planning and financial plan should make the targets realistic: a target is not a wish but the condition the state expects to achieve with its investment strategy.

**MPOs.** MPOs set their own targets under 490.105(f) and report through their planning documents. Bridge engineers working with MPOs should recognize that MPO targets usually support or adopt the state's.

## Structurally deficient deck area minimum and penalty

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**Definition.** 23 CFR 490.405 and 490.411(b) define structurally deficient for purposes of the minimum condition requirement. Beginning with calendar year 2018 and thereafter, a bridge is classified as structurally deficient when one of NBI Items 58 Deck, 59 Superstructure, 60 Substructure or 62 Culverts is 4 or less. Before 2018, the definition also included Item 67 Structural Evaluation or Item 71 Waterway Adequacy rated 2 or less. Under the current definition, a structurally deficient NHS bridge is therefore one classified as Poor.

**Minimum level.** 490.411(a) requires states to maintain bridges so that the percentage of the deck area of NHS bridges classified as structurally deficient does not exceed **10.0 percent**. It applies to bridges carrying the NHS, including ramps, and NHS bridges crossing a state border.

**Calculation and timing.** FHWA computes the ratio of structurally deficient deck area to total NHS bridge deck area for each state, to one tenth of a percent, using Item 49 length and Item 52 deck width (Item 32 for qualifying culverts). Under 490.411(d), FHWA determines this annually from NBI data cleared as of June 15 and notifies states of compliance with 23

U.S.C. 119(f)(2) before October 1. Under 490.411(e), states must submit their most current NBI data to FHWA no later than March 15 each year.

**Penalty.** 490.413(a) states that if FHWA determines that, for the 3-year period preceding the determination, more than 10.0 percent of the state's NHS bridge deck area is structurally deficient, then during the following fiscal year the state must obligate and set aside an amount equal to 50 percent of the funds apportioned to the state for fiscal year 2009 under the former 23 U.S.C. 144 (the Highway Bridge Program), from NHPP apportionments, only for eligible projects on NHS bridges. The set-aside continues each year until less than 10 percent of NHS bridge deck area is structurally deficient. FHWA made the first determination by October 1, 2016.

**Interpretation.** The penalty does not reduce total funding; it constrains its use, forcing money to NHS bridges. But it removes flexibility to balance pavements and bridges, which is why states track their structurally deficient deck area closely.

**Illustrative check.** As an illustration with invented numbers: a state with 30,000,000 sq ft of NHS bridge deck and 2,400,000 sq ft structurally deficient is at 8.0%, below the 10.0% minimum. If two large bridges totaling 900,000 sq ft drop to a 4 rating, it reaches 11.0%. If that persisted for the 3-year period FHWA evaluates, the set-aside would apply.

**Data timing for engineers.** Because FHWA uses NBI data cleared as of June 15, and states submit by March 15, the timing of inspections and of rating changes after repairs matters. A bridge repaired in January but not re-inspected and re-rated until autumn may still count as Poor in that year's data. Agencies sometimes schedule post-construction inspections to update ratings promptly. The underlying rule is simple: ratings must reflect the condition observed, updated when the condition changes.

**Relation to Good/Poor measures.** The 10% minimum is a floor that applies regardless of a state's own Poor target. A state could set a Poor target of 6% and meet it, while still needing to stay below 10% structurally deficient by deck area over the 3-year evaluation.

## Preservation, work types and federal eligibility

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FHWA's Bridge Preservation Guide supplies the vocabulary that connects BMS recommendations to fundable work. Its figure of bridge action categories places maintenance (routine and preventive), preservation, rehabilitation and replacement within bridge asset management.

### Definitions.

- *Maintenance:* work to maintain the system or respond to conditions or events to restore functional operation. It includes routine and preventive maintenance.
- *Routine maintenance:* work performed in reaction to an event, season or short-term operational need, without preservation value. Examples: trash and dead animal removal, snow removal and deicing, graffiti removal, hazardous material removal, asphalt patching with no membrane on a concrete deck, and accident or storm damage. Not federally eligible.
- *Bridge preservation:* actions or strategies that prevent, delay or reduce deterioration of bridges or elements, restore function, keep bridges in good or fair condition, and extend service life. May be cyclic or condition-driven.
- *Preventive maintenance:* a cost-effective means of extending service life by applying treatments to elements, including cyclical and condition-based activities.
- *Cyclical maintenance:* performed on predetermined intervals. Examples: cleaning and washing decks and super/substructure, flushing drains, cleaning joints, deck/parapet/rail and crack sealing, and sealing concrete.

- *Condition-based maintenance*: performed in response to known defects identified through inspection. Examples include drain repair, joint seal replacement, joint repair or elimination, electrochemical extraction and cathodic protection, deck repair with overlays, deck overlays, approach slab repair, superstructure patching and coatings, spot/zone/full painting, steel member repair, fatigue crack mitigation, bearing restoration, movable bridge machinery work, substructure patching and coatings, pile jackets and wraps, channel cleaning and scour countermeasures.
- *Rehabilitation*: major work to restore structural integrity or correct major safety defects (citing 23 CFR 650.403(c)), such as deck or superstructure replacement and substructure strengthening.
- *Replacement*: total replacement with a new facility in the same corridor, meeting current standards.

**Eligibility summary.** The guide's Table 4: routine maintenance is not eligible for federal funds; cyclical and condition-based preservation, rehabilitation and replacement are eligible.

**Condition mapping.** The guide's performance figure (attributed to FHWA's Raj Ailaney) aligns work with condition: cyclic maintenance for NBI 9, 8, 7 or element CS1; condition-based maintenance for NBI 6, 5 or CS2 and CS3; rehabilitation or replacement for NBI 4 or below or CS4. That matches the Part 490 classes: Good bridges are candidates for cyclic preservation, Fair for condition-based, Poor for rehabilitation or replacement.

**The halo effect.** The guide explains a caution relevant to condition-based deck repair: when delaminated concrete is removed and replaced with chloride-free repair material, high chloride concentrations in surrounding concrete can drive rapid corrosion around the patch. That is why its examples pair deck repair with overlays, cathodic protection or electrochemical extraction. Deck work is covered in BR-DP02 and BR-C02.

**Condition-based work and ratings.** The guide notes condition-based maintenance improves the condition of the treated portion but may or may not raise the component rating. Its example: a substructure rated fair for spalls and exposed reinforcement was rerated good after loose concrete was removed, steel cleaned and new concrete placed. For Part 490 measures, only a component rating change moves a bridge between classes.

**Design life versus service life.** The guide defines design life as the period a component or bridge is expected to function when designed, constructed and maintained per standards, and service life as the period it actually provides the desired function with appropriate preservation. It states that a steadfast preservation program and quality workmanship during service life are necessary for an asset to reach its design life.

## Building and measuring a preservation program

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FHWA's Bridge Preservation Guide describes a bridge preservation program as performing cost-effective cyclical and condition-based preventive maintenance to prolong service life and delay rehabilitation or replacement. It says establishing one can be simple: start by cyclically cleaning or washing good and fair bridges and add activities as the program develops. Its eleven steps:

1. Identify agency goals and objectives.
2. Identify bridges to preserve: those where preservation is feasible and beneficial, in good or fair condition, with adequate load capacity and continuing to meet traffic demands.
3. Develop a list of cyclical and condition-based actions, considering how BMEs protect NBEs.
4. Establish rules for the actions.
5. Use the actions to develop life-cycle plans.
6. Develop performance measures for the effectiveness of actions, projects and programs.

7. Develop methods to evaluate benefits.
8. Dedicate funds for preservation.
9. Implement and evaluate projects.
10. Monitor and measure performance.
11. Report and improve the program.

**Agency rules.** The guide defines an agency rule as guidance on when and what action to perform. A cyclical rule is an action plus an interval; a condition-based rule is an action triggered by element or component condition. Its example cyclical rule for decks rated 7 or better lists sweeping or washing every 1 to 2 years, crack sealing and deck sealing every 3 to 5 years, polymer overlays every 8 to 12 years, and polymer-modified asphalt overlays every 12 to 15 years. Its example condition-based rule triggers an epoxy overlay or deck patching based on rating and defect area on the top and bottom surfaces. Rules flag candidates; when a rule is satisfied, further evaluation decides whether to act. Rules do not account for relative priority among actions or bridges, which must be weighed under budget constraints, along with net benefit, length of life extension, contractor availability, bundling of work along routes, and traffic operations.

**Measuring performance.** The guide says measures of accomplishment are comparative, comparing actions completed with actions planned, and that average element condition as a preservation measure must focus on bridges in the preservation population. Example agency measures: GCRs in Good, Fair or Poor; percent of deck joints in CS2 or better; percent of steel protective coating in CS2 or better. Its performance figure states preservation is effective when the flows into worse categories (X from Good to Fair, Y from Fair to Poor) are minimized, with the desired goal that improvements exceed declines. It notes that because results are not recorded until the next scheduled inspection, measuring program performance may take multiple inspection cycles.

**Funding and reporting.** Work completed links costs to benefits, supplemented by an unconstrained BMS scenario; both support funding requests. Reporting to executives and the public, from simple reports to dashboards, sustains support. The guide cites the Michigan Transportation Asset Management Council dashboard of historical and forecasted bridge conditions as an example.

**Getting started.** The guide's practical suggestions: start a cleaning program with brooms, shovels, hoses and pressure washers; have crews check joints for leakage and replace seals, prioritizing bridges with beam ends still in good condition; adopt scheduled replacement of wearing surfaces, coatings, sealers and joint seals instead of waiting for defects; track their condition and update intervals; and quantify and publicize reductions in annualized costs.

BR-DP01 covers preservation programs in more depth. This course's point is how preservation fits the federal framework: preservation is the work type that keeps Good bridges Good and Fair bridges from becoming Poor, which is what the Part 490 measures and the TAMP's life-cycle planning reward.

## Putting it together: from inspection to reported measure

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The federal framework forms a loop that starts and ends with inspection.

**1. Inspection.** NBIS inspections produce component ratings and element condition data. The component ratings for Items 58, 59, 60 and 62 classify each NHS bridge as Good, Fair or Poor under 490.409 and determine structurally deficient status under 490.411. Element data populate the BMS.

**2. Data submission.** States submit NBI data to FHWA by March 15 (490.411(e)). FHWA uses data cleared as of June 15 for the structurally deficient determination and for significant progress on bridge targets.

**3. Management system.** The BMS, meeting 515.17, stores and updates data, forecasts deterioration, evaluates benefit-cost of alternatives including no action, identifies needs, optimizes within budget and recommends programs.

**4. TAMP.** The state's five certified processes (gap analysis, life-cycle planning, risk management, financial plan and investment strategies) use BMS output to build a 10-year plan approved by the DOT head and updated at least every 4 years. FHWA checks annually that funding allocations are reasonably consistent with the plan's investment strategies by work type.

**5. Targets.** The state sets 2- and 4-year targets for percent Good and percent Poor by NHS deck area, consistent with the TAMP, and reports them in the Baseline Performance Period Report.

**6. Programming and work.** Investment strategies flow into the STIP (515.9(h)) and become projects: preservation, rehabilitation and replacement.

**7. Re-inspection.** Completed work changes conditions, captured at the next inspection, closing the loop. FHWA's significant progress determination compares actual condition against baseline and target.

**Common weak links.** Based on the regulatory structure (these are observations, not cited findings):

- Inconsistent ratings near the 7/6 and 5/4 boundaries distort measures and deterioration models.
- Element data recorded without adequate quantities or defects weaken forecasts.
- Unit costs not updated make financial plans and optimization unreliable.
- Delayed re-rating after work leaves completed improvements out of reported measures.
- Non-state NHS bridges with incomplete data undermine the "regardless of ownership" requirement.

**Illustrative scenario.** As an illustration only: a state's BMS shows that its large population of 1970s steel girder bridges with deck ratings of 6 and coating condition mostly CS2 and CS3 will, under current funding, migrate to Poor within 8 to 10 years. Life-cycle planning compares three scenarios: continue worst-first replacement; shift funds to deck overlays and zone painting on Fair bridges; or a mix. The mix scenario minimizes life-cycle cost while keeping Poor below the target and well below the 10% structurally deficient floor. The TAMP's investment strategy adopts it, the financial plan shows funding by work type, and annual programming delivers it. Four years later, inspection data show fewer bridges moving from Fair to Poor, which is the preservation performance measure the Bridge Preservation Guide describes.

**The engineer's responsibilities.** Rate accurately and consistently. Record element data completely. Supply realistic work types, unit costs and deterioration assumptions. Identify risks honestly. Re-rate promptly after work. And never let a target influence a rating: the measures are only meaningful if the data are true.

## Key takeaways

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- 23 CFR 515.17 requires bridge management systems with documented procedures for data, deterioration forecasting, life-cycle benefit-cost (including no action), needs, optimization and programming.
- The TAMP must cover at least 10 years, be built from five certified processes and be updated at least every 4 years; FHWA checks annually that spending matches its investment strategies.
- NHS bridges are Good if the lowest of Items 58/59/60 (or 62) is 7–9, Fair if 5–6 and Poor if 4 or less; percent Good and percent Poor are deck-area weighted.
- States set 2- and 4-year targets in 4-year performance periods; significant progress means better than baseline or meeting the target.

- If more than 10.0% of NHS bridge deck area is structurally deficient over the 3-year period, a set-aside of NHPP funds for NHS bridges applies.

## References

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1. 23 CFR Part 515 — Asset Management Plans
2. 23 CFR Part 490, Subpart D — National Performance Management Measures for Assessing Bridge Condition
3. FHWA, Bridge Preservation Guide: Maintaining a Resilient Infrastructure to Preserve Mobility, FHWA-HIF-18-022, 2018

Study text only; the final quiz is taken online. Verify all references against the edition your agency has adopted.