Appendix N

While federal law requires preservation/rehabilitation of historic bridges be considered, there is no standard procedure to determine when rehabilitation is appropriate and when replacement is justified. The American Association of State Highway and Transportation Officials (AASHTO) publication *Guidelines for Historic Bridge Rehabilitation and Replacement*, published November 2008, provides decision makers a process for balancing engineering judgment, historic perspectives, and environmental issues in deciding when rehabilitation is appropriate and when replacement is justified. The following discussion describes the conceptual rehabilitation alternative and the AASHTO process, applying it to the US 421 Ohio River Bridge between Milton, Kentucky and Madison, Indiana. Additional discussions on the prudence and feasibility of the Rehabilitation and other alternatives will be undertaken as part of the Section 4(f) evaluation during later project phases.

CONCEPTUAL REHABILITATION ALTERNATIVE

As discussed in Chapter 2 of the *Initial Location Alternatives Screening Report*, the rehabilitation alternative is intended to extend the life of the existing US 421 Bridge. Rehabilitation includes a variety of measures that address the structural condition of the bridge. However, it does not address the substandard geometry of the existing US 421 Bridge (narrow travel lanes, no shoulders, etc).

The Rehabilitation Alternative consists of ongoing inspections and maintenance needed to allow the bridge to be structurally sufficient without posting a vehicle weight limit during a 25-year period after the rehabilitation. The rehabilitation of the US 421 Bridge will require inspection, rehabilitation engineering, deck replacement, steel member repairs, blast cleaning of remaining existing steel members and painting. Additionally, miscellaneous repairs and regular inspections will be necessary over the 25-year period after rehabilitation to assure that the structure can safely carry two lanes of HS20 truck traffic. (H stands for highway; S stands for Semi. The 20 stands for 20 tons with 4 tons on the front axle of the semi tractor and 16 tons on each of the axles on the trailer. An HS20 truck is a three axle tractor trailer truck having a maximum of 8,000 pound weight on the tractor axle and 32,000 pound loading on each of the two trailer axles.) A more detailed description of this alternative is presented in the draft *No Build and Rehabilitation Concepts White Paper*.

COMPARISON AGAINST AASHTO GUIDANCE

In the *AASHTO Guidelines for Historic Bridge Rehabilitation and Replacement*, a four-step process guides decision makers through the rehabilitate versus replace debate.

1. Understand what makes a bridge historic
2. Apply structural and functional considerations
3. Address historical and environmental considerations
4. Apply the decision-making thresholds

Step 1. Historic Significance of the Bridge

A thorough understanding of why the bridge is important historically is the basis for planning and engineering assessments. Some features may be less historically significant and therefore may be able to be repaired or replaced with minimal harm.

The existing US 421 Milton-Madison Bridge

The existing Milton-Madison Bridge was constructed in 1929 by the J. G. White Engineering company. The steel truss bridge is composed of 18 spans of various types, including cantilever through truss spans, a Baltimore through truss span, Pratt through truss spans, a Pratt deck truss span, a plate girder span, and I-beam spans. It was originally constructed as a toll bridge. According to correspondence from the Indiana and Kentucky State Historic Preservation Offices (SHPO), the bridge represents one of the three earliest bridges built to carry automobiles between the two states, the sole surviving bridge built by J. G. White through the National Toll Bridge Company, and one of the earliest remaining cantilever truss bridges spanning a major river in Kentucky. The bridge is eligible for listing in the National Register of Historic Places under criteria A (events contributing to broad patterns), B (associated with historically significant people) and C (distinctive characteristics of construction technique, period, etc.).

Step 2. Structural and Functional Considerations

This step determines if adequate engineering criteria can be achieved while preserving the historically significant elements of the bridge. There are three general categories of functional and operational adequacy that must be satisfied.

1. Condition of the Superstructure and Substructure
2. Load-carrying Capacity
3. Geometric and Safety Features

2.1 Condition of the Structure

The National Bridge Inspection Standards developed by the Federal Highway Administration (FHWA) are typically used to describe the adequacy of the superstructure and substructure. These standards rate bridge components on a 0 (failed) to 9 (excellent) scale, based on the overall visible conditions. Engineering experience indicates that members rated 4 (poor) or above are usually able to be rehabilitated. Structural adequacy ratings are determined during in-depth inspections by trained bridge inspectors and bridge engineers.

Once the extent of structural deficiencies is known, appropriate rehabilitation treatments – and associated costs –are considered.

Bridge inspection reports for the Milton-Madison Bridge are presented in the *Existing Bridge Deficiencies White Paper*, Appendix A of the *Needs and Deficiencies Report* available on the project website. The condition of various members is documented in **Table 1**, based on various inspections since 1995.

Table 1 – Member Conditions

Component	**Inspection Rating**				
	1995	**2000**	**2002**	**2006**	**2009**
Superstructure	3	6	6	5	4
Stringers/Girders/Beams	4	6	6	5	5
Floor Beams	3	6	5	4	4
Trusses (Main Members)	5	7	6	4	3
Trusses (Bracing, Portals)	5	7	7	7	5
Substructure	6	6	6	6	6

A major rehabilitation effort was undertaken on the superstructure in 1997 to address structural deficiencies. This effort consisted of deck replacement, structural steel repairs, concrete patching, and painting. In the nine years between the 1997 rehabilitation and the 2006 inspection, the floorbeams and main truss members have deteriorated substantially to the condition that they are rated as structurally deficient again.

2.2 Load-Carrying Capacity

All bridges included in the transportation network are required to be able to carry a certain weight of vehicle. Section loss and aging can lead to reduced capacity. Materials testing may be necessary to determine the actual loading a structure can support. It may be possible to increase the live load (vehicle weight) a bridge can support by reducing the dead load (weight of the bridge itself).

The US 421 Bridge was originally constructed in 1929 and the superstructure components have experienced serious deterioration since that time. The 2009 Fracture Critical Inspection resulted in a 15-ton weight limit being placed on the bridge. Once repairs have been made, the need for this weight limit will be reevaluated.

The age, condition, and type of steel used in the US 421 Bridge lead to concerns about fatigue. Structural members lose strength as a result of rusting, pitting, and corrosion. Corrosion reduces fatigue strength – the ability of a material to support a repetitive loading and unloading. Research analyses for truss bridges that are similar to the US 421 Bridge suggest that the structure may be approaching its life expectancy based on the volume of vehicles crossing it since it first opened to traffic. During its life, the US

421 Bridge has experienced over 2 million cycles of loadings from traffic crossing the river. Also, steel can deform and fracture more easily at lower temperatures. Inspections indicate that the type of the carbon steel used in the structural members of the US 421 Bridge have been deteriorating at a rapid rate over the last 15 years. This can be seen in the inspection ratings shown in Table 1. The properties of the existing carbon steel structural members of the US 421 Bridge marginally meet minimum AASHTO strength requirements under average temperature conditions. When the temperature drops below 20 degrees (F), the structural strength of these steel members significantly decline and their properties fall under the minimum AASHTO strength requirements. This means the steel tends to be brittle and if it fails it would potentially be a "non-ductile" type of failure. This means there is a concern that there would not be a lot of warning before such an incident of failure occurs. Also corrosion causes pitting and results in stress that can accelerate the reduction in the safe fatigue life of the carbon steel members of the US 421 Bridge. When the end of a steel member's safe fatigue life is reached, fatigue cracks will occur that act as a “seed” for major failure cracks. If the corroded, brittle steel components are not repaired or replaced, additional load restrictions or closing of the structure will be necessary in the future. For more information, refer to the *Existing Bridge Deficiencies White Paper*, available online.

2.3 Safety and Geometric Features

According to the *AASHTO Guidelines for Historic Bridge Rehabilitation and Replacement*, for a bridge to remain in use for vehicular traffic, it must be geometrically adequate and safe. This consideration takes into account the number of lanes, lane and shoulder widths, approach roadway widths, horizontal clearances to roadside obstacles, stopping sight distances, vertical clearances and more. The standards for these criteria are identified in the *AASHTO Policy on Geometric Design of Highways and Streets* (which includes bridge geometric design recommendations) and vary depending on the road’s functional classification, rural or urban setting, and the average daily traffic volume.

A comparison of the existing US 421 Bridge to the *AASHTO Policy on Geometric Design of Highways and Streets* shows a number of deficiencies. These deficiencies are described in the *Needs and Deficiencies Report*, available on the project website and are summarized below:

- Narrow Lanes. Two 10-foot lanes are provided, compared to 11-12 feet recommended by AASHTO.
- No shoulders. The existing bridge has no shoulders, compared to the minimum 4 feet recommended by current guidance from AASHTO.
- Inadequate cross-slope. Both Kentucky and Indiana recommend a 2% cross-slope on bridges to drain water away from the centerline. The existing bridge provides a 1% cross-slope.
- Inadequate slope. Segments along the existing bridge are level; both states require a minimum slope of 0.3% to 0.5% to provide adequate drainage on bridges.

- o Substandard stopping sight distance. Three locations along the existing bridge restrict the distances drivers can see, creating safety concerns if vehicles in front slow or stop.
- o Inadequate deflection angles. In two locations, the horizontal alignment changes without providing a transitional curve; this does not meet current design criteria.
- o Inadequate vertical clearance over roadways. The bridge passes over High Street in Kentucky with a 12-foot 4-inch vertical clearance. This does not meet the recommended clearance of 14 feet 6 inches for local roads.

The bridge has two 10 foot lanes

The existing truss superstructure for the US 421 Bridge cannot be rehabilitated and widened to provide adequate travel lane or shoulder widths as identified in the *AASHTO Policy on Geometric Design of Highways and Streets*. The substandard stopping sight distances for the US 421 Bridge cannot be improved to meet minimum stopping sight distances in the *AASHTO Policy on Geometric Design of Highways and Streets* by any bridge rehabilitation. Therefore, rehabilitating the existing bridge cannot meet the modern geometric standards identified in the *AASHTO Policy on Geometric Design of Highways and Streets*.

The significance of the narrow lanes, no shoulders, and substandard stopping sight distance geometric deficiencies is manifested in vehicular crashes occurring on the bridge. In the four year analysis period discussed in the *Needs and Deficiencies Report*, 48 crashes were reported on the bridge, including 12 crashes resulting in injuries. Nearly half of these crashes happened as one vehicle impacted the rear end of another vehicle which may be stopped or moving. The density of closely-spaced access points at either end of the bridge, coupled with reduced sight distances and no usable shoulders contribute to the frequency of this type of crash. Anecdotal reports regarding minor collisions between passing trucks knocking off sideview mirrors indicate these occurrences are related to the narrow lanes although these unreported incidents are not available for statistical analysis.

The narrowness of the existing bridge also deters pedestrians and bicyclists from crossing the river between communities. Madison in particular has an extensive network of sidewalks and cyclist trails. A PAG member representing the local bicycle club indicated that cyclists and pedestrians do not routinely cross the US 421 Bridge because of the narrowness of the bridge and lack of sidewalk. In addition, citizens in both communities rely on the bridge for access to jobs, markets, retail and service centers, health care, and for other social and economic connections. Based on 2000 Census data, an estimated 10% of households in the study area do not own a vehicle.

Limited public transportation is available around Madison, but none of the existing service providers extend into Kentucky.

Step 3. Historical and Environmental Considerations

Federal legislation (including SAFETEA-LU, the National Historic Preservation Act and the National Environmental Policy Act) require coordination with historic preservation groups and other stakeholders on federal projects. Preservation, rehabilitation, and avoidance of adverse effects should be given due consideration to protect historic resources.

Historic and environmental considerations vary by project, but a number of common issues which should be looked at include the following:

- Are there environmental constraints, e.g. wetlands, archaeological sites, etc?
- Does the necessary work to address the deficiencies exceed what is considered to be prudent?
- Can the goals be achieved without adversely affecting historic properties or with only minor impacts?
- Was avoiding the historic structure considered?
- Can the goals be achieved with a less strict set of design standards?
- Have non-construction alternatives that meet the project purpose been explored?
- Have the views of the community been addressed?

For the Milton-Madison Bridge Rehabilitation/Replacement Project, the project team has attempted to identify and consider a wide variety of environmental and historic issues. The *Environmental Overview Report*, available on the project website, identifies known resources in the project area including geology, surface water resources, air quality issues, noise-sensitive resources, the existing viewshed, characteristics of the communities and their populations, ecology, cultural resources, historic structures, archaeological sites, hazardous materials sites, and wells. This information was collected so that competitive alternatives could be developed which minimize historic and environmental impacts. The *Initial Location Alternatives Screening Report*, also available on the project website, describes the development of bridge location alternatives and the initial round of alternatives evaluation.

Step 4. Decision-Making Thresholds

Step 4 of this process builds on steps 1-3. It determines whether rehabilitation of the bridge is “feasible and prudent” in light of the engineering design criteria for adequacy (Step 2) and the environmental and historic considerations (Step 3) identified earlier.

To be “feasible,” an alternative must be able to be implemented. The technology exists today to do almost anything if costs and resources are unlimited. “Prudence” applies “common sense” to feasibility, asking if an alternative is practical and considering costs, resources, and engineering/environmental constraints that affect it. FHWA defines six cases in which 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. It has extraordinary initial and/or life-cycle costs.
6. It causes unique problems or other factors.

It should be noted that the *AASHTO Guidelines for Historic Bridge Rehabilitation and Replacement* uses the words “prudent and feasible” in its determination of whether the rehabilitation option is a realistic alternative to pursue. The words “prudent and feasible” are also used in the requirements of Section 4(f) as outlined in 23 CFR 774.17. It is important to note that the words “prudent and feasible” are used in different context in the *AASHTO Guidelines for Historic Bridge Rehabilitation and Replacement* and 23 CFR 774.17 and have different applications in each of the decision-making procedures.

It is important to note that documentation of how all of the alternatives considered for this project meet the “prudent and feasible” requirements of Section 4(f), as outlined in 23 CFR 774.17, will be done during the Section 4(f) evaluation for the project.

A comparison of initial costs and life-cycle costs between rehabilitation and replacement alternatives is an important factor in the decision-making process. Considering rehabilitation may be justified if it costs less initially than replacing the structure, has similar life-cycle costs, and provides at least a 25-year service life. Rehabilitation should correct deficiencies without requiring constant maintenance.

The decision to rehabilitate a historic bridge should balance costs and impacts against the cultural/historic significance of the bridge and the effects construction would have on the surrounding environment. Considering the bigger picture could lead to the decision that other factors are more important than preserving the historic bridge. A decision to replace a historic structure should not be made unless other methods to address deficiencies without adversely affecting the structure have been considered.

4.1 Classifications based on Adequacy

The *AASHTO Guidelines for Historic Bridge Rehabilitation and Replacement* defines six categories based on the adequacy of the condition, capacity, and features described in Section 2. These thresholds, shown in Table 2, help define when rehabilitation may be considered feasible and prudent.

Table 2 – Adequacy Groups

Group	Description
I	Adequate structural condition, load-carrying capacity, and geometry
II	Inadequate geometry; Adequate structural condition and load-carrying capacity
III	Inadequate load-carrying capacity; Adequate structural condition and geometry
IV	Inadequate load-carrying capacity and geometry; Adequate structural condition
V	Inadequate load-carrying capacity and structural condition; Adequate geometry
VI	Inadequate load-carrying capacity, structural condition, and geometry

In the case of the Milton-Madison Bridge, the geometry (narrow lanes, stopping sight distance), condition of the superstructure (showing continual deterioration since the 1997 rehabilitation and rated "poor" overall in 2009), and load-carrying capacity (based on structural condition and steel fatigue) are considered inadequate. This fits the bridge in Group VI by the AASHTO thresholds.

The *Guidelines* state that a bridge with inadequate geometry may not have rehabilitation potential if:

- It cannot be widened to improve substandard geometry. *The US 421 Bridge cannot be widened to provide lane or shoulder widths that meet AASHTO standards.*
- It is too narrow for current traffic demands, has inadequate approach geometry, and cannot be improved in a cost-effective manner. *Narrow traffic lanes on the bridge contribute to safety issues. The approaches to the bridge have substandard elements: inadequate turning radii at intersections and sharp horizontal curves.*
- It cannot be widened without destroying elements that make it historically significant. *To provide an adequate cross-section, the historic truss elements would have to be removed and widened. Although a new superstructure could mimic the historic features, the actual elements would be destroyed.*

The *Guidelines* state that a bridge with inadequate load-carrying capacity may not have rehabilitation potential if:

- It cannot be strengthened cost effectively. *Strengthening all of the brittle and corroded members to restore unrestricted load carrying capacity will require replacement of numerous members. The history of the bridge indicates that extensive rehabilitations will be required periodically to maintain fracture critical members at an adequate level.*
- It serves a high percentage of truck traffic but cannot be made adequate.

According to the *Guidelines*, is bridges in Group VI are “severely deteriorated and deficient.” A bridge in Group VI is substandard in all three adequacy categories and cannot be corrected in a prudent and feasible manner are very unlikely to have rehabilitation potential.

Conclusion

Rehabilitation of the US 421 Milton-Madison Bridge over the Ohio River includes measures to extend the service life of the structure by addressing structurally deficient members. Maintenance, repair work, and ongoing inspections will extend the life of the bridge 25 years and allow the bridge to serve traffic volumes without a weight restriction. However, rehabilitation cannot address the existing geometric deficiencies. It is not feasible to provide adequate lane and shoulder widths that meet AASHTO design criteria on the existing bridge. Nor is it possible to correct the existing sight distance deficiencies with a rehabilitation project. Likewise, safety issues associated with these elements would not be improved.

Therefore, according to above analysis in accordance the process described in the *AASHTO Guidelines for Historic Bridge Rehabilitation and Replacement*, the *Needs and Deficiencies Report* for the Milton-Madison Bridge Project and conceptual rehabilitation data available to date, the US 421 Bridge over the Ohio River between Milton and Madison is “very unlikely to have rehabilitation potential” and should be classified in Group VI.