Value Engineering Study Report

US 51 Bridge Replacement over the Ohio River

KYTC Item No. 01-1140.00

Wickliffe, Kentucky to Cairo, Illinois

May 19, May 22-26, 2023

Prepared by:

HDR Engineering, Inc.
4645 Village Square Drive, Suite F
Paducah, KY 42001

Disclaimer

The information contained in this report is based on the professional opinions of the Value Engineering (VE) team members as developed during the study. These opinions are based on the information that was provided to the team at the time of the study. As the project continues to develop, recommendations and findings should be reevaluated as new information is received.

All costs displayed in the report are based on best available information at the time of the study and, unless otherwise noted, used the estimate as provided to the VE team. All drawings, graphics, maps, photos, etc., used in the report were supplied by the study sponsor or developed during the study.

The disposition of recommendations is based on the information in this report; it is independent of the resolutions generated after the study. HDR has no participation, direct or indirect, in such decisions.

For any recommendations that are accepted by the owner and design team because of this VE study, the responsibility for implementation into the design rests with the designer of record.

Study Statistics	
Baseline Cost:	$376M
Number of Recommendations:	10
Total Number of Team Members:	7
KYTC Employees:	1
Others:	6
Facilitator Consultant:	HDR

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Executive Summary

Introduction

This report summarizes the events and results of the hybrid (virtually and in-person) VE study conducted by HDR Engineering, Inc. for Kentucky Transportation Cabinet (KYTC) on the US 51 bridge replacement over the Ohio River project connecting Wickliffe, Kentucky to Cairo, Illinois. The VE study consisted of a 6-day workshop that was conducted with a multidisciplinary team May 19, May 22-26, 2023 at the KY Transportation Cabinet Office Building 200 Mero St. Frankfort, KY 40601 and using Microsoft Teams.

Project Overview

The existing location of the US 51 Cairo Bridge spans the Ohio River is just north of the convergence of the Ohio and Mississippi rivers along the Ohio River connecting Cairo Illinois and Wickliffe Kentucky. The purpose of this project is to improve cross river mobility and safety by constructing a replacement bridge that meets current design standards and accommodates projected traffic demands. The proposed structure will have two 12' foot driving lanes with 8' shoulders, increasing the space for vehicles and incident accessibility. The Illinois side of the facility highlights a roundabout to channel traffic at the T-intersection. To accommodate maritime traffic, the bridge will span a minimum of 800 feet per USCG requirement. The main channel is spanned with a tied arch superstructure.

At the time of the VE study, the total cost of the project, including construction and right of way was estimated at $376 million.

Scope of VE Study

The primary objectives of the study, through execution of the Value Methodology Job Plan (Appendix A), were to:

- Verify or improve on the various design concepts for the US 51 bridge replacement over the Ohio River project.
- Conduct a thorough review and analysis of the key project functions using an independent, multidiscipline, cross-functional team.
- Improve the value of the project through innovative measures aimed at improving the performance while reducing costs of the project.

VE Recommendations

The VE team generated 41 ideas for the project. These concepts were compared against the baseline developed by the project team. The concepts that resulted in improved performance were further developed by the VE team and resulted in 10 recommendations (Table 1).

Table 1. Summary of Recommendations

#	Recommendation Title	Cost Savings/ (Cost Added) ($M)	Performance Improvement (%)
1	Facilitate Staging Locations	($0.08)	+2%
2	Use Soil Improvements Techniques	($9.36)	+22%
3	Conduct a Non-linear Time History Analysis	($1.70)	+22%
4	Pre-design by Load Testing	$7.57	+23%
5	Increase End Bearing Resistance of Foundations	$17.31	+11%
6	Use Isolation Bearings with Batter Piles	$11.39	+8%
7	Use Innovative Delivery Method	$13.18	+9%
8	Deliver and Remove Material by Rail - Build a Temp Spur	$0.00	+13%
9	Use Concrete Pavement	$4.67	+9%
10	Increase Span Length of Approach structures	$3.12	+9%

The individual recommendations are summarized below; the detailed information about each recommendation is included in Section 7.3.

1— Facilitate Staging Locations – This recommendations purpose is to reduce risk to the contractor leading to reduced cost in the bids by creating staging areas within KYTC right of way and to initiate the Area(s) of Potential Effect (APE) process earlier in the project development process. The VE team also recommends expanding the APE coverage area.

2— Use Soil Improvements Techniques – The VE team recommends using deep soil mixing, jet grouting, compaction grouting and wick drains or a combination of treatments or ground improvement methods. Also, the team recommends extending treatment 10' beyond the pier area to mitigate against liquefaction and increase the resistance of the foundations.

3— Conduct a Non-linear Time History Analysis – The VE team recommends conducting a non-linear time history analysis, which provides insight into seismic response and assists in decisions leading to super and sub structure design. The resulting design may increase reliability of the structure and reduce risk of seismic impacts.

4— Pre-design by Load Testing – This recommendation is to let as soon as possible a separate contract for a pre-design foundation load test program to reduce and identify the unknowns of geotechnical conditions, leading to an improved design and reliability.

5— Increase End Bearing Resistance of Foundations – The VE team recommends using concrete or grout filled pipe piles exclusively or in combination with post grouted drilled shafts to increase the end bearing resistance for both pipe piles and drilled shaft foundation options.

6— Use Isolation Bearings with Batter Piles – The VE team recommends the use of batter piles in combination with isolation bearings to improve resistance to lateral loads during a seismic event.

7— Use Innovative Delivery Method - The VE team recommends using design build project delivery method to take advantage of innovative construction means and methods, reduce risk to the owner, and possibly reduce costs and duration of construction.

8— Deliver and Remove Material by Rail - Build a Temporary Spur – The VE team recommends delivering and removing materials using the Canadian National Railway railroad tracks. These tracks are strategically located near the project site and offer off site storage flexibility.

9— Use Concrete Pavement – This recommendation is to use concrete pavement on the roadway approaches in lieu of asphalt.

10— Increase Span Length of Approach Structures– The VE team recommends reducing the number of piers by increasing span length to up to 450 ft on the approach structures and to 1000 ft on the arch for units 1,2 and 3.

Implementation of Recommendations

To facilitate implementation, a Value Engineering Recommendation Approval Form is included as Appendix B. If the Cabinet elects to reject or modify a recommendation, please include a brief explanation of the decision.

The VE team wishes to express its appreciation to the project design managers for the excellent support they provided during the study. We hope that the recommendations and design considerations provided will assist in the management decisions necessary to move the project forward through the project delivery process.

Sincerely,

Jose Theiler, PE, CVS®
Principal - East Region
Project Risk Management and Value Engineering

1 Introduction

This VE report summarizes the events of the hybrid (virtually and in-person) VE study conducted for Kentucky Transportation Cabinet and facilitated by HDR using Microsoft Teams as a collaboration environment. The subject of the study was US 51 Bridge Replacement over the Ohio River. The VE study was conducted May 19, May 22-26, 2023 while the project was in the preliminary engineering/ environmental analysis phase.

1.1 Scope of VE Study

Value is expressed as the relationship between functions and resources, where function is measured by the performance attributes defined by the customer, and resources are measured in materials, labor, price, and time required to accomplish that function. VE focuses on improving value by identifying the most resource-efficient way to reliably accomplish a function that meets the performance expectations of the customer.

The primary objectives of the study, through execution of the Value Methodology Job Plan (Appendix A), were to:

- Validate or improve on the various concepts for the identified section of the US 51 Bridge Replacement over the Ohio River project.
- Conduct a thorough review and analysis of the key project functions using a multidiscipline, cross-functional team.
- Improve the value of the project through innovative measures aimed at improving the performance while reducing costs of the project.

With this process, the VE team identified the essential project functions and alternative ways to achieve those functions; the team then selected the optimal recommendations to develop into workable solutions for value improvements.

1.2 VE Team Members

The VE study was facilitated by a Certified Value Specialist (CVS) from HDR. Multiple representatives and members of the KYTC project team also participated in the VE process to provide insight into the project’s background and design development, as well as their requirements for the project and expectations for the VE study. Their support of this study is greatly appreciated, and the results provided herein reflect the information they provided throughout the study.

The VE team included the following. See Appendix C for details of attendees.

- Jonathan Guess, HDR
- Christopher Johnson, VMA, HDR
- Brian Keaney, HDR
- Raheel Malik, HDR
- Anthony Messmer, HDR
- Katy R Stewart, KYTC
- Jose Theiler, CVS, HDR




2 Information Phase

The VE team received the documentation and drawings from the project design team as shown in Table 2. The design team also introduced the project and its characteristics on the first day of the study. Project details and challenges as presented by the design team are summarized below.

2.1 Information Provided to VE Team

Table 2 lists the project documents provided to the VE team for use during the study.

Table 2. Information Provided to the VE Team

Document/Drawing/Schematic	Document Date
Cost Estimate	
Roadway Cost for VE Study	5/9/2023
US-51 Cost Estimate VE Study	5/23/2023
Preferred Structure Plans	
Preferred Structure Plans VE Study	3/29/2023
Structural Reports	
Set of structural reports	4/22/2020
SCI Simulation Report	
US51 Bridge Navigation Feasibility Report	7/15/2020
US51 Bridge Replacement Project Completed Simulation Matrix	6/4/2020
Hydraulic Reports	
US51 Combined Hydraulics Summary Report	1/19/2023
Preliminary Geotech Report	
Preliminary Report US51 KY Cairo Bridge Geotechnical Report	11/30/2022
Plan of Construction	
US51 Constructability Review	12/23/2022
Risk Register with NEPA Documents	
US 51 Risk Register	5/17/2023
Planning-Environment	
Public Meeting Summaries	6/1/2023
Agency Coordination Notebook	10/1/2023
Master Agency Coordination Mailing List	8/20/2013
Master Public Involvement Mailing List	4/26/2013
Agency Coordination	
Set of meeting minutes with other agencies	9/27/2019

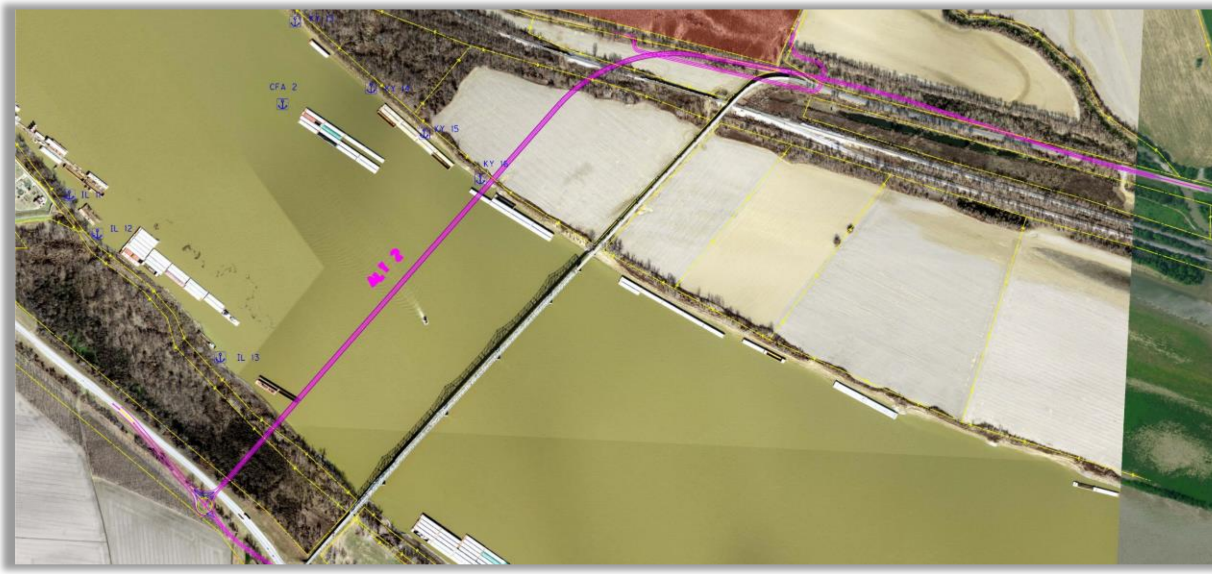
MOA	
Set of MOA documents	5/18/2021
Cultural Historic Report	
Set of Cultural and Historic Reports	6/11/2020
APE	
2019-12-18 APE approval	12/18/2019
Archaeology Report	
Cairo Sonar Report	1/23/2020
Bridge Overview Report Illinois	2/7/2020
Kentucky Overview FINAL	2/7/2020
Purpose and Need	
US51 Project Purpose and Need	1/30/2020
Bridge Condition Report	
Existing Bridge Assessment - Final	4/22/2020
Design	
Set of bridge design files	7/18/2019
Existing Bridge Evaluation	
Inspection Comparisons documents	N/A
PL&G	
Set of PL&G Documents	9/29/2020

2.2 Project History/Information

The existing location of the US 51 Cairo Bridge spans the Ohio River Just north of the convergence of the Ohio and Mississippi rivers along the Ohio River connecting Cairo Illinois and Wickliffe Kentucky. The original bridge was constructed between 1936 and 1938 and has one lane of traffic in each direction. The location makes US 51 Cairo bridge an integral part of the regional roadway network. Closures of the bridge redirects users through a 90-mile detour.

The proposed US 51 bridge replacement project will provide a new structure built to current safety standards and constructed to withstand the high seismic activity in the area. The new location of the structure is North (980' upstream) of the current placement. Also, a roundabout intersection has been chosen for further design development. The structures' pier locations are awaiting further hydrologic investigation to determine the location and size of the piers. A tied-arch bridge design has been selected to develop further after a comprehensive analysis of competing styles were examined This project is regionally import for the traveling public and industry alike.

Figure 1. Project Location



2.3 Proposed Improvements

US 51 Bridge Replacement - The objective of the planning study in the preliminary engineering phase of project development was to evaluate multiple locations, design, and construction scenarios to replace the US 51 Cairo bridge.

The project seeks to accomplish two overarching goals for the US 51 Cairo bridge replacement:

- Improve cross river mobility between Wickliffe, Kentucky and Cairo, Illinois
- Design the replacement US 51 Cairo bridge to address safety factors within the existing US 51 Cairo bridge to improve reliability

The project was in the preliminary engineering/environmental analysis phase at the time this report was created, which provided the VE team the opportunity to review multiple alternatives developed by the design team. Currently, alternative two is the preferred selection for location. The new location of the structure is North (980' upstream) of the current placement. Also, a roundabout intersection has been chosen for further design development. The structures' pier locations are awaiting further hydrologic investigation to determine the location and size of the piers. A tied-arch bridge design has been selected to develop further after a comprehensive analysis of competing styles were examined.

2.4 Constraints and Controlling Decisions

As part of the project briefing, the VE team was given the following project constraints and controlling factors that needed to be considered when evaluating ideas:

- Avoid impacting the Canadian National Railway bridges along the Kentucky shoreline
- Maintain access to Cooper's Bottom Road
- Avoid impacting the Conservation Easement east of US 51

2.5 Risk Identification

A risk analysis was not completed as part of this VE project; however, during the VE study, the team identified several risks, as follows:

- The project falls within the New Madrid Fault; if an earthquake occurs the new bridge may collapse or suffer catastrophic damage.
- Material delivery and on-site production capabilities are limited and may cause delay to schedule duration
- Flooding and large fluctuations in river elevations during construction increase the complexity of construction and safety concerns for personnel.
- Material acquisition timeline is important; any disruptions to supplies can impact schedule duration causing increase cost to the project
- Coordination with Canadian National Railway can be cumbersome and complicated. This increases the risk of to the project schedule due to negotiating access agreements and design considerations.
- Limited locations for construction staging increases the delivery times and distances for materials to travel increasing the risk of non-conforming pavement materials.
- Roadway overtopping can cause delay due to lack of access to the project site
- Complex construction increases the risk of uncertainty and creates the possibility additional unforeseen work.
- Geological makeup of the ground and liquefaction/ lateral spread potential are prevalent risks based on the makeup of the soil in the site area.
- Wind impacts on the proposed structure may create a risk due to the surface area exposed for torsional vibrations and vertical bending
- Slope stability is a considerable risk due to the proposed riverbank pier location, proposed construction method and seismic activity in the area
- Material price fluctuations / Market conditions are risks because they are unknowns and are not reasonably quantifiable for current estimates based on past expenditures
- Vessel impacts to bridge components create risk due to this project propose a structure of a highly traveled waterway and placing immovable objects on the waterway being traveled.
- Any bridge closures to the existing bridge will create a 90-mile vehicle detour adding risks to emergency services and others traveling US51
- Bridge foundations and seismic activity impact are corelated risks until advice geotechnical analysis can be completed to confirm design decisions on foundation sizes as related to seismic activities in the area.
- Hydraulic functions will need to be further analyzed to understand the full scope of scouring on the proposed structure. The risk is the structure may not be designed to accommodate the full hydraulic flow of the Ohio river

2.6 Project Observations

The first day of the study included a presentation from KYTC's consultant project design team. The following summarizes key project issues, project drivers, and observations identified during this session:

Key Project Issues

- Any bridge closures to existing bridge create a 90-mile vehicle detour
- Seasonal flooding and river level fluctuations complicate construction
- Construction complexity and constructability issues due to geotechnical makeup of the soil
- Ground soil conditions and potential for liquefaction/lateral spread are concerns for the proposed construction techniques in a seismic zone
- Bridge foundations and seismic activity impacts need to be evaluated further for right sizing
- Hydraulic functions and the scouring potential are concerns that need to be evaluated more
- Steel and concrete prices due to market conditions and rapid fluctuations increase the risk of exceeding project budget limits

Observations

- Cost estimate supplied is dated 2019 and for comparison purposes, they would need to be escalated to current prices
- Advance the creation of the hydraulic/hydrologic analysis to improve design inputs and outcomes.
- Early coordination by KYTC with stakeholders such as Canadian National Railway and Phoenix Paper could reduce risk and construction schedule duration
- Proposed speed at Illinois roundabout needs to be reviewed for potential traffic flow considerations
- Construction complexity is high due to river elevation fluctuations, channel depths, and ground soil conditions.
- Opportunity to reduce the number of bridge piers and reconfigure locations is available. Need to review pier design for further consideration.

2.7 Project Schedule

The project was in the preliminary engineering phase with final design expected to be completed in 2025. The current schedule is shown in Table 3. It was assumed that the project will be constructed using the design-bid-build (DBB) delivery method. Letting could be as early as 2025 but is expected in 2026 dependent on funding availability.

Table 3. Project Schedule

Project Phase	Date
Bridge Type study	2022
Ohio River Geotechnical Boring and Analysis	2023
Environmental Commitments and Mitigation	2022-2030
Final Design and Permitting	2024-2025
ROW and Land Acquisition	2024-2028
Construction	2025-2030

2.8 Project Cost Estimate

At the time of the study, the VE team was provided with the most recent cost estimate. An abbreviated estimate is shown in Table 4. See Appendix D for a detailed estimate.

Table 4. Cost Estimate – Baseline Concept

Cost Item	Cost	Percent of Total	Cumulative Percentage
Pier Foundations	$ 76,806,121	20.4%	20%
Contingency (20%)	$ 56,712,480	15.1%	35%
Structural Steel	$ 55,146,600	14.7%	50%
Arch Alternate - Structural Steel GR70	$ 33,282,218	8.8%	59%
Mobilization (6.5%)	$ 22,117,868	5.9%	65%
Concrete Class A	$ 19,126,995	5.1%	70%
Roadway	$ 15,000,000	4.0%	74%
Drilled Shaft - 96IN (Common)	$ 12,432,000	3.3%	77%
Arch Alternate - Barges and Workboats	$ 11,000,000	2.9%	80%
Concrete Class AA	$ 9,867,638	2.6%	83%
Earthwork	$ 7,520,000	2.0%	85%
Arch Alternate - Network Cables	$ 7,220,390	1.9%	87%
Arch Alternate - Structural Steel GR50	$ 6,377,330	1.7%	88%
Steel Reinforcement	$ 5,976,536	1.6%	90%
Contingency Trestle	$ 5,000,000	1.3%	91%
Demolition	$ 5,000,000	1.3%	93%
Steel Reinforcement Epoxy Coated	$ 3,907,600	1.0%	94%

Pavement / Misc.	$ 3,243,750	0.9%	95%
Abutment Ground Improvements	$ 3,000,000	0.8%	95%
Trestle	$ 2,500,000	0.7%	96%
Drilled Shaft - 60in (Common)	$ 2,106,000	0.6%	97%
Bearings	$ 2,000,000	0.5%	97%
Roadway Contingency (12%)	$ 1,777,750	0.5%	98%
Rail system single slope- 40 IN	$ 1,608,418	0.4%	98%
Modular Expansion Joint	$ 1,545,000	0.4%	98%
Concrete Overlay - Latex	$ 1,364,590	0.4%	99%
ROW	$ 1,276,500	0.3%	99%
Slope Ground Improvements	$ 1,200,000	0.3%	99%
Structure Excavation Common	$ 921,600	0.2%	100%
Disc Expansion Bearing	$ 750,000	0.2%	100%
Latex Concrete Overlay	$ 423,300	0.1%	100%
Utilities	$ 182,000	0.0%	100%

3 Project Analysis

3.1 VE Focus Points and Observations

Prior to the VE study and during the Information Phase, several activities were conducted to better understand the baseline concept. The following summarizes key focus points and observations identified during these sessions and during the VE team's initial analysis.

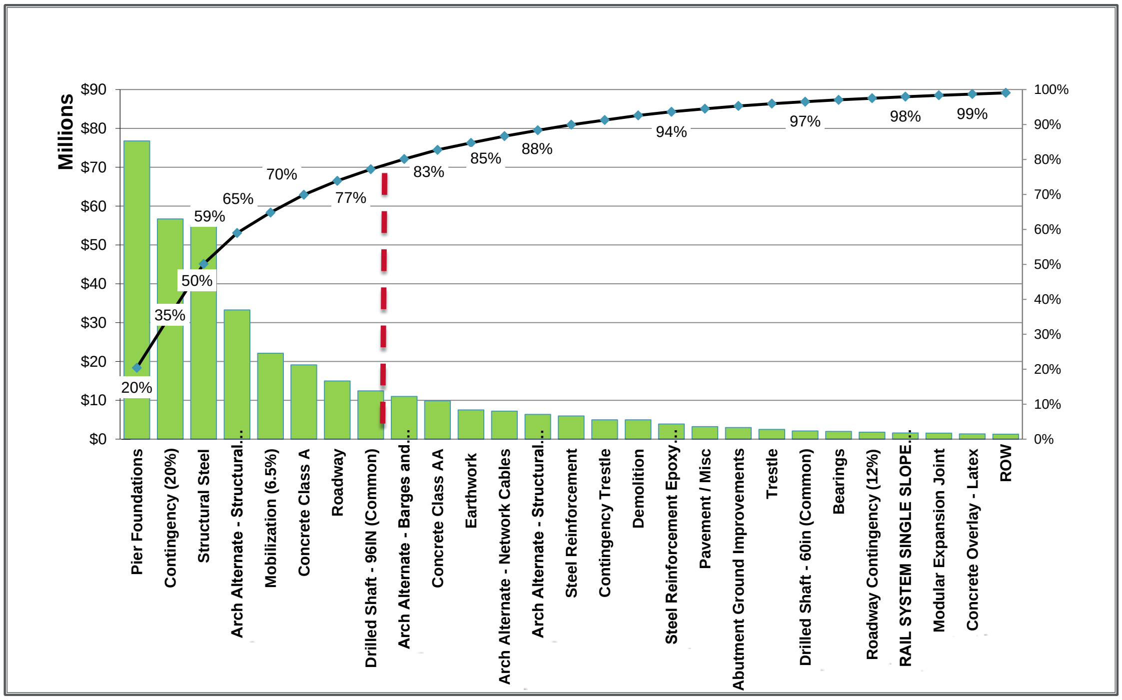
- Foundation sizing needs to be evaluated further to achieve right sizing and review constructability options due to complexity of proposed foundation's location
- Overall constructability challenges are complex and increase risk; Opportunity to simplify construction and reduce risks through alternate material delivery methods
- Seismic activity impacts on the project are probable due to the high seismic activity in the area and the projects' location within the New Madrid Fault
- Liquefaction/ Lateral spread are potential occurrences and risks due to the poor geological makeup of the ground in the project area
- Hydraulic functions need to be evaluated further to understand the impact it will have on the bridge and scouring
- Material prices (Steel and Concrete) fluctuate rapidly due to market conditions being volatile. This creates risk to the project budget.
- Limited ROW and staging areas are project constraints that need to be reviewed for alternate uses and find alternative space to use
- Flooding and river elevation fluctuations increase construction complexity and increase risk
- Wind impacts need to be mitigated not to cause torsional distortion
- Bridge Pier locations need to be evaluated based on further geotechnical information and bridge span optimization opportunities
- Preserve safe vehicle operations through design of the new structure and roadway

3.2 Cost Model

The VE facilitator prepared a cost model from the cost estimate, which was provided by the project team. The model was organized to identify major construction elements or trade categories, the design team's estimated costs, and the percent of total project cost for the significant cost items (Figure 2).

The cost model allows the team to focus on project elements with the highest degree of impact and utilize their time most effectively. Pareto's Law states that 80% of a project's cost will be in 20% of the work. The vertical red dotted line below as represented in Figure 2. delineates opportunities to find value with the greatest impact. Based upon Pareto's Law, project components to the left of the red dotted line have the highest opportunity to find value and allows the project team to focus on components that enhance efficiency and effectiveness of the VE study.

Figure 2. Cost Model



3.3 Value Metrics

The value metrics process was used as an analysis tool to evaluate the baseline project and the VE recommendations. Value metrics is a system of techniques predicated on the theory that value is an expression of the relationship between the performance of a function and the cost of acquiring it. It provides a standardized means of identifying, defining, evaluating, and measuring performance. Performance is quantified in terms of how well a set of attributes contribute to the overall functional purpose of a given project.

The basic equation used for calculating value is:

$$Value = \frac{Performance}{Cost + Time}$$

In other words, value is equivalent to the relationship of the resources needed to provide a certain level of performance for a given function. Performance is defined as a set of requirements and attributes of a project’s scope that are pertinent to the project's purpose and need. Participant responses are elicited for a series of paired comparisons in which the performance of alternatives is compared, with consideration of the project purpose and need, while considering the relative intensity of preference of one criterion over another.

The following pages describe the steps in the value metrics process.

3.3.1 Performance Requirements

Performance requirements represent essential, nondiscretionary aspects of project performance. Any concept that fails to meet the project's performance requirements, regardless of whether it was developed during the project's design process or during the VE study, cannot be considered a viable solution.

Concepts that do not meet a performance requirement cannot be considered further unless such shortcomings are addressed through the VE study process in the form of VE recommendations. It should be noted that in some cases, a performance requirement may also represent the minimum acceptable level of a performance attribute.

During the initial phase of the workshop, the VE facilitator led the VE team and executive team to the definition of performance requirements and can be found in Section 2.4 and listed below. These requirements were used throughout the evaluation of ideas and recommendations to make sure they were met.

- Meet current design standards
- Meet minimum vertical clearance of 387.8'
- Meet minimum horizontal clearance of 800'

3.3.2 Performance Attributes

Performance attributes are an integral part of the value analysis process. The performance of each project must be properly defined and agreed on by the project team, VE team, and representatives at the beginning of the study. These attributes represent those aspects of a project's scope and schedule that possess a range of potential values.

Performance attributes can generally be divided between project scope components (highway operations, environmental impacts, maintainability, and system preservation) and project delivery components. It is important to make a distinction between performance *attributes* and performance *requirements*. Performance requirements are mandatory and binary in nature. All performance requirements must be met by any VE alternative concept being considered. Performance attributes possess a range of acceptable levels of performance. For example, if the project was the design and construction of a new bridge, a performance requirement might be that the bridge must meet all current seismic design criteria. In contrast, a performance attribute might be project schedule, which means that a wide range of alternatives could be acceptable that had different durations.

The VE team, along with the project team, identified and defined the performance attributes for this project and then defined the baseline concept as it pertains to these attributes. The performance attributes shown in Table 5 were used throughout the study to identify, evaluate, and document ideas and recommendations. The baseline performance measures for each recommendation can be found in Section 7.3.

Table 5. Performance Attributes and Description

Performance Attribute	Description of Attribute	Baseline Concept
Risk	An assessment of risk to the project from the structural performance perspective, including resistance and resiliency against liquefaction, wind, scour, and vessel impacts to bridge components	• The bridge is on the northern end of the New Madrid Fault seismic zone and subject to earthquakes • Tied arch bridge with drilled shaft and pipe piles. • Pier placement avoids two ground anomalies • Pier foundation design increases exposure to vessel damage due to being < 10' depth during seasonal river elevation fluctuations Use of 72in x 2in pipe pile with constrictor plate • For drilled shafts, increase diameter and extend further below DD zone • Use of 72in x 2in pipe pile with constrictor plate, drilled shafts at critical locations of specific diameter • Ground modification at Piers
Maintainability	An assessment of the long-term maintainability of the facilities and equipment. Maintenance considerations include the overall durability, longevity, and maintainability of structures and systems; ease of maintenance; accessibility and safety considerations for maintenance personnel.	• Maintenance access meets standard • Roadway is asphalt • Steel construction for all spans • Concrete construction for substructure • Paint system requires two applications over the expected life cycle
Construction Impacts	An assessment of the temporary impacts to the public during construction related to traffic disruptions, detours, and delays; impacts to existing utilities; impacts to businesses and residents relative to access, visual effects, noise, vibration, dust, and construction traffic; environmental impacts.	• Construction is done off-line of existing bridge and roadway – no closures or detours planned • One lane operation with flagger will be used during approaches at the RR crossing and US51 tie in

Table 5. Performance Attributes and Description

Performance Attribute	Description of Attribute	Baseline Concept
Environmental Impacts	An assessment of the permanent impacts to the environment including ecological (i.e., flora, fauna, air quality, water quality, visual, noise); socioeconomic impacts; impacts to shore edge; impacts to cultural, recreational, and historic resources.	• Minor impacts to natural environment • Mooring relocations possible • 0.54 acres of temporary easement required on a property that contains a floodplain conservation easement
Project Schedule	An assessment of the total project delivery from the time as measured from the time of the VE Study to completion of construction.	• Bridge Type study (2022) • Ohio River Geotechnical Boring and Analysis (2023) • Environmental Commitments and Mitigation (2022-2030) • Final Design and Permitting (2024-2025) • ROW and Land Acquisition (2024-2028) • Construction (2025-2030)

3.3.3 Performance Attribute Matrix

The performance attribute matrix was used to determine the relative importance of the performance attributes for the project. The project and VE team evaluated the relative importance of the performance attributes that would be used to evaluate the creative ideas.

These attributes were compared in pairs (Figure 3), asking the question: “Which one is more important to the purpose and need of the project?” (e.g., A or B, A or C, A or D, etc.) The letter code (e.g., “A”) was entered into the matrix for each pair. After all pairs were discussed, they were tallied (after normalizing the scores by adding a point to each attribute) and the percentages calculated. These scores were then used to calculate the value of each recommendation during the VE team’s performance evaluation scoring (Section 6).

Figure 3. Performance Attribute Matrix

Performance Attributes Criteria Matrix							
Paired Comparison							
						Total points	**% of Total**
Risk	**A**	**A**	**A**	**A**	**A**	**5.0**	**33%**
Maintainability		**B**	**B/C**	**B/D**	**B**	**3.0**	**20%**
Construction Impacts			**C**	**C**	**C**	**3.5**	**23%**
Environmental Impacts				**D**	**D**	**2.5**	**17%**
Project Schedule					**E**	**1.0**	**7%**
					Total	**15.0**	**100%**

4 Function Analysis Phase

4.1 Overview

Function analysis results in a unique view of the project. It transforms project elements into functions, which help guide the VE team in considering the functional concepts of the project–independent of the current design. Functions are defined in verb-noun statements to reduce the needs of the project to their most elemental level (Table 6). Identifying the functions of the major design elements of the project allows a broader consideration of alternative ways to accomplish the functions.

The abbreviations following each of the functions in Table 6 indicate the type of function, as follows:

H = Higher Order (a function that is higher order than the project itself, explaining the societal reason the project is being done)

B = Basic (a critical function denoting the critical elements of the project)

S = Secondary (an important function, but not the reason the project is being done)

A = All-the-Time (a function that must happen all the time through the project)

C = Causative (a function that is essential to initiate the project)

L = Lower Order (a function is the input to the project and outside the scope)

O = One Time Function (A secondary function that occurs only once in the performance of the project)

Table 6. Random Function Identification

Project Element	Functions
Roadway	Improve (cross-river) mobility (H) Improve reliability (B) Enhance safety (B) Accommodate bicycles (S) Accommodate pedestrians (S) Reduce conflicts (S) Inform users (S) Improve visibility (S) Separate traffic (S) Remove water (S) Increase (riding) area (S) Create space (S) Construct Improvements (S) Use intelligent technology (S) Convey information (S) Illuminate facility (S) Create grade (S) Collect water (S) Convey water (S) Improve (material) availability (S)

Table 6. Random Function Identification

Project Element	Functions
	Introduce traffic (L)
Bridge functions	Span river (H) Transfer loads (B) Support loads (B) Locate structure (B) Provide strength (S) Control deflection (S) Improve efficiency (S) Provide path (S) Resist scour (S) Improve hydrodynamics (S) Protect foundations (S) Resist quakes (S) Reduce weight (S) Improve soils (S) Optimize stiffness (S) Improve flexibility (S) Reduce (liquefactions) risk (S) Resist (wind) loads (S) Resist (water) loads (S) Resist (vessel) impacts (S) Improve aerodynamics (S) Improve drag (S) Lengthen span (S) Protect structure (S) Avoid (geotechnical) issues (S) Avoid (embankment) placement (S) Improve safety (S) Shorten bridge (S) Avoid conflicts (S) Improve (roadway) geometry (S)
Construction Functions	Construct Bridge (H) Create superstructure (B) Create substructure (B) Support weight (S) Create foundation (S) Connect foundation (S) Connect superstructure (S) Control geometry (S) Hang weight (S) Construct segment (S) Test capacity (S) Control quality (S) Install unit (S) Connect units (S) Construct (hanging) system (S) Erect segment (S) Build (floor) system (S) Facilitate construction (S)

Table 6. Random Function Identification

Project Element	Functions
	Install beams (S) Construct (diving) sequence (S) Build workforce (S) Mobilize resources (S) Protect environment (S) Deliver materials (S) Deliver equipment (S) Establish APE (S) Protect public (S) Protect resources (S) Access site (S) Clear site (S) Create (work) zone (S) Establish (staging) areas (S)
Project Objectives	Accommodate trucks (S) Satisfy USCG (S) Minimize (traffic) disruptions (S) Preserve environment (S) Accommodate (maritime) vessels (S) Improve (travel time) reliability (S) Improve (life cycle) costs (S) Avoid (seismic) over-stress (S) Meet standards (S) Improve (design) Life (S) Maintain (hydraulic) capacity (S)
One Time Functions	Phase construction (O) Mobilize resources (O) Sequence work (O)
All Time Function	Reduce risk (A) Remove (utility) conflicts (A) Protect workers (A) Protect drivers (A) Delineate (work) zone (A) Manage traffic (A)

4.2 Function Analysis System Technique Diagram

The Function Analysis System Technique or “FAST” diagram arranges the functions in logical order so that when read from left to right, the functions answer the question “How?” If the diagram is read from right to left, the functions answer the question “Why?” Functions connected with a vertical line are those that happen at the same time as, or are caused by, the function at the top of the column. The FAST diagram (Figures 4,5,6) provided the VE team with an understanding of which functions offer the best opportunity for cost or performance improvement.

Figure 4. FAST Diagram – Roadway Functions

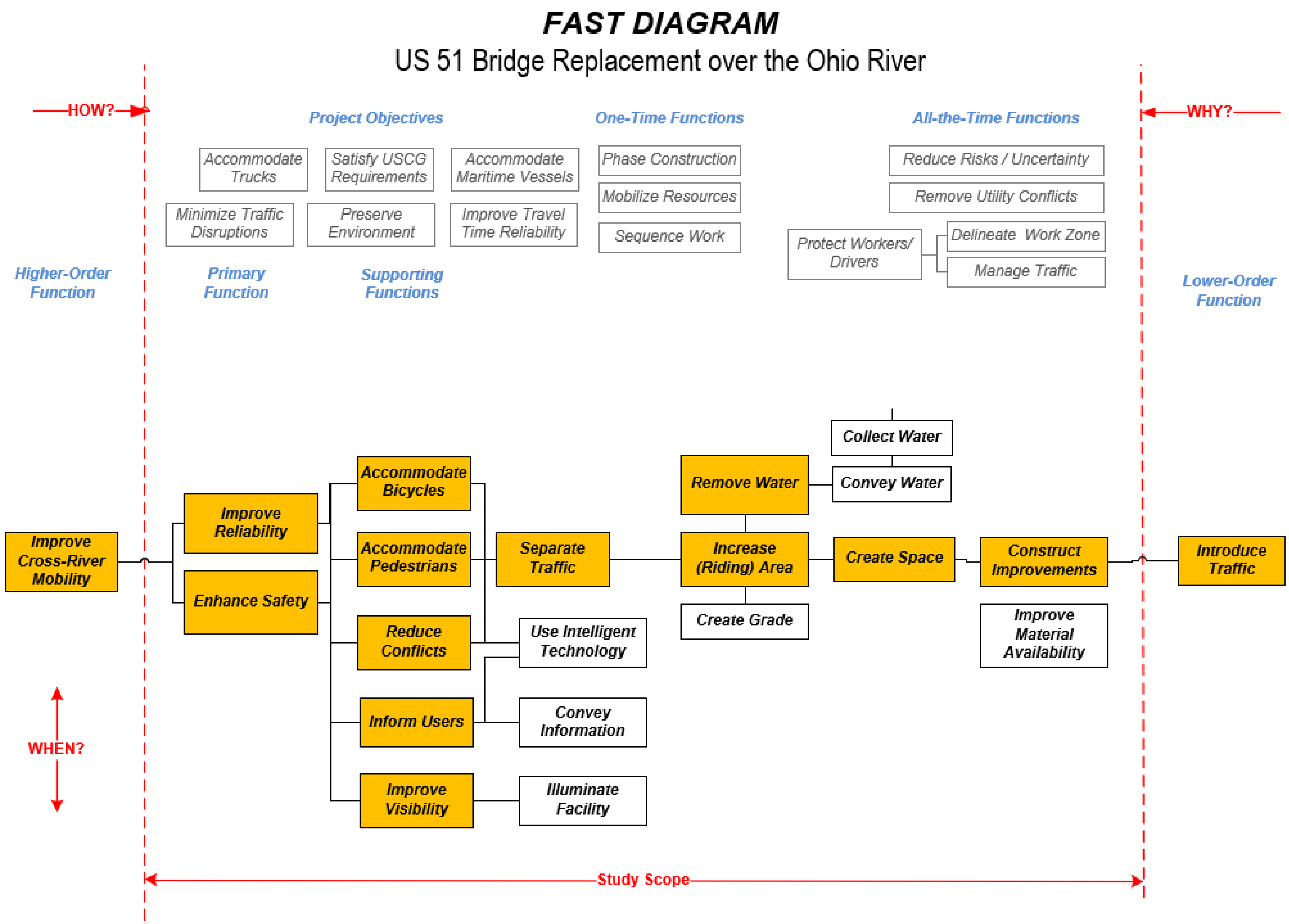


Figure 5. FAST Diagram Cont. – Bridge Functions

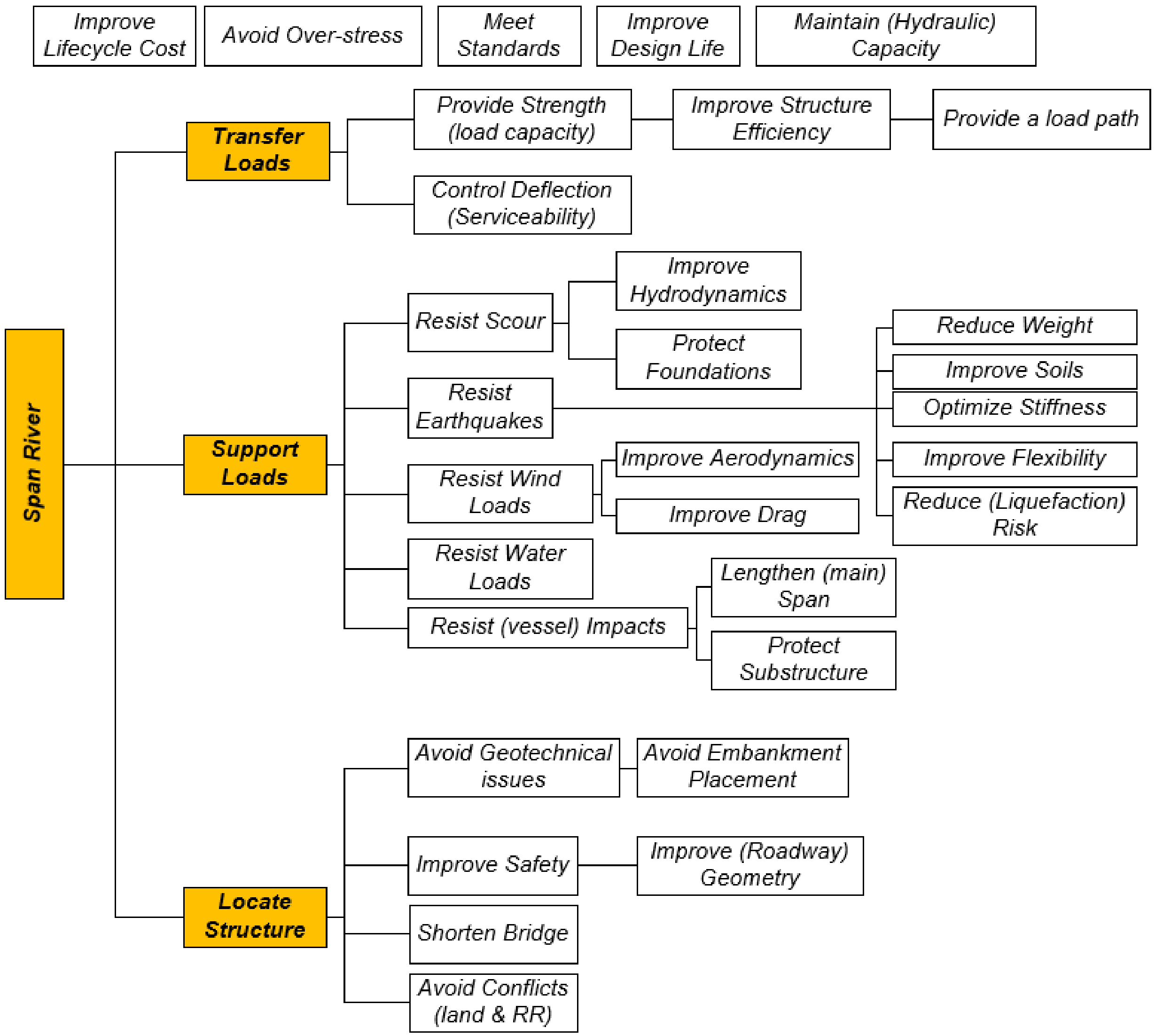
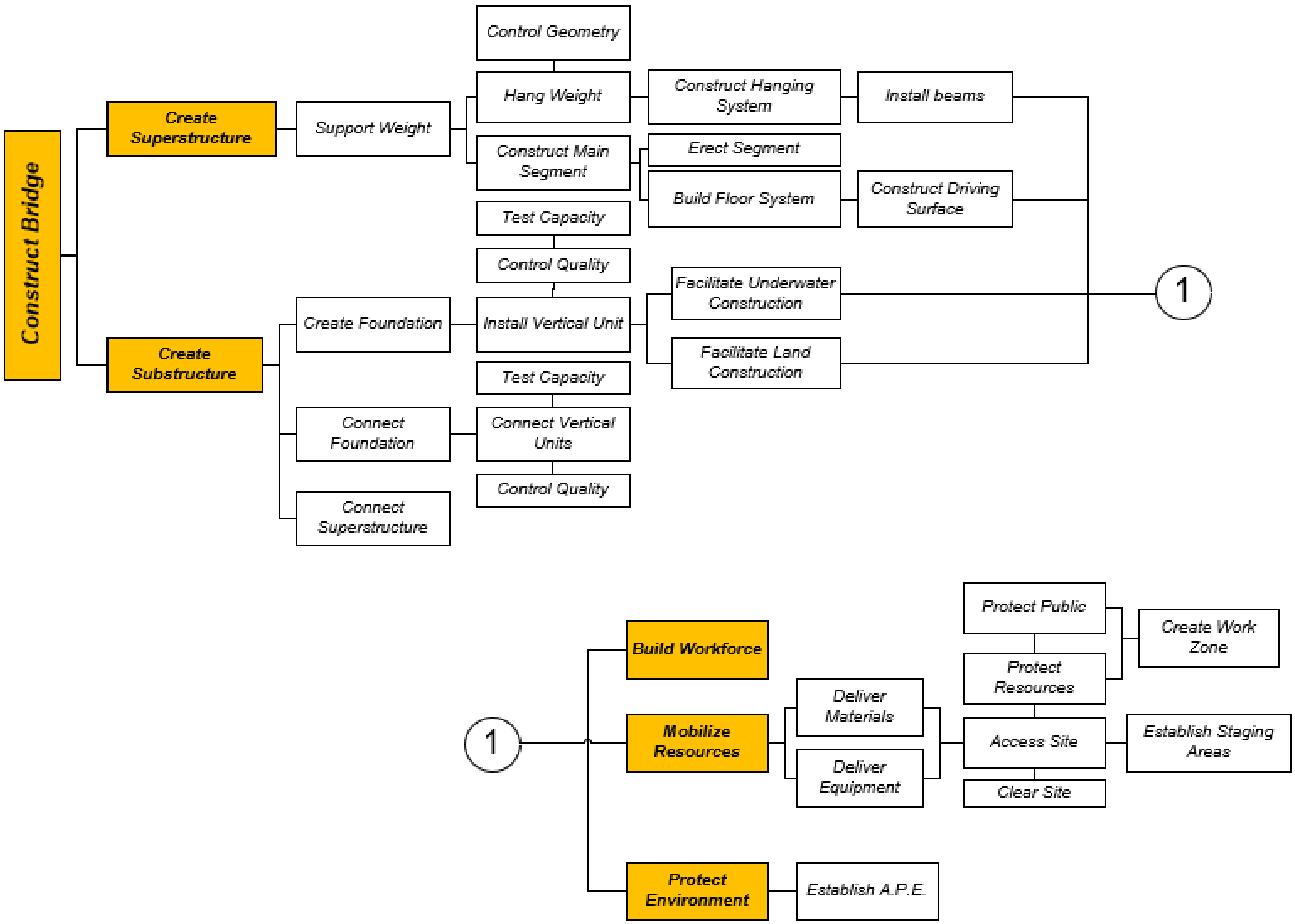


Figure 6. FAST Diagram Cont. – Construction Functions



5 Creativity Phase

During the Creativity Phase, the VE team generated ideas on how to perform the various functions. The idea list was grouped by function or major project element. All the ideas generated are recorded in Table 7. The final disposition of each idea is included at the end of Section 6.

Table 7. Creative Idea List

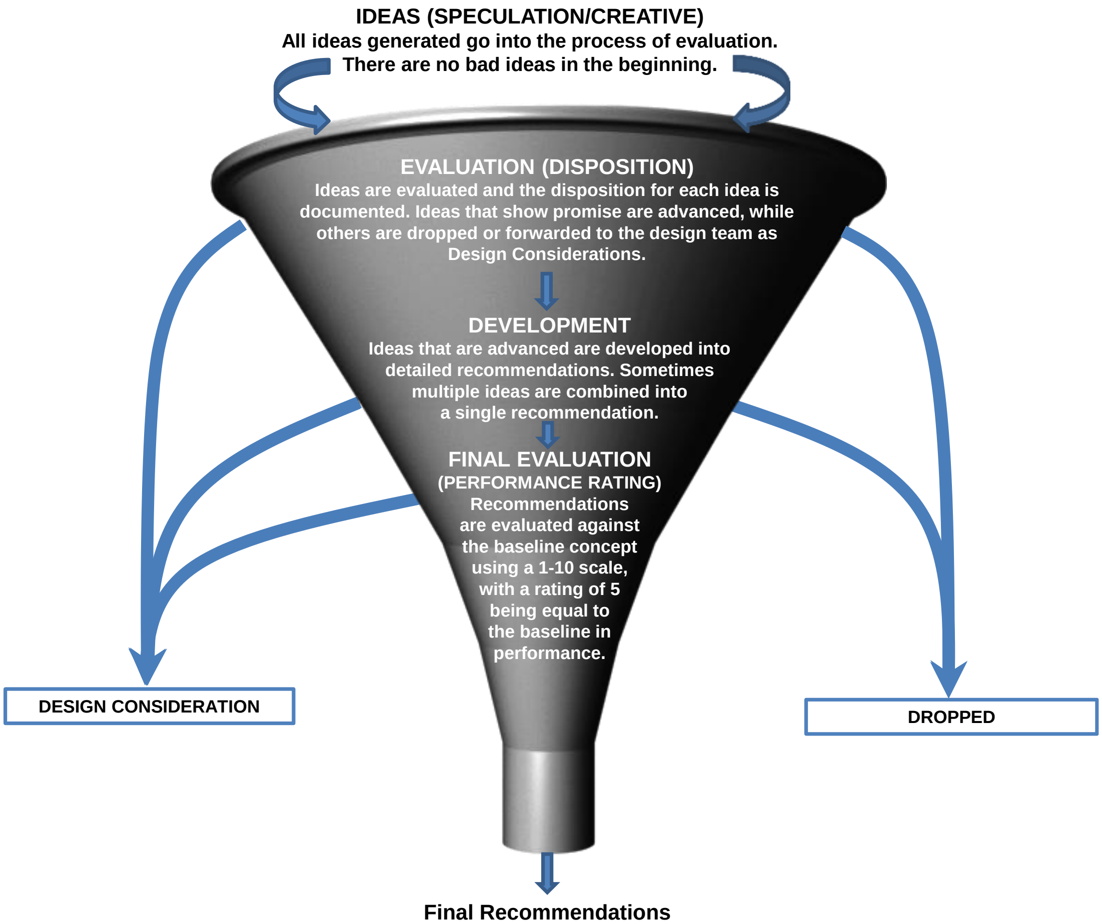
Idea No.	Description
Function: Accommodate Pedestrians & Bicyclists	
24	Create a SUP for pedestrians and bicyclist
Function: Construct Bridge	
13	Create a temporary structure to access river piers and construct from trestle structure
14	Use top-down construction
15	Build main channel structure (Arch) off-site and barge-in then lift structure in place
19	Use design build or CMAR delivery method
21	Eliminate cofferdam and construct substructure from higher elevation
35	Add incentives for early completions
Function: Create Work Zone	
22	Create a floating staging area to rise with flooding levels
33	Create staging areas within KYTC property
34	Initiate the APE process early and expand area
Function: Enhance Safety	
25	Realign the roadway to cross the river at a diagonal and improve roadway geometry
36	Use median barrier on bridge
37	Use ITS to convey bridge conditions
38	Use DMS Sign to communicate bridge conditions
39	Install lighting throughout the bridge facility
Function: Mobilize Resources	
23	Deliver and remove material using the RR. Build temporary spur.
Function: Reduce Scour	
26	Build a caisson around substructures to improve hydrodynamics
Function: Resist (Vessel) Impacts	
31	Install markers to footers in the navigational channels (perch footers)

Function: Resist Earthquakes	
5	Advance geotechnical investigations
6	Review seismic assumptions and use seismic standards (reduce requirements)
11	Conduct a non-linear time history analysis
17	Use isolation bearings at the arch and the approaches
Function: Resist Wind	
28	Include aeroelastic stability improvements on the superstructure to prevent torsional instability
30	Shaping the towers more aerodynamically; edge beam shape or wind fairing
Function: Span River	
1	Use steel/concrete cable stayed bridge
2	Use lifecycle cost analysis to determine bridge type
16	Use mixed type materials (Steel and Concrete) for areas as applicable
41	Develop a cost loaded 4D schedule analysis to determine the best combination of piers / spans
Function: Stabilize Soils	
9	Use soil mixing ground improvement method (multiple locations)
10	Use grouting to improve soils
27	Use "wick" Prefabricated Vertical Drains (PVD) drains
Function: Support Loads	
3	Pre-design by load testing
4	Reduce number of piers in the floodplain. Lengthen the spans of the approaches using arch or truss or steel box type structures
7	Use concrete filled steel pipe piles
8	Use friction reducers in the pile to reduce drag forces
12	Locate piers outside lateral spreading zones
18	Use larger pile diameters
20	Reassess the anchor piers for cable stay options and improve size
29	Improve structure to account for tornado wind speeds
32	Place the pile cap lower using a mudline footing
40	Use concrete pavement on the roadway approaches

6 Evaluation Phase

Although each project is different, the evaluation process for each VE effort can be thought of in its simplest form as a way of combining, evaluating, and narrowing ideas until the VE team agrees on the recommendations to be forwarded. Figure 7 depicts the typical information flow for this part of the Value Methodology Job Plan.

Figure 7. VE Process Information Flow



6.1 Evaluation Process

The evaluation process begins by going through the ideas brainstormed during the Creativity Phase. Considering the information provided to the VE team at the time of the study and the constraints and controlling decisions that were also given to them, the team discussed the ideas and documented their advantages and disadvantages based on their relationship to the baseline concept.

The VE team also compared each idea with its baseline concept to determine whether the performance of the attribute (as introduced in Section 3.3) was better than, equal to, or worse than the baseline concept.

Each idea was then carefully evaluated, with the VE team reaching consensus on the overall ranking of the idea (ranking values 0 through 3, as defined below).

3 = Advance for further development

2 = Design consideration; include as a comment or consideration for design team

1 = Poor Opportunity/dropped from further development

0 = Unacceptable impact/fatal flaw

This ranking resulted in the initial disposition of the idea. Those ideas ranked as a 3 were developed further; low-ranking ideas (those ranked 0 or 1) were dropped from further consideration; and those that were ranked 2 were brought forward as ideas the design team should pursue.

6.2 Evaluation Summary

All the ideas that were generated during the Creativity Phase using brainstorming techniques are detailed in Table 8.

Table 8. Idea Evaluation Summary Table

Idea #	Description	Advantages	Disadvantages	Rating	Comments
Function: Span River					
1	Use steel/concrete cable stayed bridge	• Larger spans • May reduce number of piers • May reduce substructure costs • May reduce maintenance costs • May reduce scour • Reduces construction duration	• May increase superstructure costs • Access to cable stayed are difficult for maintenance	*2*	*VE team further evaluated this idea and concluded that it shoud be developed as a design validation. Combine 1,2,14,20*
2	Use lifecycle cost analysis to determine bridge type	• Improves complete costing of the bridge • Improves the selection of the bridge	• May require deeper analysis	*2*	*VE team further evaluated this idea and concluded that it shoud be developed as a design validation. Combine 1,2,14,20*
Function: Support Loads					
3	Pre-design by load testing	• Reduce the unknowns of geotechnical conditions • May reduce foundation costs • Reduce uncertainty for contractor and owner • May assist on means and methods of construction • May reduce the amount of resistance required	• Adds upfront costs • Duration of design may increase • Slight increase in design costs • Contractor may choose different means and methods based on results	*3*	*Moved to the Development Phase for further evaluation*

Ranking Scale:
3 = Advance for further development
2 = Design consideration; include as a comment or consideration for design team
1 = Poor opportunity/dropped from further development
0 = Unacceptable impact/fatal flaw

(green) = Advanced as recommendation
(yellow) = Forwarded as design consideration
(red) = Dropped from further development

Table 8. Idea Evaluation Summary Table

Idea #	Description	Advantages	Disadvantages	Rating	Comments
4	Reduce number of piers in the floodplain. Lengthen the spans of the approaches using arch or truss or steel box type structures	• May reduce substructure costs • May reduce schedule duration • Reduce project risk • Reduces number of piers	• May increase superstructure costs • Steal box is more difficult to inspect	*3*	*Moved to the Development Phase for further evaluation*
Function: Resist Earthquakes					
5	Advance geotechnical investigations	• Reduces uncertainty • Assist in substructure selection • Advance location of the substructure • Will improve costing	• Funding availability	*2*	*Design team to further evaluate*
6	Review seismic assumptions and use seismic standards (reduce requirements)	• May reduce foundation costs • May improve overall design and performance	• None discussed	*2*	*VE team further evaluated this idea and concluded that it shoud be developed as a design validation. Provide new assumption on other bridges.*
Function: Support Loads					
7	Use concrete filled steel pipe piles	• Reduce costs relative to reduce shaft • Reduce the thickness of steel pipe • Increase bending capacity	• Increase costs relative to steel piles • Increase complexity of construction	*3*	*Moved to the Development Phase for further evaluation*
8	Use friction reducers in the pile to reduce drag forces	• Reduces drag force • Reduce the length of foundation required	• Increase costs per unit of length	*2*	*Design team to further evaluate*

Ranking Scale:
3 = Advance for further development
2 = Design consideration; include as a comment or consideration for design team
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Table 8. Idea Evaluation Summary Table

Idea #	Description	Advantages	Disadvantages	Rating	Comments
Function: Stabilize Soils					
9	Use soil mixing ground improvement method (multiple locations)	• Reduces risk of liquefaction • Increases load bearing capacity of piles	• Increase costs	*3*	*Moved to the Development Phase for further evaluation*
10	Use grouting to improve soils	• Reduces risk of liquefaction • Increases load bearing capacity of piles	• Increase costs	*3*	*Moved to the Development Phase for further evaluation*
Function: Resist Earthquakes					
11	Conduct a non-linear time history analysis	• May lead to improved design • Increase reliability of the design • May lead to cost savings	• Slight cost increase	*3*	*Moved to the Development Phase for further evaluation*
Function: Support Loads					
12	Locate piers outside lateral spreading zones	• May lead to a reduction in substructure size • Reduce costs	• May lead to longer spans • Increase in span costs	*1*	*Dropped from further consideration*
Function: Construct Bridge					
13	Create a temporary structure to access river piers and construct from trestle structure	• Improves access for river work • May supplement access for mobilization and demobilization	• Contractor means and methods	*2*	*Design team to further evaluate*

Ranking Scale: 3 = Advance for further development
2 = Design consideration; include as a comment or consideration for design team
1 = Poor opportunity/dropped from further development
0 = Unacceptable impact/fatal flaw

= Advanced as recommendation
= Forwarded as design consideration
= Dropped from further development

Table 8. Idea Evaluation Summary Table

Idea #	Description	Advantages	Disadvantages	Rating	Comments
14	Use top-down construction	• Reduces the need to river operations • Not impacted by floods • Reduces the need for mobilization and demobilization during flood season	• Steel spans are too large for top down construction • May get into means and methods	*2*	*VE team further evaluated this idea and concluded that it shoud be developed as a design validation. Combine 1,2,14,20*
15	Build main channel structure (Arch) off-site and barge-in then lift structure in place		• Baseline	*1*	*Dropped from further consideration*
Function: Span River					
16	Use mixed type materials (Steel and Concrete) for areas as applicable	• More costs effective • Improves material availability	• May complicate design • May require different type of contractors	*2*	*Design team to further evaluate*
Function: Resist Earthquakes					
17	Use isolation bearings at the arch and the approaches	• May reduce foundation costs • Improves seismic performance • Reduces stress of the structure	• Increase maintenance	*3*	*Moved to the Development Phase for further evaluation*
Function: Support Loads					
18	Use larger pile diameters	• Reduces the number of piles • Increase the bearing capacity • May reduce schedule duration	• Requires specialty equipment	*2*	*Design team to further evaluate*

Ranking Scale: 3 = Advance for further development
2 = Design consideration; include as a comment or consideration for design team
1 = Poor opportunity/dropped from further development
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(green) = Advanced as recommendation
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(red) = Dropped from further development

Table 8. Idea Evaluation Summary Table

Idea #	Description	Advantages	Disadvantages	Rating	Comments
Function: Construct Bridge					
19	Use design build or CMAR delivery method	• Reduce costs • Reduce schedule duration • Improve constructability	• CMAR not a common practice	*3*	*Moved to the Development Phase for further evaluation*
Function: Support Loads					
20	Reassess the anchor piers for cable stay options and improve size	• May reduce construction costs	• May increase design costs	*2*	*VE team further evaluated this idea and concluded that it shoud be developed as a design validation. Combine 1,2,14,20*
Function: Construct Bridge					
21	Eliminate cofferdam and construct substructure from higher elevation	• Reduces costs • Extends work season • Shorten schedule duration	• Requires specialty contractor • Requires specialty equipment • Baseline	*1*	*Dropped from further consideration*
Function: Create Work Zone					
22	Create a floating staging area to rise with flooding levels	• Reduces mobilization and demobilization costs • May be able to place closer to the site	• Feasibility • Means and methods	*1*	*Dropped from further consideration*

Ranking Scale:
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(red) = Dropped from further development

Table 8. Idea Evaluation Summary Table

Idea #	Description	Advantages	Disadvantages	Rating	Comments
Function: Mobilize Resources					
23	Deliver and remove material using the RR. Build temporary spur.	• Provides a means of access • May improve schedule duration • Reduces contractor risks • Provides means to remove materials (demo)	• RR agreement • Means and methods	*3*	*Moved to the Development Phase for further evaluation*
Function: Accommodate Pedestrians & Bicyclists					
24	Create a SUP for pedestrians and bicyclist	• Accommodates bicyclists • Accommodates pedestrians • Reduces conflicts between bicyclists and vehicles • Improves multimodal access	• May not have demand • Requires larger footprint for bridge and RR • Increase costs • Increase maintenance • Requires barrier • Requires lighting	*2*	*Design team to further evaluate*
Function: Enhance Safety					
25	Realign the roadway to cross the river at a diagonal and improve roadway geometry	• Improves sight distance • Larger curve radius • Higher design speed	• Longer bridge • Skew bridge construction • Increase costs • Complex construction	*1*	*Dropped from further consideration*
Function: Reduce Scour					
26	Build a caisson around substructures to improve hydrodynamics	• Reduces scour	• Increase costs • May increase water rise	*1*	*Dropped from further consideration*

Ranking Scale:
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(green) = Advanced as recommendation
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Table 8. Idea Evaluation Summary Table

Idea #	Description	Advantages	Disadvantages	Rating	Comments
Function: Stabilize Soils					
27	Use "wick" Prefabricated Vertical Drains (PVD) drains	• Reduces waiting periods for embankment settlements • Shortens schedule durations • Easy to install • More affordable than other ground improvement methods	• Requires additional temp drainage	*3*	*Moved to the Development Phase for further evaluation*
Function: Resist Wind					
28	Include aeroelastic stability improvements on the superstructure to prevent torsional instability	• Stabilizes structure	• Requirement for cable stay and unbraced arch types	*1*	*Dropped from further consideration*
Function: Support Loads					
29	Improve structure to account for tornado wind speeds	• Improves resiliency and durability	• Increase costs of superstructure and substructure	*2*	*Design team to further evaluate*
Function: Resist Wind					
30	Shaping the towers more aerodynamically; edge beam shape or wind fairing	• Improves aerodynamics • May reduce wind load requirements • Reduces wind resistance	• More complex construction • Increase costs	*2*	*Design team to further evaluate*
Function: Resist (Vessel) Impacts					
31	Install markers to footers in the navigational channels (perch footers)	• May avoid vessel impacts	• USCG requirement	*2*	*Design team to further evaluate*

Ranking Scale:
3 = Advance for further development
2 = Design consideration; include as a comment or consideration for design team
1 = Poor opportunity/dropped from further development
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(green) = Advanced as recommendation
(yellow) = Forwarded as design consideration
(red) = Dropped from further development

Table 8. Idea Evaluation Summary Table

Idea #	Description	Advantages	Disadvantages	Rating	Comments
Function: Support Loads					
32	Place the pile cap lower using a mudline footing	• May avoid vessel impacts • Reduce maintenance costs • Reduce conflicts	• Increase costs	*2*	*Design team to further evaluate*
Function: Create Work Zone					
33	Create staging areas within KYTC property	• Reduces contractor risks • Reduces staging costs • May reduces environmental impacts by the contractor	• Means and methods • Proximity to the project	*3*	*Moved to the Development Phase for further evaluation*
34	Initiate the APE process early and expand area	• May reduce risk and costs	• May increase consultant costs	*3*	*Moved to the Development Phase for further evaluation*
Function: Construct Bridge					
35	Add incentives for early completions	• Reduce schedule duration • Reduces overhead costs	• May not be necessary • Not a schedule driven project	*2*	*Design team to further evaluate*
Function: Enhance Safety					
36	Use median barrier on bridge	• Reduces conflicts	• Increases costs • Increase dead load • Increases maintenance • Reduces emergency operations	*1*	*Dropped from further consideration*
37	Use ITS to convey bridge conditions	• Reduces conflicts • Advance warning to the traveling public	• Increase costs • Increase maintenance	*2*	*Design team to further evaluate*

Ranking Scale:
3 = Advance for further development
2 = Design consideration; include as a comment or consideration for design team
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(green) = Advanced as recommendation
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(red) = Dropped from further development

Table 8. Idea Evaluation Summary Table

Idea #	Description	Advantages	Disadvantages	Rating	Comments
38	Use DMS Sign to communicate bridge conditions	• Reduces conflicts • Advance warning to the traveling public	• Increase costs • Increase maintenance	*2*	*Design team to further evaluate*
39	Install lighting throughout the bridge facility	• Improves visibility • Improves sight distance during night time operation • Reduces conflicts	• Increase costs • Increase maintenance • Requires partnership agreement with Illinois	*2*	*Design team to further evaluate*
Function: Support Loads					
40	Use concrete pavement on the roadway approaches	• Increase life of pavement • Matches existing pavement • Improves resilience • Improves life cycle costs	• May increase capital costs	*3*	*Moved to the Development Phase for further evaluation*
Function: Span River					
41	Develop a cost loaded 4D schedule analysis to determine the best combination of piers / spans	• Optimized costs and schedule • Improves construction duration • Reduces contractors risk • Improves costs and schedule confidence	• Slight increase in design costs	*2*	*Design team to further evaluate*

Ranking Scale:
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7 Development Phase

This phase of the Value Methodology Job Plan takes the ideas that ranked the highest in the Evaluation Phase and further develops them into full VE recommendations. In many cases, it is possible that one or more ideas were combined to form an overall recommendation, which was then evaluated further by the VE team.

In the case of this project, of the 41 ideas that were generated during the Creativity Phase, 13 of those ideas were evaluated high enough to be taken forward, combined, and developed further. Some of the ideas were deemed more appropriate as a design consideration for the design team to explore further. During the development of two recommendations, the VE team validated the design teams baseline project element, rather than developed into a VE recommendation (Section 7.5). For the Development Phase, narratives, drawings, calculations, and cost estimates were prepared for each recommendation.

The VE recommendation documents in this section are presented as written by the team during the VE study. While they have been edited from the draft VE report to correct errors or better clarify the recommendation, they represent the VE team's findings during the VE study.

Each recommendation consists of a summary of the baseline concept, a description of the suggested change, a listing of its advantages and disadvantages, discussion of schedule and risk impacts (if applicable), a cost comparison, change in performance, and a brief narrative comparing the baseline design with the recommendation. Sketches, calculations, and performance measure ratings are also presented. The cost comparisons reflect a comparable level of detail as in the baseline estimate.

7.1 Summary of Recommendations

- The recommendations developed by the VE team are shown in Table 9. The table summarizes each recommendation's cost impact and performance improvement.

Table 9. Summary of Recommendations

#	Recommendation Title	Cost Savings/ (Cost Added) ($M)	Performance Improvement (%)
1	Facilitate Staging Locations	($0.08)	+2%
2	Use Soil Improvements Techniques	($9.36)	+22%
3	Conduct a Non-linear Time History Analysis	($1.70)	+22%
4	Pre-design by Load Testing	$7.57	+23%
5	Increase End Bearing Resistance of Foundations	$17.31	+11%
6	Use Isolation Bearings with Batter Piles	$11.39	+8%

Table 9. Summary of Recommendations

#	Recommendation Title	Cost Savings/ (Cost Added) ($M)	Performance Improvement (%)
7	Use Innovative Delivery Method	$13.18	+9%
8	Deliver and Remove Material by Rail - Build a Temporary Spur	$0.00	+13%
9	Use Concrete Pavement	$4.67	+9%
10	Increase Span Length of Approach structures	$3.12	+9%

7.1.1 FHWA Functional Benefit Criteria

Each year, state departments of transportation are required to report on VE recommendations to the Federal Highway Administration (FHWA). In addition to cost implications, FHWA requires state departments of transportation to evaluate each approved recommendation in terms of the project features that recommendation benefits. If a specific recommendation can be shown to provide benefit to more than one feature described below, count the recommendation in each category that is applicable. These same criteria can be found on each of the individual recommendations that follow.

- **Safety:** Recommendations that mitigate or reduce hazards on the facility.
- **Operations:** Recommendations that improve real-time service and/or local, corridor, or regional levels of service of the facility.
- **Environment:** Recommendations that avoid or mitigate impacts to natural and or cultural resources.
- **Construction:** Recommendations that improve work zone conditions or expedite the project delivery.
- **Right-of-way:** Recommendations that lower the impacts or costs of right-of-way.

7.2 Value Engineering Recommendation Approval

The resolution or disposition of recommendations is based on the information in this report and is independent of the proceeding of the VE study. HDR has no participation, direct or indirect, in such decisions. The VE Recommendation Approval form shown in Appendix B is intended to aid the project manager in tracking and informing the Cabinet's Value Engineer in annual reporting of VE activities to FHWA. Resolution and disposition of recommendations contained in Appendix B are pending.

7.3 Individual Recommendations

Based on the evaluation process, individual recommendations were developed. Each recommendation consists of a summary of the baseline concept, a description of the recommendation, a listing of its advantages and disadvantages, and a brief narrative that includes justification, sketches, photos, assumptions, and calculations as developed by the VE team. Final recommendations can be found beginning on page 7-3.

VE RECOMMENDATION NO. 1: FACILITATE STAGING LOCATIONS	Idea No(s). 33, 34

Baseline Concept

KYTC will not specify and/or provide an area for contractor to stage equipment/materials/etc.

Only areas within the KYTC Right of Way could be used without the contractor pursuing an agreement with other property owners.

Recommendation Concept

The VE team discussed the following ideas to reduce risk of contractor and reduce costs related to work zone selection:

- Create staging areas within KYTC or IDOT property
- Initiate the APE process early and expand area

Advantages	Disadvantages
• Reduces contractor risks • Reduces staging costs • May reduce environmental impacts by the contractor • Save time	• Means and methods • Proximity to the project

Cost Summary	Construction	Right-of-way	Total
Baseline Concept	$0	$0	$0
Recommendation Concept	$0	$80,000	$80,000
Cost Avoidance/ (Added Value)	$0	($80,000)	($80,000)

FHWA Function Benefit

Safety	*Operations*	*Environment*	*Construction*	*Right-of-way*
			✓	

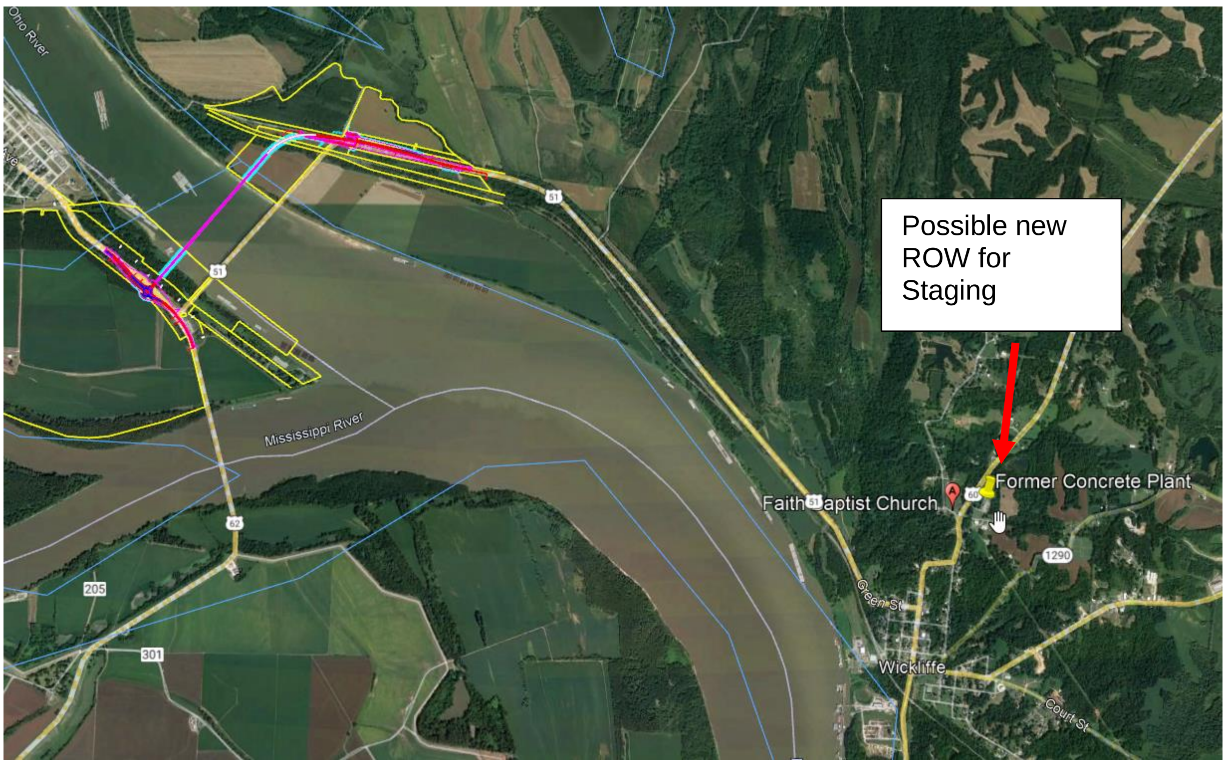
VE RECOMMENDATION NO. 1: FACILITATE STAGING LOCATIONS	Idea No(s). 33, 34

Discussion/Sketches/Photos/Calculations

Technical Discussion/Sketches

There is very little space within the project limits for contractor staging that is not in the flood plain. This could cause the contractor to stop operations to move equipment and materials to higher ground causing significant delays to the project. If KYTC were to provide a KYTC owned area nearby that could be used for staging, it could reduce risk for the contractor when bidding the project, save time, and save money.

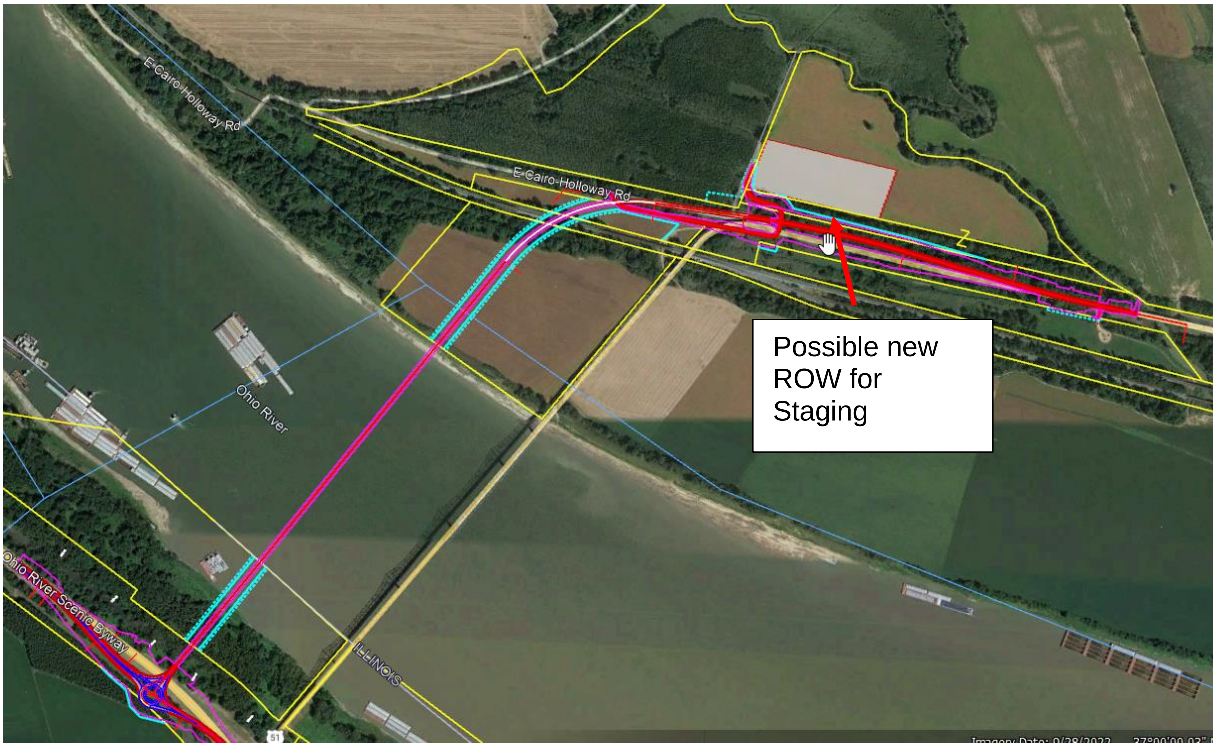
From discussion with the project team, KYTC does not own any property near the project that could be used. KYTC could possibly acquire some additional right of way that is out of the flood plain in hopes of speeding up the project and reducing contractor risk when bidding the project. An option for KYTC purchase or some other type of agreement would be the area shown on the map below where a batch plant was previously set up for a concrete pavement project. This location is approximately 3 miles from the project.



Recommendation – Location #1

VE RECOMMENDATION NO. 1: FACILITATE STAGING LOCATIONS	Idea No(s). 33, 34

KYTC could possibly buy some extra Right of Way in the area shown below. This 10-acre area would be convenient for staging.



Recommendation – Location #2

VE RECOMMENDATION NO. 1: FACILITATE STAGING LOCATIONS	Idea No(s). 33, 34

Illinois may have a property around Fort Defiance Park that could be used for contractor staging if they would be agreeable. Giving the contractor this area as an option could help with operations on the Illinois side of the project.

Recommendation – Location #3

Assumptions/Calculations

KYTC has Right of Way funds available for the project to purchase an area for contractor staging. Assuming a 10-acre parcel for staging as mentioned and as shown above, at a unit cost of $8,000 per acre, total cost of new ROW $80,000.

VE RECOMMENDATION NO. 1: FACILITATE STAGING LOCATIONS	Idea No(s). 33, 34

The VE team learned that Illinois may be agreeable to allowing the contractor to utilize the area they own at Fort Defiance State Park for staging as well. It is assumed that no additional cost is associated with this area.

No costs have been calculated for the area where the batch plant was set up for another project. It may be possible to simply get an agreement in place for use of the property since it has been used for similar purposes before.

The VE team recommends using locations #1, Kentucky location and #3, Illinois location. There are not any known costs associated with the use of these locations as of today. Location #2, Kentucky side, would incur $80,000.00 costs and therefore recommended if location #1 is not available.

VE Study Cost Calculations

US 51 Bridge over Ohio River Replacement

		Baseline Concept			VE Recommended Concept		
Component	**Unit**	**Qty**	**Cost/Unit**	**Total**	**Qty**	**Cost/Unit**	**Total**
ROW (Staging Area)	Acr	0	$ 8,000.00	$ -	10	$ 8,000.00	$ 80,000
				$ -		$ -	$ -
				$ -		$ -	$ -
				$ -		$ -	$ -
				$ -		$ -	$ -
				$ -		$ -	$ -
				$ -		$ -	$ -
				$ -		$ -	$ -
				$ -		$ -	$ -
				$ -		$ -	$ -
				$ -		$ -	$ -
				$ -		$ -	$ -
				$ -		$ -	$ -
Subtotal Construction				$ -			*$ 80,000*
Mark-Up (MOT, Mob., PE, CEI)	0%			$ -			$ -
Total Construction				**$ -**			**$ 80,000**
Utility Costs				$ -		$ -	$ -
Right of Way Costs				$ -		$ -	$ -
TOTAL CAPITAL COST				***$ -***			***$ 80,000***
COST CAPITAL SAVINGS / (VALUE ADDED)							**$ (80,000)**

VE RECOMMENDATION NO. 1: FACILITATE STAGING LOCATIONS

Idea No(s). 33, 34

VE RECOMMENDATION NO. 1	IDEA NO.		
Facilitate Staging Locations			
PERFORMANCE MEASURES / **Attributes and Rating Rationale for Recommendation**	*Performance*	*Baseline*	*Recommendation*
Risk	*Rating*	5	5
No change	*Weight*	33.3	
	Contribution	166.5	166.5
Maintainability	*Rating*	5	5
No change	*Weight*	20.0	
	Contribution	100	100
Construction Impacts	*Rating*	5	5
No change	*Weight*	23.3	
	Contribution	116.5	116.5
Environmental Impacts	*Rating*	5	5
Similar impacts to natural resources and ROW	*Weight*	16.6	
	Contribution	83	83
Project Schedule	*Rating*	5	5.5
Having closer staging areas with access to the site will shorten construction times and may be able to extend seasonal work	*Weight*	6.6	
	Contribution	33	36.3
	Total Performance	499	502
		Net Change in Performance	1%

VE RECOMMENDATION NO. 2: USE SOIL IMPROVEMENTS TECHNIQUES	Idea No(s). 9, 10, 27

Baseline Concept

The current preliminary Geotechnical Report dated November 30, 2022, recommends pile supported embankments using either timber piles or rigid inclusion/controlled modulus columns (CMC). PVDs (Wick Drains) were considered under embankments to help accelerate consolidation settlement and reduce waiting periods but not for mitigation of seismic slope stability.

Recommendation Concept

In addition to the options already evaluated, at each substructure foundation, it is recommended to consider other soil or ground improvement methods to mitigate against liquefaction and increase the resistance of the foundations. For this application area, methods typically considered that could help increase the soil's resistance to liquefaction include:

- Deep soil mixing
- Jet Grouting
- Compaction Grouting and Wick Drains (limited areas)

Advantages	Disadvantages
• Reduces risk of liquefaction • Increases load bearing capacity of piles • Can reduce foundation lengths	• Increases costs

Cost Summary	Construction	Right-of-way	Total
Baseline Concept	$105,051,600	$0	$105,051,600
Recommendation Concept	$114,417,389	$0	$114,417,389
Cost Avoidance/ (Added Value)	$(9,365,789)	$0	$(9,365,789)

FHWA Function Benefit

Safety	*Operations*	*Environment*	*Construction*	*Right-of-way*
✓	✓		✓	

VE RECOMMENDATION NO. 2: USE SOIL IMPROVEMENTS TECHNIQUES	Idea No(s). 9, 10, 27

Discussion/Sketches/Photos/Calculations

Technical Discussion/Sketches

From FHWA-NHI-16-027 GEC 013 April 2017 – Ground Modification Methods Reference Manual – Volume 1 (Figure 1)

Increase resistance to liquefaction	• Aggregate Columns • Deep Dynamic Compaction • Deep Mixing • Jet Grouting • Vibro-Compaction	Techniques generally to modify and improve soil susceptible to liquefaction. Aggregate columns also provide drainage path for excess pore water pressure.

Figure 1

Deep Soil Mixing

This method is used to change the in-situ compression and strength characteristics of the soils and reduces the soil compressibility. It is a mass mixing method that blends a binder with soil in-situ to produce a soil-cement. The binder materials can consist of cement, lime, fly ash, slag, or others. Deep mixing can be done by the wet method or the dry method. The wet method would probably be the preferred method for this project. Columns can be up to 8 feet in diameter and go to depths of 100 feet. The wet method does produce soil spoil, but these spoils can be used in other embankment areas. It has been used in Alexandria, VA for I-95/Rte 1 Interchange, I-15 Utah, I-90/I-93NB Interchange, Boston, MA, New Orleans Levee system.

Geotech Tools Information sheets are attached.

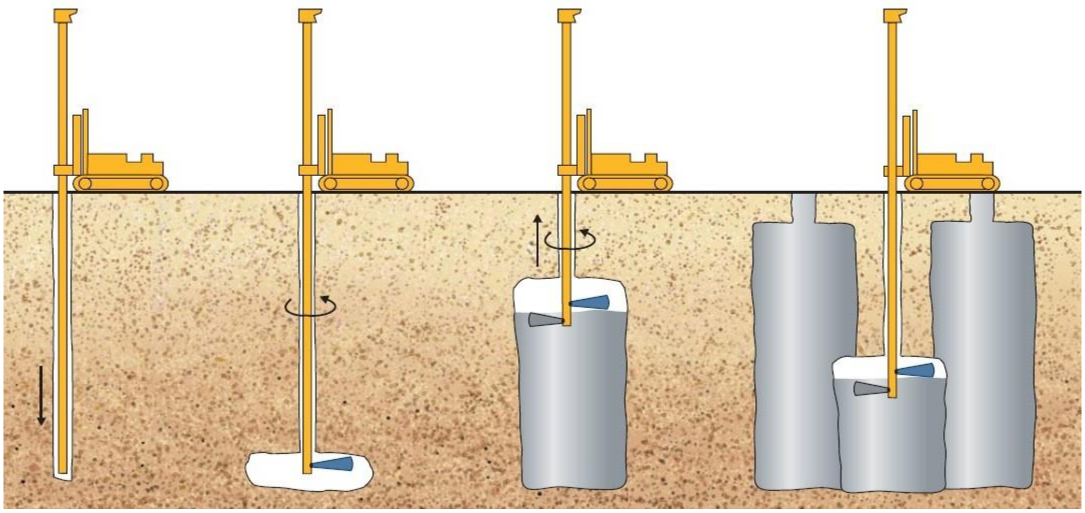
Option 1

VE RECOMMENDATION NO. 2: USE SOIL IMPROVEMENTS TECHNIQUES	Idea No(s). 9, 10, 27

Jet Grouting

Jet grouting techniques uses high pressure, high velocity erosive jets of water and/or air to break down the soil structure and replacing with cement-based grout. The methods transform soil into a mixture of soil and cement, typically referred to as "soilcrete." It can be used in all types of soils and used above or below the groundwater. Columns can be installed to depths of 150 feet. Projects it has been used on is the Central Artery/Tunnel Project in Boston, MA, Brigantine Cut and Cover Tunnel Project in Atlantic City, NJ, and I-78 and Route 33 Interchange Ramps in Bethlehem, PA.

Geotech Tools Information sheets are attached.



Option 2

Option 2

VE RECOMMENDATION NO. 2: USE SOIL IMPROVEMENTS TECHNIQUES	Idea No(s). 9, 10, 27

Compaction Grouting (limited areas to improve stability and for working platforms)

Compaction grouting strengthens and stiffens soils through densification by displacement of the soil as grout is injected into the soil.

Wick Drains (limited areas to reduce waiting periods)

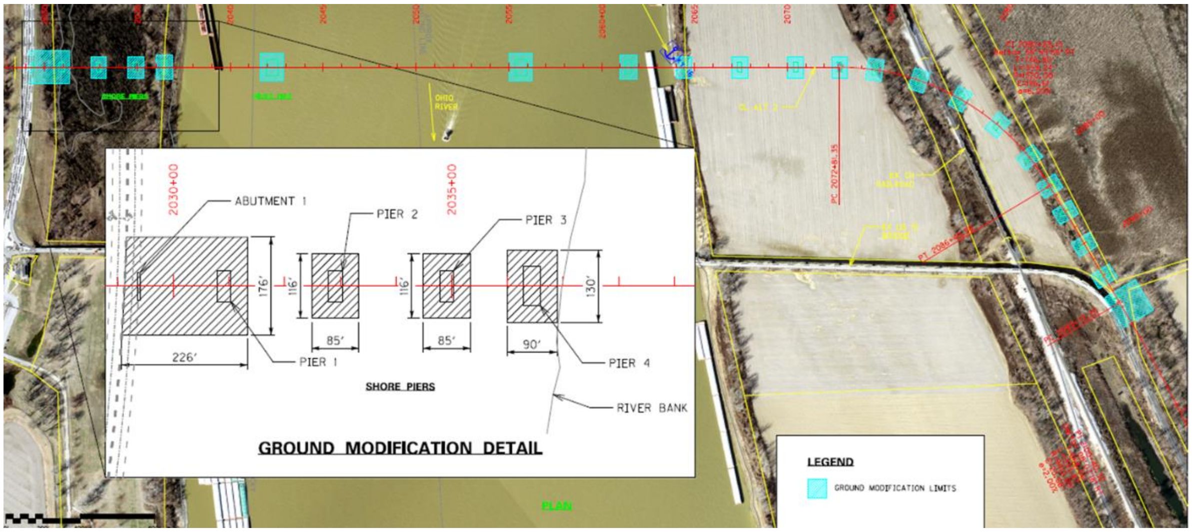
PVDs or Wick drains are rectangular cross-section shaped bands consisting of geotextile filter material surrounding a plastic core. They are vertically pushed into the soil through the depth of improvement. During loading, water is pushed upward through the plastic core. It accelerates the consolidation rate and strength gain of fine-grained soils by reducing the drainage paths. They are relatively fast to install and can be used in combination with other soil improvement methods to achieve certain goals for wait periods, stability, and strength gain in certain parts of the project.

Option 3

Assumptions/Calculations

The VE team reviewed assumptions by the project team in the presentation of the project, slide 60, showing the proposed dimensions of the ground improvements (see excerpt below).

VE RECOMMENDATION NO. 2: USE SOIL IMPROVEMENTS TECHNIQUES	Idea No(s). 9, 10, 27



Using these assumptions, the volumes of soil mixing material at an assumed depth of 75', is close to 850,000 CY. The cost of ground improvements based on the project team's assumptions is shown below, for a total of an additional $96 million.

VE Study Cost Calculations
US 51 Bridge over Ohio River Replacement

		Baseline Concept			VE Recommended Concept		
Component	**Unit**	**Qty**	**Cost/Unit**	**Total**	**Qty**	**Cost/Unit**	**Total**
Abutment Ground Improvement (Unit 1)	LS	1	$ 1,500,000	$ 1,500,000		$ 1,500,000	$ -
Slope Ground Improvement (Unit 1)	LS	1	$ 200,000	$ 200,000		$ 200,000	$ -
Slope Ground Improvement (Unit 3)	LS	1	$ 1,000,000	$ 1,000,000		$ 1,000,000	$ -
Abutment Ground Improvement (Unit 5)	LS	1	$ 1,500,000	$ 1,500,000		$ 1,500,000	$ -
Deep soil mixing Mobilization	LS	0	$ 100,000	$ -	1	$ 100,000	$ 100,000
Deep soil mixing	CY	0	$ 105.40	$ -	829,656	$ 105.40	$ 87,445,696
Piers Foundations	LS	1	$ 78,000,000	$ 78,000,000	0.9	$ 78,000,000	$ 70,200,000
Subtotal Construction				*$ 82,200,000*			*$ 157,745,696*
Mark-Up (MOT, Mob., PE, CEI)	28%			$ 22,851,600			$ 43,853,303
Total Construction				**$ 105,051,600**			**$ 201,598,999**
Utility Costs				$ -		$ -	$ -
Right of Way Costs				$ -		$ -	$ -
TOTAL CAPITAL COST				***$ 105,051,600***			***$ 201,598,999***
COST CAPITAL SAVINGS / (VALUE ADDED)							**$ (96,547,399)**

The VE team's experience shows that the ground improvements typically extend 10' beyond the size of the pier. Taking these assumed dimensions at a depth of 75', the soil mixing material is close to 180,000 CY. The cost of ground improvements based on the VE team assumptions is shown below, for a total of an additional $9.35 million.

VE RECOMMENDATION NO. 2: USE SOIL IMPROVEMENTS TECHNIQUES	Idea No(s). 9, 10, 27

VE Study Cost Calculations

US 51 Bridge over Ohio River Replacement

		Baseline Concept			VE Recommended Concept		
Component	**Unit**	**Qty**	**Cost/Unit**	**Total**	**Qty**	**Cost/Unit**	**Total**
Abutment Ground Improvement (Unit 1)	LS	1	$ 1,500,000	$ 1,500,000		$ 1,500,000	$ -
Slope Ground Improvement (Unit 1)	LS	1	$ 200,000	$ 200,000		$ 200,000	$ -
Slope Ground Improvement (Unit 3)	LS	1	$ 1,000,000	$ 1,000,000		$ 1,000,000	$ -
Abutment Ground Improvement (Unit 5)	LS	1	$ 1,500,000	$ 1,500,000		$ 1,500,000	$ -
Deep soil mixing Mobilization	LS	0	$ 100,000	$ -	1	$ 100,000	$ 100,000
Deep soil mixing	CY	0	$ 105.40	$ -	182,433	$ 105.40	$ 19,228,473
Piers Foundations	LS	1	$ 78,000,000	$ 78,000,000	0.9	$ 78,000,000	$ 70,200,000
Subtotal Construction				*$ 82,200,000*			*$ 89,528,473*
Mark-Up (MOT, Mob., PE, CEI)	28%			$ 22,851,600			$ 24,888,916
Total Construction				**$ 105,051,600**			**$ 114,417,389**
Utility Costs				$ -		$ -	$ -
Right of Way Costs				$ -		$ -	$ -
TOTAL CAPITAL COST				***$ 105,051,600***			***$ 114,417,389***
COST CAPITAL SAVINGS / (VALUE ADDED)							**$ (9,365,789)**

The VE team assumed a pier size reduction of about 10%, leading to some substructure cost savings. It was not assumed that other cost savings can be achieved on the superstructure as well, which are not shown in these calculations.

In summary, the VE team recommends soil mixing ground improvements extending 10' beyond the pier area and further adjust the depth of the improvement to eliminate the liquefaction risk.

VE RECOMMENDATION NO. 2: USE SOIL IMPROVEMENTS TECHNIQUES

Idea No(s). 9, 10, 27

VE RECOMMENDATION NO. 2	IDEA NO.		
Use Soil Improvements Techniques			
PERFORMANCE MEASURES / **Attributes and Rating Rationale for Recommendation**	*Performance*	*Baseline*	*Recommendation*
Risk	*Rating*	5	8
Reduces risk of liquefaction	*Weight*	33.3	
	Contribution	166.5	266.4
Maintainability	*Rating*	5	6
Improves scour, settlement	*Weight*	20.0	
	Contribution	100	120
Construction Impacts	*Rating*	5	5
Less noise (slight improvement)	*Weight*	23.3	
	Contribution	116.5	116.5
Environmental Impacts	*Rating*	5	5
No change	*Weight*	16.6	
	Contribution	83	83
Project Schedule	*Rating*	5	4.5
Less piles, less time to install and drive It takes time to inject soil mix	*Weight*	6.6	
	Contribution	33	29.7

VE RECOMMENDATION NO. 3: CONDUCT A NON-LINEAR TIME HISTORY ANALYSIS	Idea No. 11

Baseline Concept

Response spectrum analysis is presently being used for seismic design.

Recommendation Concept

Conduct a non-linear time history analysis to assist in decisions leading to super and sub structure design.

Advantages	Disadvantages
• Increases reliability of the design • Provides insight into seismic response • May lead to cost savings	• May lead to increase in cost if it identifies an issue that the conventional response spectrum analysis did not identify. But this additional cost adds to relaiability of the design

Cost Summary	Preliminary Engineering	Right-of-way	Total
Baseline Concept	$0	$0	$0
Recommendation Concept	$1,700,000	$0	$1,700,000
Cost Avoidance/ (Added Value)	$1,700,000	$0	$1,700,000

FHWA Function Benefit

Safety	*Operations*	*Environment*	*Construction*	*Right-of-way*
✓			✓	

VE RECOMMENDATION NO. 3: CONDUCT A NON-LINEAR TIME HISTORY ANALYSIS	Idea No. 11

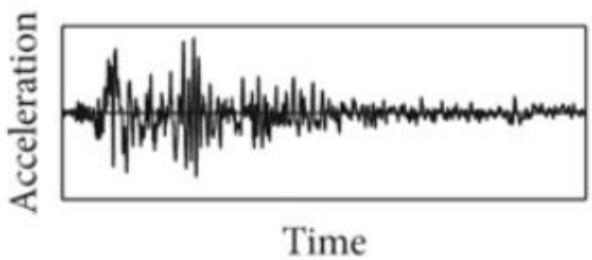
Discussion/Sketches/Photos/Calculations

Technical Discussion/Sketches

Response spectrum analysis (RSA) is an analytical approach based in the frequency domain, the Nonlinear Time History Analysis, NLTH, is based in the time domain.

RSA is an elastic analysis but, the structure undergoes significant inelasticity during an earthquake. The response of isolation bearings is equivalent to major inelasticity. NLTH captures all of this.

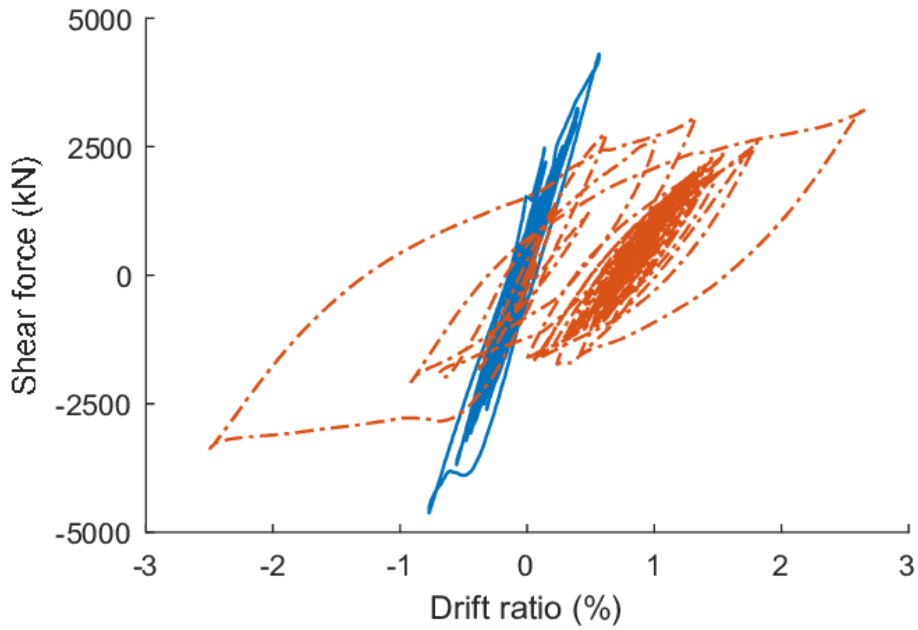
Further, seismic waves arrive from a particular direction, and travel along the length of the bridge and excite columns at different times. NLTH can capture this out of phase response effect and potentially provide savings that an RSA would not reveal. RSA is an in-phase analysis.



Baseline

VE RECOMMENDATION NO. 3: CONDUCT A NON-LINEAR TIME HISTORY ANALYSIS	Idea No. 11

(a)



(b)

Recommendation

The results of this analysis will lead to improved design, superstructure, and substructure selection as well as possible constructability considerations. In addition, when using isolation bearings, it is likely that this analysis is a requirement, and the design team should further investigate its applicability.

Assumptions/Calculations

The cost of a study of this nature is in the order of 7,500 engineering hours plus quality checks and reviews, which on average could reach $1,700,000

VE RECOMMENDATION NO. 3: CONDUCT A NON-LINEAR TIME HISTORY ANALYSIS	Idea No. 11

VE Study Cost Calculations

US 51 Bridge over Ohio River Replacement

		Baseline Concept			VE Recommended Concept		
Component	**Unit**	**Qty**	**Cost/Unit**	**Total**	**Qty**	**Cost/Unit**	**Total**
Non liner time history analysis	Hr	0	$ 226.67	$ -	7,500	$ 226.67	$ 1,700,000
				$ -		$ -	$ -
				$ -		$ -	$ -
				$ -		$ -	$ -
				$ -		$ -	$ -
				$ -		$ -	$ -
				$ -		$ -	$ -
				$ -		$ -	$ -
				$ -		$ -	$ -
				$ -		$ -	$ -
				$ -		$ -	$ -
				$ -		$ -	$ -
				$ -		$ -	$ -
Subtotal Construction				*$ -*			*$ 1,700,000*
Mark-Up (MOT, Mob., PE, CEI)	0%			$ -			$ -
Total Construction				**$ -**			**$ 1,700,000**
Utility Costs				$ -		$ -	$ -
Right of Way Costs				$ -		$ -	$ -
TOTAL CAPITAL COST				***$ -***			***$ 1,700,000***
COST CAPITAL SAVINGS / (VALUE ADDED)							**$ (1,700,000)**

VE RECOMMENDATION NO. 3: CONDUCT A NON-LINEAR TIME HISTORY ANALYSIS

Idea No. 11

VE RECOMMENDATION NO. 3	IDEA NO.		
Conduct a Non-linear Time History Analysis			
PERFORMANCE MEASURES **Attributes and Rating Rationale for Recommendation**	***Performance***	***Baseline***	***Recommendation***
Risk Improves understanding of seismic behavior of structure Improves reliability in the design Improves resiliency	***Rating***	5	7.5
	Weight	33.3	
	Contribution	166.5	249.8
Maintainability With improved resiliency, repairs after a seismic event will likely have less impacts than the baseline	***Rating***	5	6
	Weight	20.0	
	Contribution	100	120
Construction Impacts No change	***Rating***	5	5
	Weight	23.3	
	Contribution	116.5	116.5
Environmental Impacts No change	***Rating***	5	5
	Weight	16.6	
	Contribution	83	83
Project Schedule No change	***Rating***	5	5
	Weight	6.6	
	Contribution	33	33
	Total Performance	499	602
		Net Change in Performance	21%

VE RECOMMENDATION NO. 4: PRE-DESIGN BY LOAD TESTING	Idea No. 3

Baseline Concept

According to the preliminary geotechnical report dated November 30, 2022, it indicates that a design phase load test program may be performed prior to final design. It would be performed on each foundation type considered. It would include both static and dynamic load testing.

Recommendation Concept

The recommendation is to create a separate contract for a Pre-Design Foundation Load Test Program, with early letting date.

Advantages	Disadvantages
• Reduce the unknowns of geotechnical conditions • May reduce foundation costs • Reduce uncertainty for contractor and owner • May assist on means and methods of construction • May reduce the amount of resistance required	• Adds upfront costs • Duration of design may increase • Slight increase in design costs • Contractor may choose different means and methods based on results

Cost Summary	Construction	Preliminary Engineering	Total
Baseline Concept	$98,311,835	$0	$98,311,835
Recommendation Concept	$88,480,651	$2,260,000	$90,740,651
Cost Avoidance/ (Added Value)	$9,831,183	$2,260,000	$7,571,184

FHWA Function Benefit

Safety	*Operations*	*Environment*	*Construction*	*Right-of-way*
✓			✓	

VE RECOMMENDATION NO. 4: PRE-DESIGN BY LOAD TESTING	Idea No. 3

Discussion/Sketches/Photos/Calculations

Technical Discussion/Sketches

The program would require design plans indicating location(s), foundation layout and details, test methods, specifications, and other notes. The design of the test program will need to consider foundation sizes relative to test loads and locations to test in order to capture worst case conditions of the site (or similar). The test program needs to consider means and methods that are most likely to be used in the actual construction. Other things that should be considered when modelling and analyzing the test program should include:

- Simulating unsupported conditions around the foundations. An outer diameter casing can be installed through the upper soils that are subject to scour and liquefaction. This would mimic scour and liquefaction that would occur in this design event.
- Model a liquefaction event during pile load testing. Some precedent has been set from a study in California.
- Carry the load testing to “failure” conditions to capture the nominal resistances rather than maximum loading conditions. This may not be feasible using production size diameters therefore, there is precedent and AASHTO allows for small diameter foundation units to test and still be comparable.
- Incorporate soil improvement methods around the area of foundation load testing to see the advantages those methods could provide. The soil improvement could mimic how the foundations will react to ground modifications. The secondary benefit is it will indicate the effectiveness of soil improvement at this site and provide data to be used in final design.
- Use instrumentation inside the piles or shafts in addition to the ones typically used at the tops of the foundation. This information will provide useful unit load transfer values and lateral deflection with depth.
- Consider the best application of loads to apply the loads in the test program. For example, consider traditional top-down static load testing, Osterberg Load Cell Testing (bottom-up), and Statnamic load (or APPLE) testing. Consider both axial and lateral load testing.
- During installation of driven piles (or even casing) use Dynamic Testing (PDA) to measure stresses, hammer performance, and resistances from impact driving. Consider the hammer size and types. Use CAPWAP to refine measurements and report results.

For drilled foundations, use shaft calipers for verticality and diameter measurements, cameras, or shaft inspection devices (SID) for cleanliness during drilling. Use Crosshole Sonic Logging (CSL) and Thermal Integrity Profiling (TIP) to measure concrete placement quality. Traditional Static Axial Load Test

VE RECOMMENDATION NO. 4: PRE-DESIGN BY LOAD TESTING	Idea No. 3

Baseline

VE RECOMMENDATION NO. 4: PRE-DESIGN BY LOAD TESTING	Idea No. 3

Recommendation - Osterberg Load Cell Testing

VE RECOMMENDATION NO. 4: PRE-DESIGN BY LOAD TESTING	Idea No. 3

Project Location

Link to website of The Treasure Island Liquefaction Test – Final Report by Scott A. Ashford & Kyle M. Rollins

https://rosap.ntl.bts.gov/view/dot/15497

Assumptions/Calculations:

The table below details the testing operations costs.

Also, considering that this method of design has shown efficiencies in typical assumptions, the VE team considered possible cost savings by right sizing the pile foundations of the project. Typically, and depending on assumptions made in the baseline, cost savings could range from 5% to 15%; the VE team assumed 10% design efficiencies for this project considering its early stages of design.

VE RECOMMENDATION NO. 4: PRE-DESIGN BY LOAD TESTING	Idea No. 3

Assumptions/Calculations

VE Study Cost Calculations

US 51 Bridge over Ohio River Replacement

		Baseline Concept			VE Recommended Concept		
Component	**Unit**	**Qty**	**Cost/Unit**	**Total**	**Qty**	**Cost/Unit**	**Total**
Produce Load Test Design Plans and Bid Documents	EA		$ 50,000	$ -	1	$ 50,000.00	$ 50,000
Mobilization/Demobilization	EA		$ 500,000	$ -	1	$ 500,000.00	$ 500,000
Sacrificial Pipe Piles - Supply and Install	EA		$ 100,000	$ -	2	$ 100,000.00	$ 200,000
Sacrificial Drilled Shafts - Materials and Drill	EA		$ 200,000	$ -	2	$ 200,000.00	$ 400,000
Soil Improvement Test Option	EA		$ 100,000	$ -	1	$ 100,000.00	$ 100,000
Load Test Setups and Performance of Tests	EA		$ 120,000	$ -	6	$ 120,000.00	$ 720,000
Instrumentation and Monitoring	EA		$ 75,000	$ -	2	$ 75,000.00	$ 150,000
Dynanic Load Testing	EA		$ 10,000	$ -	4	$ 10,000.00	$ 40,000
Shaft QC Testing (SID, CSL, TIP, etc.)	EA		$ 50,000	$ -	2	$ 50,000.00	$ 100,000
Pier Foundations	LS	1	$ 76,806,121	$ 76,806,121	0.9	$ 76,806,121.00	$ 69,125,509
				$ -		$ -	$ -
				$ -		$ -	$ -
				$ -		$ -	$ -
Subtotal Construction				*$ 76,806,121*			*$ 71,385,509*
Mark-Up (MOT, Mob., PE, CEI)	28%			$ 21,505,714			$ 19,355,142
Total Construction				**$ 98,311,835**			**$ 90,740,651**
Utility Costs				$ -		$ -	$ -
Right of Way Costs				$ -		$ -	$ -
TOTAL CAPITAL COST				***$ 98,311,835***			***$ 90,740,651***
COST CAPITAL SAVINGS / (VALUE ADDED)							**$ 7,571,183**

VE RECOMMENDATION NO. 4: PRE-DESIGN BY LOAD TESTING	Idea No. 3

VE RECOMMENDATION NO. 4	IDEA NO.		
Pre-Design by Load Testing			
PERFORMANCE MEASURES / **Attributes and Rating Rationale for Recommendation**	*Performance*	*Baseline*	*Recommendation*
Risk Increases reliability and confidence in the design (length and constructability of the shaft/pier)	*Rating*	5	7.5
	Weight	33.3	
	Contribution	166.5	249.8
Maintainability No change	*Rating*	5	5
	Weight	20.0	
	Contribution	100	100
Construction Impacts No change	*Rating*	5	5
	Weight	23.3	
	Contribution	116.5	116.5
Environmental Impacts No change	*Rating*	5	5
	Weight	16.6	
	Contribution	83	83
Project Schedule Improves duration during construction as it will reduce the learning curve of soil testing during construction	*Rating*	5	5.5
	Weight	6.6	
	Contribution	33	36.3
	Total Performance	499	586
		Net Change in Performance	17%

VE RECOMMENDATION NO. 5: INCREASE END BEARING RESISTANCES OF FOUNDATIONS	Idea No. 7

Baseline Concept

According to the Geotechnical Engineering Report dated November 30, 2022, pipe piles and drilled shafts have been considered as a possible foundation types. Open-ended steel pipe piles have been proposed to be driven to achieve the proposed required nominal resistances. The shafts have been proposed to rely on both skin and tip resistance within the soil to achieve the required nominal resistances.

Other methods to help increase the end-bearing resistance include using constrictor plates inside the steel pipe piles. For drilled shafts, it was proposed to have permanent casings driven to below the liquefiable layer to reduce down-drag loads and the remaining resistance to be made up in the skin friction.

Recommendation Concept

The proposed recommendation are methods to increase the end bearing resistances for both pipe piles and drilled shaft foundation options.

Proposed methods to increase end bearing resistance include:

- Concrete or grout filled steel pipe piles, and/or.
- Post-grouted drilled shafts

Advantages	Disadvantages
• Reduce costs relative to reduced shaft/pile lengths • Reduce the thickness of steel pipe • Increase bending capacity	• Increase costs relative to steel piles and drilled shafts • Increase complexity of construction • Increased QA/QC needed

Cost Summary	Construction	Right-of-way	Total
Baseline Concept	$116,733,338	$0	$116,733,338
Recommendation Concept	$99,415,037	$0	$99,415,037
Cost Avoidance/ (Added Value)	$17,318,301	$0	$17,318,301

FHWA Function Benefit

Safety	*Operations*	*Environment*	*Construction*	*Right-of-way*
✓			✓	

VE RECOMMENDATION NO. 5: INCREASE END BEARING RESISTANCES OF FOUNDATIONS	Idea No. 7

Discussion/Sketches/Photos/Calculations

Technical Discussion/Sketches

Methods to increase end bearing resistances in driven steel pipe piles include creating a plug at the bottom by drilling out the inside to the tip elevation and pouring concrete for the entire length. Tremie pour or pressure grouted tip create the end bearing surface and load transfer occurring from inside the steel pipe pile to the end bearing surface. The concrete placement will have to occur in the wet, below the water.

The inclusion of a completely concrete-filled pipe pile will also increase the lateral stiffness of the steel pipe pile foundation unit, possibly reducing the number of piles driven. This is a secondary positive benefit to the increased end bearing resistances. By designing for more end bearing, it is possible to reduce the steel thickness that has been assumed.

A method to increase end bearing resistances in drilled shafts include using post-grouting or base grouting at the tips of the shafts. It involves the injection of grout under pressure below the tip of the drilled shaft to improve performance when subjected to axial compressive loads. Post-grouting includes the use of one or more tubes or pipes that pass from the top of the shaft to a grout distribution apparatus located at the tip of the shaft. Most of the post-grouting application involve injecting neat cement gout.

According to Report No. FHWA-HIF-17-024 – Evaluation and Guidance Development for Post-Grouted Drilled Shafts for Highways, dated March 2017(Figure 1).

Post-grouting at the tip of drilled shafts has been purported to:

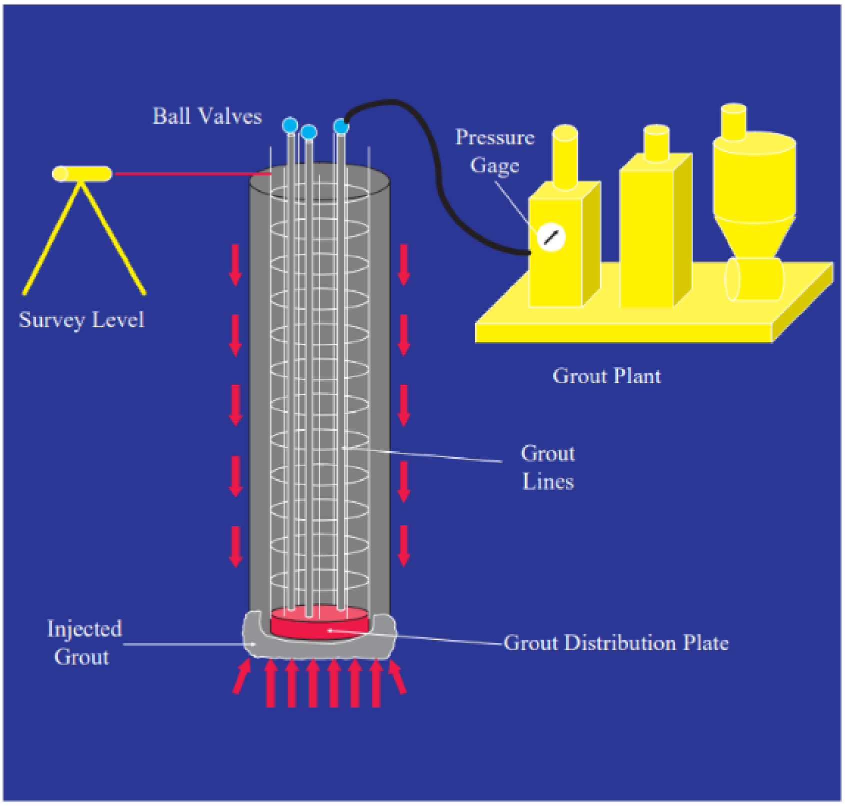
- Increase the tip resistance of drilled shafts, thereby allowing design lengths of drilled shafts to be shortened.
- "Stiffen" the load-deformation response of a shaft by pre-mobilizing side and tip resistance.
- Verify a "lower-bound" load carrying resistance of a drilled shaft as a function of the maximum sustained grout pressure.
- Reduce the effects of, and risk associated with, bottom cleanliness and potential "soft-bottom" conditions.

Figure 1

VE RECOMMENDATION NO. 5: INCREASE END BEARING RESISTANCES OF FOUNDATIONS	Idea No. 7

Baseline

The Post Grouted Shaft Process



Option 1

VE RECOMMENDATION NO. 5: INCREASE END BEARING RESISTANCES OF FOUNDATIONS	Idea No. 7

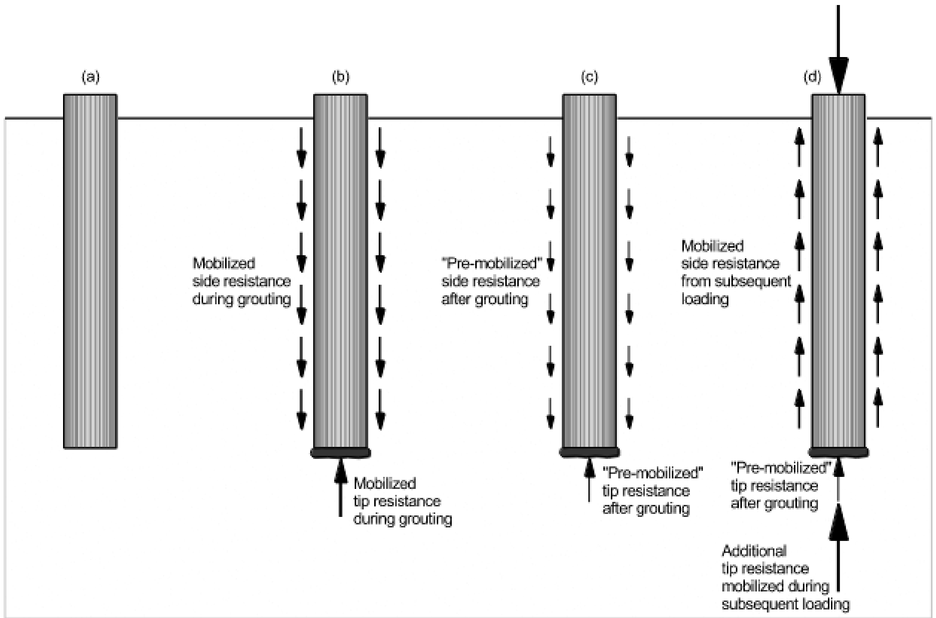


Figure 2.1: Schematic illustrating mobilization of resistance for PGDS: (a) constructed drilled shaft prior to post-grouting; (b) grouting at the shaft tip mobilizes negative side resistance and positive tip resistance; (c) mobilized resistance following post-grouting, including any relaxation of mobilized load that may occur following grouting; and (d) top-down loading reverses side resistance and mobilizes remaining tip resistance (adapted from Brown et al., 2010).

Option 2

Assumptions/Calculations

VE RECOMMENDATION NO. 5: INCREASE END BEARING RESISTANCES OF FOUNDATIONS

Idea No. 7

VE Study Cost Calculations

US 51 Bridge over Ohio River Replacement

		Baseline Concept				VE Recommended Concept		
Component	**Unit**	**Qty**	**Cost/Unit**	**Total**		**Qty**	**Cost/Unit**	**Total**
Drilled Shafts Lengths	LF	16440	$ 5,556	$ 91,340,640		13,974	$ 5,556	$ 77,639,544
Post-grouting shafts	CY	0	$ 500	$ -		300	$ 500	$ 150,000
				$ -			$ -	$ -
				$ -			$ -	$ -
				$ -			$ -	$ -
				$ -			$ -	$ -
				$ -			$ -	$ -
				$ -			$ -	$ -
				$ -			$ -	$ -
				$ -			$ -	$ -
				$ -			$ -	$ -
				$ -			$ -	$ -
Subtotal Construction				*$ 91,340,640*				*$ 77,789,544*
Mark-Up (MOT, Mob., PE, CEI)	28%			$ 25,392,698				$ 21,625,493
Total Construction				**$ 116,733,338**				**$ 99,415,037**
Utility Costs				$ -			$ -	$ -
Right of Way Costs				$ -			$ -	$ -
TOTAL CAPITAL COST				***$ 116,733,338***				***$ 99,415,037***
COST CAPITAL SAVINGS / (VALUE ADDED)								**$ 17,318,301**

VE RECOMMENDATION NO. 5: INCREASE END BEARING RESISTANCES OF FOUNDATIONS	Idea No. 7

VE RECOMMENDATION NO. 5	IDEA NO.		
Increase End Bearing Resistances of Foundations			
PERFORMANCE MEASURES **Attributes and Rating Rationale for Recommendation**	*Performance*	*Baseline*	*Recommendation*
Risk Improves end bearing capacity Improves resiliency	*Rating*	5	6.5
	Weight	33.3	
	Contribution	166.5	216.5
Maintainability No change	*Rating*	5	5
	Weight	20.0	
	Contribution	100	100
Construction Impacts Increases the number of concrete truck traffic	*Rating*	5	4.75
	Weight	23.3	
	Contribution	116.5	110.7
Environmental Impacts No change	*Rating*	5	5
	Weight	16.6	
	Contribution	83	83
Project Schedule Zero net change: shortens pipes thus less piling time, but it adds concrete operations	*Rating*	5	5
	Weight	6.6	
	Contribution	33	33
Total Performance		499	543
Net Change in Performance			9%

VE RECOMMENDATION NO. 6: USE ISOLATION BEARINGS WITH BATTER PILES	**Idea No. 17**

Baseline Concept

The baseline concept uses straight piles and does not include isolation bearings.

Recommendation Concept

The VE team recommends the use of batter piles in combination with isolation bearings

Advantages	Disadvantages
• Reduces foundation costs – the main driver of project costs • Improves seismic performance and therefore reliability of the structure during earthquakes.	• A marginal increase in cost due to use of hammer at the batter angle. • Marginal increase in complexity in the design and construction of pile cap.

Cost Summary	Construction	Right-of-way	Total
Baseline Concept	$100,906,817	$0	$100,906,817
Recommendation Concept	$89,513,496	$0	$89,513,496
Cost Avoidance/ (Added Value)	$11,393,322	$0	$11,393,322

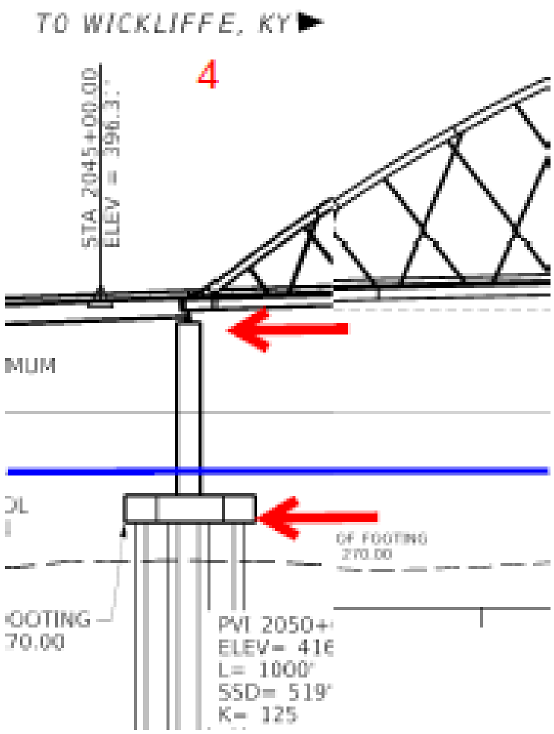
FHWA Function Benefit

Safety	*Operations*	*Environment*	*Construction*	*Right-of-way*
✓			✓	

VE RECOMMENDATION NO. 6: USE ISOLATION BEARINGS WITH BATTER PILES	Idea No. 17

Discussion/Sketches/Photos/Calculations

Technical Discussion/Sketches



Baseline

The biggest driver of cost on the project are bridge foundations. They are expensive because of the project being situated in an extremely high seismic zone as well as on inferior quality of the soil which has the potential for liquefaction during the seismic event. Liquefaction results in loss of lateral soil support and makes the piles vulnerable to bending resulting in thicker pile sections.

Seismic forces (though not exclusively) are transverse loads that are mainly generated from the inertia of the bridge mass and the inertia of the substructure mass.

At the bridge level this force tends to concentrate at the bearing level.

When the pile cap is large un-supported by soil and the top 70+ ft of soil has liquefied offering no lateral support, the substructure inertia tends to concentrate at the pile cap level. The system may then be idealized by a classical 2 degree of freedom system for gaining insight into the seismic behavior.

These Simple 2 dof models reveal that force from the bearings results mostly in axial effects in the pile. This may be understood from the truss like action shown below (Figure 1):

VE RECOMMENDATION NO. 6: USE ISOLATION BEARINGS WITH BATTER PILES	Idea No. 17

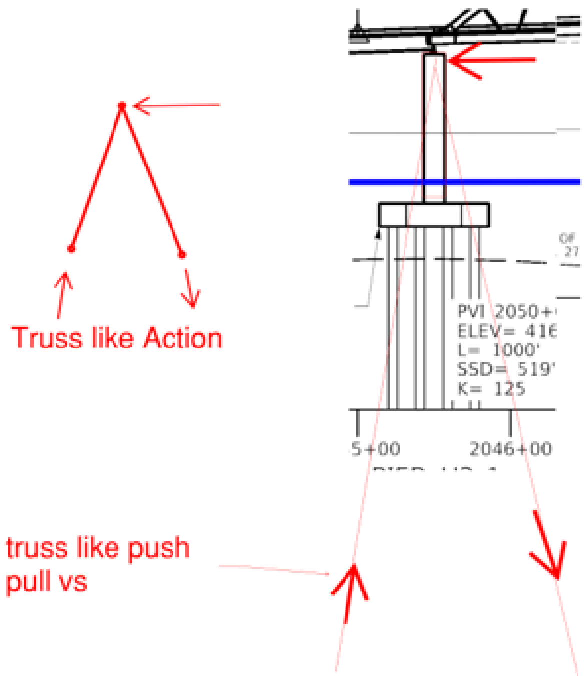
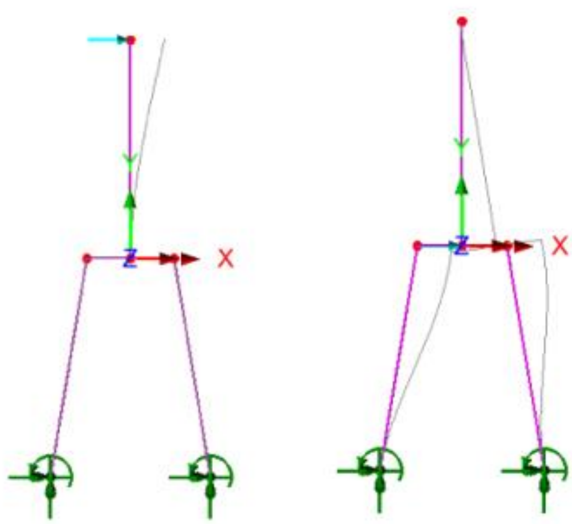


Figure 1

Force from the pilecap drives the bending of the piles. As well as some additional axial in the piles. The two actions are summarized below (Figure 2):



VE RECOMMENDATION NO. 6: USE ISOLATION BEARINGS WITH BATTER PILES	Idea No. 17

Figure 2

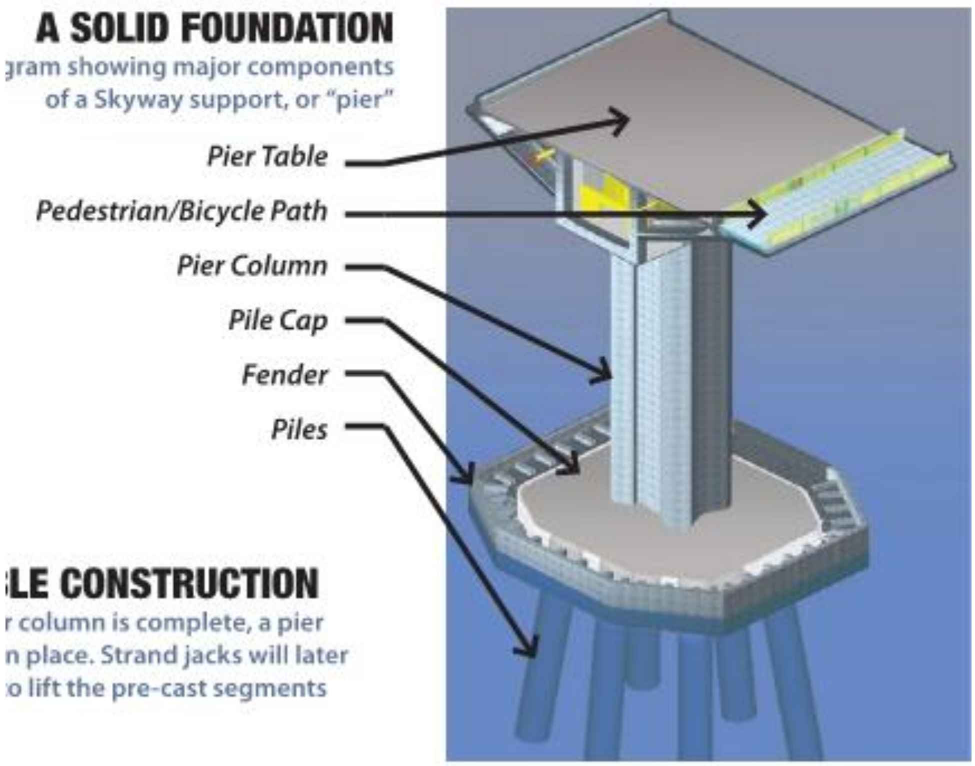
But forces at the bearings are mitigated by the isolation bearing substantially - thus what is left is the pile cap inertia which the isolation bearing does not help much with. The mass of the pile cap and substructure itself is driving the quantity and therefore cost of the substructure.

It is critical that pile cap mass be reduced. Pile cap mass may be reduced by bringing the piles closer together. One way to achieve that without affecting the group substantially is to batter the piles. This results in a positive loop - the smaller the pile cap, the smaller the loads in the pile. Reduction in pile number, even if vertical pile results in smaller pile cap – which in turn keeps the pile force levels low.

Note that batter piles in seismic zone with poor soils has precedent in San Francisco Oakland Bay bridge. See below (Figure 3, Figure 4)

Figure 3

VE RECOMMENDATION NO. 6: USE ISOLATION BEARINGS WITH BATTER PILES	Idea No. 17



Recommendation

We found that existing pile cap on the main span weighs more than the super structure reaction. There are huge gains to be made in reducing the size of the pile cap.

We feel that pile cap could be reduced by up to 1/3 and the number of piles reduced from 12 to less than 10. Our assumption is very broad and must be checked by the designer.

For quantity purposes we have reduced the piles by 20% and the pile cap by 20 %.

Assumptions/Calculations

Dead load reaction at bearing (arch span) is 7500 kips

Pile cap weight = 10000 kips

Additional trib substructure weight = 5000 kips

Liquefaction: top 75 ft.

Structure fundamental period 2 seconds

Second mode (pile cap) period 1.4 secs.

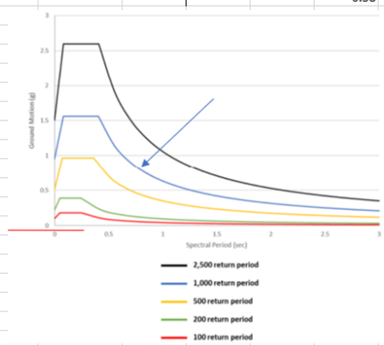
Vessel collision load = 5000 kips

Approx. 2 dof RSA analysis by hand

VE RECOMMENDATION NO. 6: USE ISOLATION BEARINGS WITH BATTER PILES

Idea No. 17

							base					iso only				iso + ftg reduction	
					RSA values			k	k-ft			k	k-ft			k	k-ft
axial	moment		axial	moment				axial	moment			axial	moment			axial	moment
28	38	1	2.80	3.80	0.40	8000	3200	8960.0	12160.0	0.2	640	1792.0	2432.0		640	1792.0	2432.0
10	182	1	1.00	18.20	0.40	15000	6000	6000.0	109200.0		6000	6000.0	109200.0	0.67	4020	4020.0	73164.0
						p cap+ col					10						
							0.533333										
					SRSS comb'n			10783.4	109875.0			6261.9	109227.1			4401.3	73204.4
												0.58	0.99			0.70	0.67
																733.5542	per 6 piles
																	DL



pile cap	1000	
super	7500	
column +	7000	
	15500	
per pile	12	
	1292	kips
sesismic fc	1000	kips
	2292	kips
	OK	

VE Study Cost Calculations

US 51 Bridge over Ohio River Replacement

		Baseline Concept			VE Recommended Concept		
Component	**Unit**	**Qty**	**Cost/Unit**	**Total**	**Qty**	**Cost/Unit**	**Total**
unit 1 concrete class A	CY	2489	$ 900.00	$ 2,240,100	2297	$ 900.00	$ 2,067,300
unit 2 concrete class A	CY	4404	$ 1,650.00	$ 7,266,600	3392	$ 1,650.00	$ 5,596,800
unit 3 concrete class A	CY	2425	$ 900.00	$ 2,182,500	2041	$ 900.00	$ 1,836,900
				$ -		$ -	$ -
pier foundations - unit 1	LS	1	$ 17,807,640	$ 17,807,640	0.9	$ 17,807,640.00	$ 16,026,876
pier foundations - unit 2	LS	1	$ 27,278,501	$ 27,278,501	0.9	$ 27,278,501.00	$ 24,550,651
pier foundations - unit 3	LS	1	$ 22,181,480	$ 22,181,480	0.9	$ 22,181,480.00	$ 19,963,332
				$ -		$ -	$ -
				$ -		$ -	$ -
				$ -		$ -	$ -
Subtotal Construction				*$ 78,956,821*			*$ 70,041,859*
Mark-Up (MOT, Mob., PE, CEI)	28%			$ 21,949,996			$ 19,471,637
Total Construction				**$ 100,906,817**			**$ 89,513,496**
Utility Costs				$ -		$ -	$ -
Right of Way Costs				$ -		$ -	$ -
TOTAL CAPITAL COST				***$ 100,906,817***			***$ 89,513,496***
COST CAPITAL SAVINGS / (VALUE ADDED)							**$ 11,393,322**

VE RECOMMENDATION NO. 6: USE ISOLATION BEARINGS WITH BATTER PILES	Idea No. 17

VE RECOMMENDATION NO. 6	IDEA NO.		
Use Isolation Bearings with Batter Piles			
PERFORMANCE MEASURES	*Performance*	*Baseline*	*Recommendation*
Attributes and Rating Rationale for Recommendation			
Risk	*Rating*	5	5
No change	*Weight*	33.3	
	Contribution	166.5	166.5
Maintainability	*Rating*	5	5
No change	*Weight*	20.0	
	Contribution	100	100
Construction Impacts	*Rating*	5	5
No change	*Weight*	23.3	
	Contribution	116.5	116.5
Environmental Impacts	*Rating*	5	5
No change	*Weight*	16.6	
	Contribution	83	83
Project Schedule	*Rating*	5	6.5
Fewer piles to install will shorten durations	*Weight*	6.6	
	Contribution	33	42.9
	Total Performance	499	509
	Net Change in Performance		2%

VE RECOMMENDATION NO. 7: USE INNOVATIVE DELIVERY METHOD	Idea No. 19

Baseline Concept

Deliver the project as a traditional Design-Bid-Build

Recommendation Concept

Deliver the project as Design-Build or CMAR delivery method

Advantages	Disadvantages
• Reduce costs • Reduce schedule duration • Improve constructability • Reduces owner risk	• CMAR not a common practice for KYTC

Cost Summary	Construction	Right-of-way	Total
Baseline Concept	$263,562,600	$0	$263,562,600
Recommendation Concept	$250,384,470	$0	$250,384,470
Cost Avoidance/ (Added Value)	$13,178,130	$0	$13,178,130

FHWA Function Benefit

Safety	*Operations*	*Environment*	*Construction*	*Right-of-way*
			✓	

VE RECOMMENDATION NO. 7: USE INNOVATIVE DELIVERY METHOD	Idea No. 19

Discussion/Sketches/Photos/Calculations

Technical Discussion/Sketches

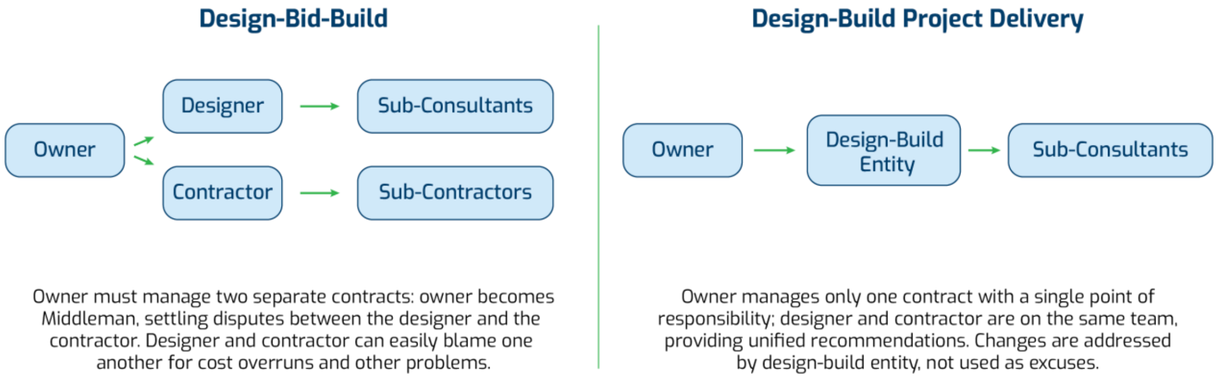
KYTC's Design Build Guidance manual has three tables that list criteria a project should meet to utilize a Design Build approach. This project meets the following criteria listed:

- The project scope is well defined.
- Project has complex constructability issues that could significantly impact the public (i.e., flooding, access, geotechnical).
- Expectation of adequate competition
- Right of Way needs are minimal.

This method of delivery could benefit KYTC in the following ways (all mentioned in KYTC's Design Build Guidance Manual):

- The DBT could introduce new design and/or construction alternatives that are equal in quality or better than what contract requirements specify while still adhering to the project scope.
- Contractors can optimize project design using alternative methods best suited to their capabilities and approaches.
- Design and/or construction can be fast-tracked.
- Construction can begin while initial design package submissions are reviewed for acceptance by KYTC.

With the fact that construction can begin prior to the initial design package acceptance, which means the contractor could begin procuring materials earlier which could lead to savings given the volatility of the current market where price increases are seen regularly as time progresses.



Baseline vs. Recommendation

Assumptions/Calculations

Only the Design Build option is presented in this recommendation since KYTC has not pursued the use of the Construction Manager at Risk approach in the past and does not have policies in place. This is still an option though should KYTC choose to pursue it.

Design build projects have proven to reduce schedules and improve on construction costs, typically between 5 and 8% of construction. This project being a bridge, offers multiple ways to innovations and the VE team assumed 5% cost savings for DB vs. DBB.

VE RECOMMENDATION NO. 7: USE INNOVATIVE DELIVERY METHOD	Idea No. 19

Total Bridge Cost:

	Item Cost	Deck Area (SQ FT)
Unit 1	$ 46,059,400.00	68,553.770
Unit 2	$ 104,190,800.00	38,287.800
Unit 3	$ 51,756,300.00	77,909.290
Unit 4	$ 40,023,500.00	57,823.870
Unit 5	$ 21,532,600.00	31,140.500
Total	**$ 263,562,600.00**	
Total Innovation Opportunities (%5)	$13,178,130.00	

VE RECOMMENDATION NO. 7	IDEA NO.		
Use Innovative Delivery Method			
PERFORMANCE MEASURES / **Attributes and Rating Rationale for Recommendation**	*Performance*	*Baseline*	*Recommendation*
Risk	*Rating*	5	5
No change	*Weight*	33.3	
	Contribution	166.5	166.5
Maintainability	*Rating*	5	5
No change	*Weight*	20.0	
	Contribution	100	100
Construction Impacts	*Rating*	5	5
No change	*Weight*	23.3	
	Contribution	116.5	116.5
Environmental Impacts	*Rating*	5	5
No change	*Weight*	16.6	
	Contribution	83	83
Project Schedule	*Rating*	5	6.5
Improves by overlapping design and construction Innovative constructability techniques and strategies will lead to a reduction of durations	*Weight*	6.6	
	Contribution	33	42.9
	Total Performance	**499**	**509**
	Net Change in Performance		**2%**

VE RECOMMENDATION NO. 8: DELIVER AND REMOVE MATERIAL BY RAIL - BUILD A TEMPORARY SPUR	Idea No. 23

Baseline Concept

Contractor will have all materials delivered and all removal material brought in/taken out via barge or by truck.

C

Deliver and remove material using the RR. Build temporary spur.

Advantages	Disadvantages
• Provides a means of access • May improve schedule duration • Reduces contractor risks • Provides means to remove materials (demo)	• RR agreement • Means and methods

Cost Summary	Construction	Right-of-way	Total
Baseline Concept	$0	$0	$0
Recommendation Concept	$0	$0	$0
Cost Avoidance/ (Added Value)	$0	$0	$0

FHWA Function Benefit

Safety	*Operations*	*Environment*	*Construction*	*Right-of-way*
			✓	✓

VE RECOMMENDATION NO. 8: DELIVER AND REMOVE MATERIAL BY RAIL - BUILD A TEMPORARY SPUR	Idea No. 23

Discussion/Sketches/Photos/Calculations

Technical Discussion/Sketches

Access for material deliveries and material removal is limited due to the sharp curve on the Kentucky side of the existing bridge, and the low vertical clearance under the railroad along the dirt/gravel access road leading down to the flood plain under the approach spans. Materials for this project will be brought in by truck or barge which could be difficult for the contractor. If there was an option to bring materials in and take materials out via rail, it could benefit the project in many ways.

Baseline

KYTC could work out an agreement with the railroad to put in a temporary spur off the railroad where materials could be brought in/shipped out or start the process of getting to use lines near the project.

There is a nearly 2-mile passing loop in the proximity of the project. The railroad could be approached about using this as an area to load/off load materials. This would require additional temporary R/W be purchased, but it would also give the contractor an additional means of access to the project in the event there are issues with material delivery due to embankment in place operations. This would also require additional environmental clearances be obtained.

VE RECOMMENDATION NO. 8: DELIVER AND REMOVE MATERIAL BY RAIL - BUILD A TEMPORARY SPUR	Idea No. 23

GENERAL RAIL INFORMATION *(The below sections must be provided by Railroad Company)*

Rail Company Name: Illinois Central Railroad

AAR-DOT# (if applicable): 299076J **Railroad Milepost:** 366.170

Freight: Train Count (6am to 6pm): 5 **Train Count (6pm to 6am):** 5 **Train Count (24 hr total):** 10 **Max Speed:** 70 mph

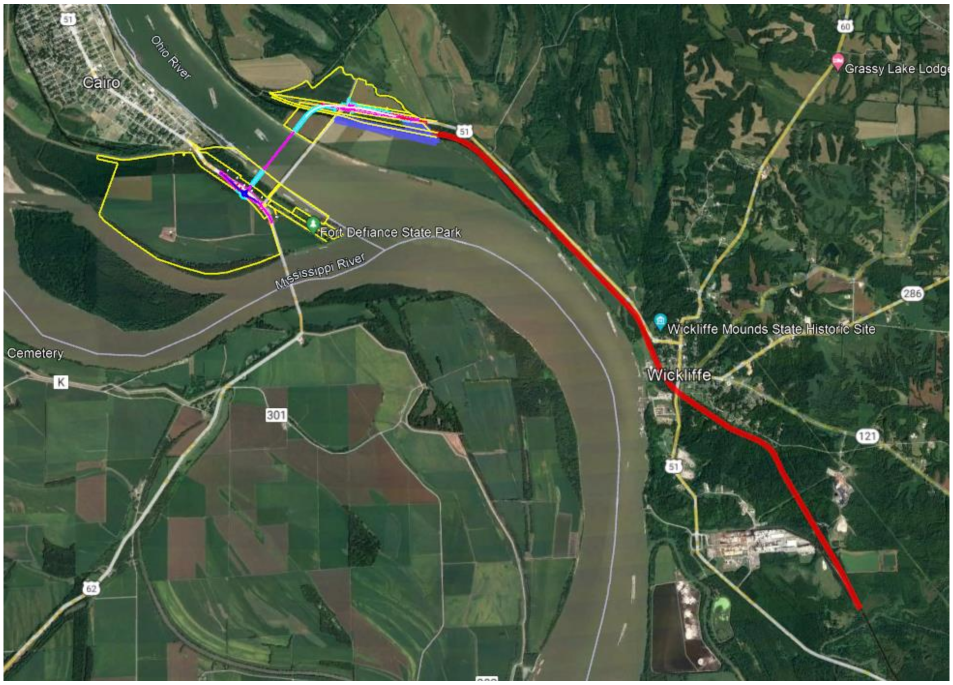
Passenger: Train Cnt. (6am to 6pm): 1 **Train Cnt. (6pm to 6am):** 1 **Train Cnt. (24 hr total):** 2 **Max Speed:** 70 mph

(This information is necessary to acquire the necessary insurances when working with Railroad Right of Way)

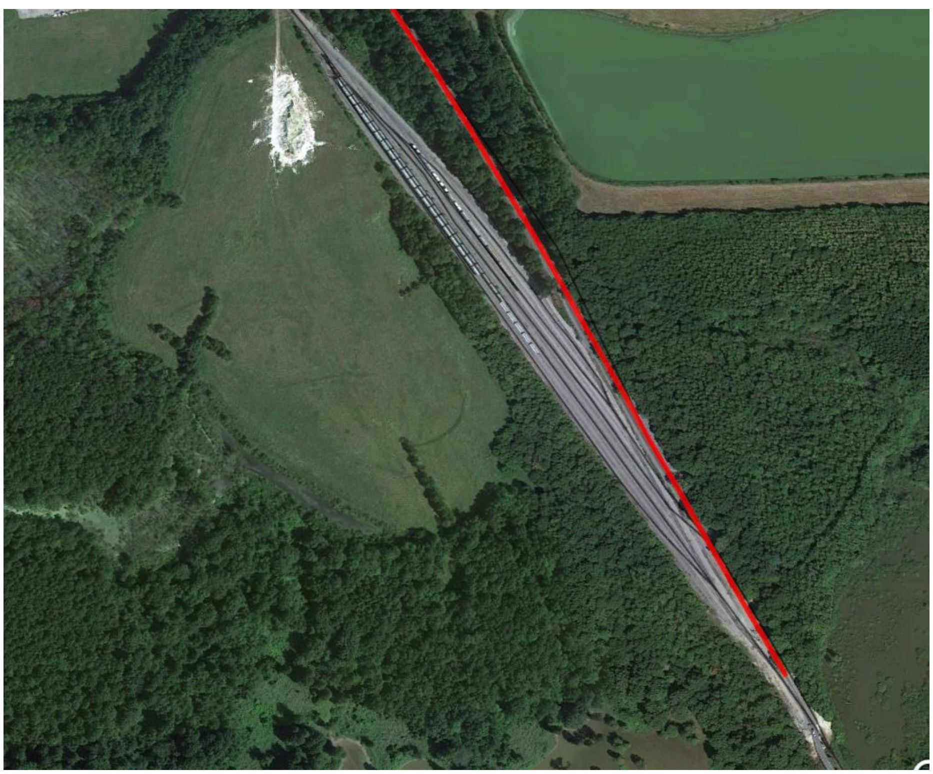
Baseline Cont.

If the railroad agreed to add an additional spur or allow the use of existing lines, then the successful contractor could approach CN/Phoenix Paper about storage and loading/unloading of materials. Having an agreement on hand would significantly lower the risk to the contractor should it engage this opportunity. There is a yard with nine lines ≈6 miles SE of the project, which could be the launching platform to ship materials to the site.

VE RECOMMENDATION NO. 8: DELIVER AND REMOVE MATERIAL BY RAIL - BUILD A TEMPORARY SPUR	Idea No. 23



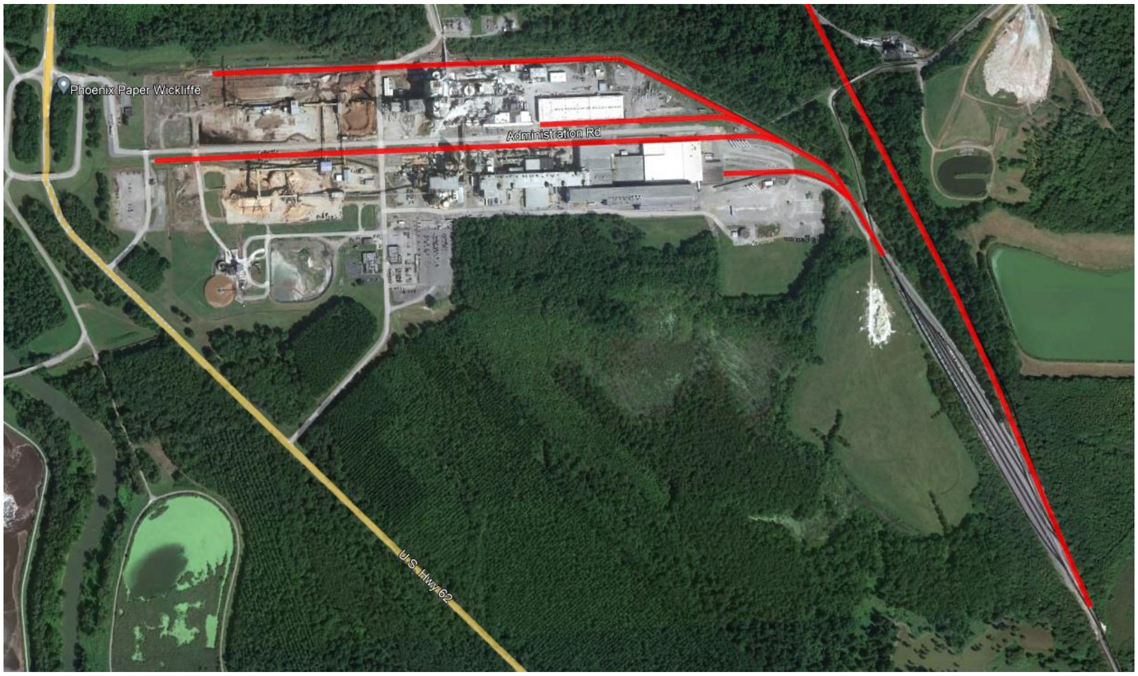
Recommendation



Recommendation Cont.

VE RECOMMENDATION NO. 8: DELIVER AND REMOVE MATERIAL BY RAIL - BUILD A TEMPORARY SPUR	Idea No. 23

If an agreement could be reached with both parties, Phoenix Paper has multiple lines at their mill that could accommodate load/unloading of materials going to and from the project. Regardless, if an agreement can be reached with CN, this could still be a location where materials could be shipped for offloading and delivery to the project site or a staging area for loading on to barges.



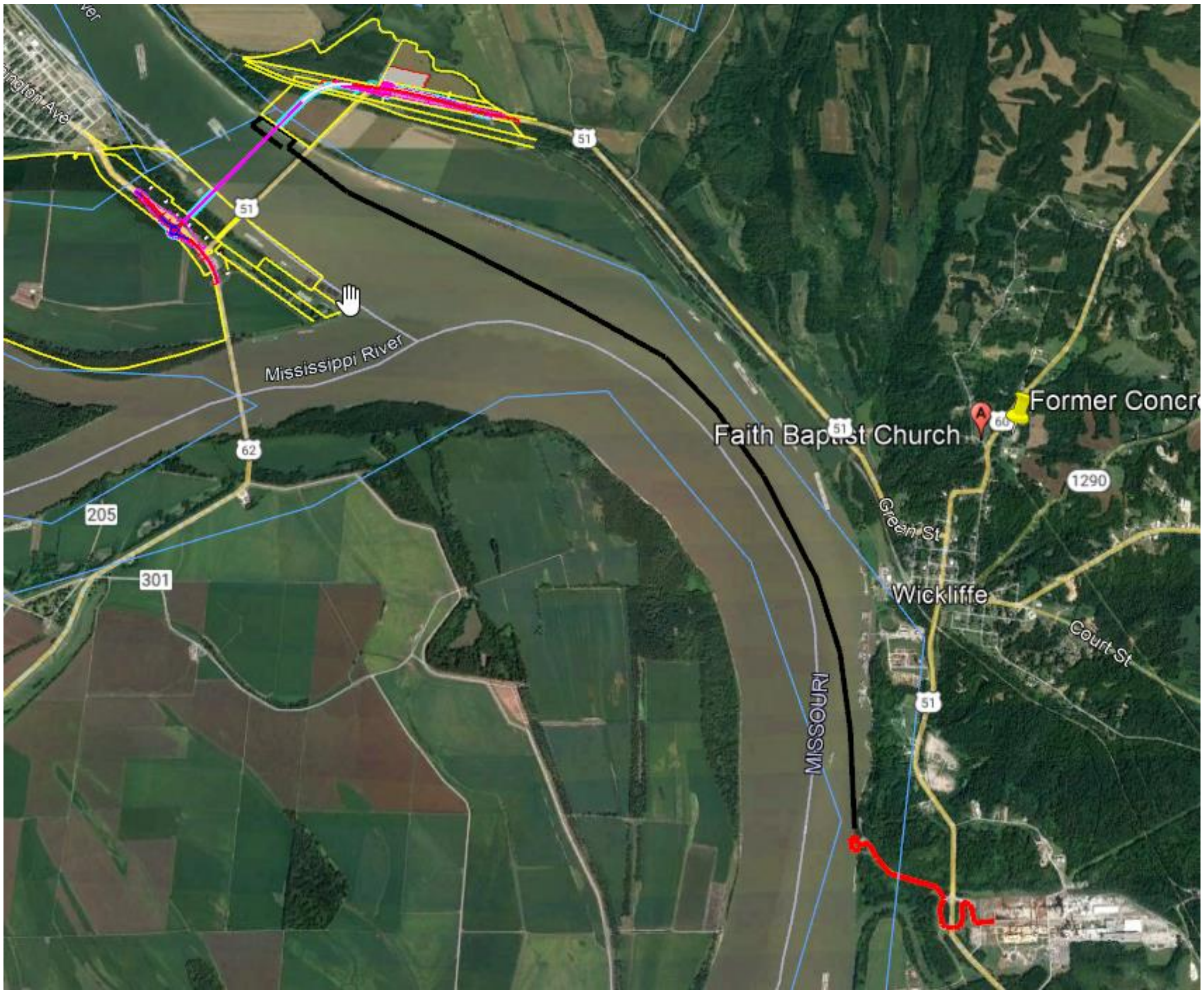
Recommendation Cont.

This facility is also located on US 51, can accommodate trucks, and has access to the river. This gets more into means and methods, but the thought is to try to determine areas where railroad use is a viable option to off-load materials with long haul and transfer to either a truck to travel to the site using US 51, to a barge to go up-river to the staging area, or via rail to a new spur west of the tracks near the job site.

Any work on the front end KYTC can accomplish, whether it be with railroad agreements or environmental clearances or partnership agreements, they will expedite construction once the project is awarded, and reduce the risk of the contractor in finding a suitable long-term facility to manage materials on and off the site.

VE RECOMMENDATION NO. 8: DELIVER AND REMOVE MATERIAL BY RAIL - BUILD A TEMPORARY SPUR	Idea No. 23

The following image shows a path via the Mississippi River.



Recommendation Cont. River Path

Assumptions/Calculations

An agreement can be reached with the railroad to allow a temporary spur to be installed for material deliveries/material removal or use existing rail.

It is highly likely that the 140 days assessed in the base cost relates to overhead work to lay down the superstructure over the RR. It is also very likely that RR flaggers will be needed throughout the construction of the project if this recommendation were to move forward.

No calculations have been made for this option because the cost of what it would take to buy additional ROW, build the spur, and get the environmental clearances in place is not known.

VE RECOMMENDATION NO. 8: DELIVER AND REMOVE MATERIAL BY RAIL - BUILD A TEMPORARY SPUR	Idea No. 23

VE RECOMMENDATION NO. 8	IDEA NO.		
Deliver and Remove Material by Rail - Build a Temporary Spur			
PERFORMANCE MEASURES / **Attributes and Rating Rationale for Recommendation**	*Performance*	*Baseline*	*Recommendation*
Risk	*Rating*	5	5
No change	*Weight*	33.3	
	Contribution	166.5	166.5
Maintainability	*Rating*	5	5
No change	*Weight*	20.0	
	Contribution	100	100
Construction Impacts	*Rating*	5	7
Less construction traffic on the road	*Weight*	23.3	
	Contribution	116.5	163.1
Environmental Impacts	*Rating*	5	5
No change	*Weight*	16.6	
	Contribution	83	83
Project Schedule	*Rating*	5	6
Reduces the risk of material delivery delays due to truck drivers shortages Improves means to deliver steel materials from long haul	*Weight*	6.6	
	Contribution	33	39.6
	Total Performance	**499**	**552**
	Net Change in Performance		**11%**

VE RECOMMENDATION NO. 9: USE CONCRETE PAVEMENT	Idea No. 40

Baseline Concept

Install asphalt pavement on the roadway approaches.

Recommendation Concept

Use concrete pavement on the roadway approaches.

Advantages	Disadvantages
• Increase life of pavement • Matches existing pavement • Improves resilience • Improves life cycle costs	• May increase capital costs

Cost Summary	Construction	Lifecycle Cost	Total
Baseline Concept	$3,096,134	$6,944,273	$10,040,407
Recommendation Concept	$5,275,773	$93,441	$5,369,214
Cost Avoidance/ (Added Value)	$(2,179,639)	$6,850,832	$4,671,193

FHWA Function Benefit

Safety	*Operations*	*Environment*	*Construction*	*Right-of-way*
	✓			

VE RECOMMENDATION NO. 9: USE CONCRETE PAVEMENT	Idea No. 40

Discussion/Sketches/Photos/Calculations

Technical Discussion/Sketches

Replacing the baseline design of asphalt approaches with JPC pavement increases the durability and longevity of the roadway. Also, having access to an on-site cement plant that produces high volumes for the structure allows for KYTC to take advantage of the economies of scale principal. Lower average pricing for pavement with onsite production vs. long hauling asphalt in small quantities at higher-than-average price. The proposed Kentucky approaches would tie into existing JPC pavement at the southern limits.

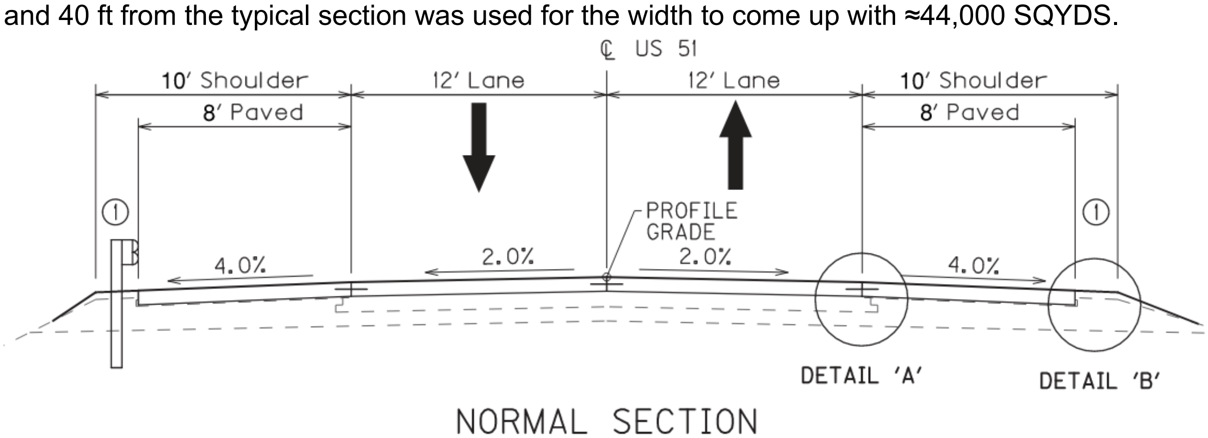
Baseline

VE RECOMMENDATION NO. 9: USE CONCRETE PAVEMENT	Idea No. 40

Recommendation

Assumptions/Calculations

Based on a recent previous project that adjoins this project and the total lifecycle cost savings, the idea of using jointed plain concrete (JPC) pavement 8 in is being recommended. To ensure similar quantities were used for calculations, 9,850 ft from the roadway estimate was used for a length and 40 ft from the typical section was used for the width to come up with ≈44,000 SQYDS.



The cost/unit was calculated off this quantity for asphalt and the concrete pricing was calculated from the adjoining project from 2020 using an inflation rate of 45% based on industry expectations. With the assumption that a mobile batch plant will set up either near or on-site the

VE RECOMMENDATION NO. 9: USE CONCRETE PAVEMENT	Idea No. 40

45% is a conservation escalation that could easily be less than calculated on the upfront cost for this recommendation.

There was also consideration made for the additional aggregate given the thickness difference between the 8.75-inch lifts of the asphalt course and the 8-inch concrete lift. This change also incorporates an 8 inches JPC shoulders, where the current design has a pavement depth of 6.5 inches. One last item is the proximity of an asphalt plant and the current design of a PG76-22 mix for the mainline applications. Delivery of the proposed asphalt over long distances increases the risk the material will not meet temperature specifications for KYTC.

The recommended concept of JPC pavement is warranted given the truck AADT percentage being 35%.

VE RECOMMENDATION NO. 9: USE CONCRETE PAVEMENT

Idea No. 40

VE Study Cost Calculations

US 51 Bridge Replacement

Component	Unit	Baseline Concept Qty	Baseline Concept Cost/Unit	Baseline Concept Total		VE Recommended Concept Qty	VE Recommended Concept Cost/Unit	VE Recommended Concept Total
New Pavement Asphalt	SY	44000	$ 55.06	$ 2,422,640.00			$ 55.06	$ -
JPC Pavement 8"	SY		$ 92.74	$ -		44000	$ 92.74	$ 4,080,648.00
Aggregate	TON		$ 25.00	$ -		1900	$ 25.00	$ 47,500.00
				$ -			$ -	$ -
Subtotal Construction				*$ 2,422,640.00*				*$ 4,128,148.00*
Mark-Up (MOT, Mob., PE, CEI)	28%			$ 673,493.92				$ 1,147,625.14
Total Construction				**$ 3,096,133.92**				**$ 5,275,773.14**
Utilities Costs				$ -				$ -
Right of Way Costs				$ -				$ -
TOTAL CAPITAL COST				***$ 3,096,133.92***				***$ 5,275,773.14***
COST CAPITAL SAVINGS / (VALUE ADDED)								**$ (2,179,639.22)**

Life Cycle Cost Analysis

				Baseline Concept	Alternative Concept
Life Cycle Period	40	Years			
Discount Rate	3.6%	https://www.whitehouse.gov/wp-content/uploads/2018/12/M-19-05.pdf			
A. Initial Costs				$ 3,096,134	$ 5,275,773
B. Annual Costs		**Total Capital Cost Savings / (Value Added)**			***$ (2,179,639.22)***
1. Annual Maintenance:	5% of area in potholes and other asphalt maintenance			$ 154,807	
2. Annual Energy:					
3. Other:					
		Total Annual Costs:		$ 154,807	$ -
		Present Value Factor (P/A):		39.7063	39.7063
		Present Value of Annual Costs:		$ 6,146,798	$ -

C. Single Future Expenditures	**Future Value**	**Year**	**PV Factor**	**Present Value**	**Present Value**
First Cycle Asphalt Resurfacing	$517,450.00	10	0.7021	$ 363,305	
First Cycle Concrete Repair	$100,000.00	15	0.5883		$ 58,831
Second Cycle Asphalt Resurfacing	$517,450.00	20	0.4930	$ 255,078	
Second Cycle Concrete Repair	$100,000.00	30	0.3461		$ 34,610
Third Cycle Asphalt Resurfacing	$517,450.00	30	0.3461	$ 179,092	
Third Cycle Concrete Repair			1.0000		$ -
Asphalt Reconstruction			1.0000	$ -	
Concrete Reconstruction			1.0000		$ -
Residual Value		40	0.2430	$ -	$ -
Present Value of Future Single Expenditures and Residual Value:				$ 797,475	$ 93,441
D. TOTAL PRESENT MAINTENANCE VALUE COST (B+C)				$ 6,944,273	$ 93,441
TOTAL MAINTENANCE SAVINGS / (VALUE ADDED):					$ 6,850,832
TOTAL LIFECYCLE COSTS:				**$ 10,040,407**	$ 5,369,214
TOTAL LIFECYCLE COSTS SAVINGS / (VALUE ADDED):					**$ 4,671,192.53**

VE RECOMMENDATION NO. 9: USE CONCRETE PAVEMENT	Idea No. 40

VE RECOMMENDATION NO. 9	IDEA NO.		
Use Concrete Pavement			
PERFORMANCE MEASURES **Attributes and Rating Rationale for Recommendation**	***Performance***	***Baseline***	***Recommendation***
Risk No change	***Rating***	**5**	**5**
	Weight	**33.3**	
	Contribution	**166.5**	**167**
Maintainability Improves life of the pavement Reduces the number of resurfacing cycles Reduces annual maintenance demands Improved performance on snow/ice events (resiliency and durability)	***Rating***	**5**	**7.5**
	Weight	**20.0**	
	Contribution	**100**	**150**
Construction Impacts Longer curing times at tying points Requires local detours or lane closures	***Rating***	**5**	**4**
	Weight	**23.3**	
	Contribution	**116.5**	**93**
Environmental Impacts No change	***Rating***	**5**	**5**
	Weight	**16.6**	
	Contribution	**83**	**83**
Project Schedule Longer curing times although not in the critical path	***Rating***	**5**	**5**
	Weight	**6.6**	
	Contribution	**33**	**33**
	Total Performance	**499**	**526**
		Net Change in Performance	**5%**

VE RECOMMENDATION NO. 10: INCREASE APPROACH SPAN LENGTH STRUCTURES	Idea No 4

Baseline Concept

Steel plate girders for approach structures and conventional steel tied arch for the main span

Recommendation Concept

Reduce number of piers by increasing span length to up to 450 ft on the approach structures and to 1000 ft on the arch. The recommended concept is developed for units 1, 2 and 3. Two pier units in the floodplain are elimianted by using this concept.

Advantages	Disadvantages
• Reduces overall cost • May reduce schedule duration • Reduce project risk by having more flexibility in locating piers • Reduces number of piers	• Increases superstructure costs • If steel tub is used; note that there may be some areas of confined space for inspection purposes. • Whether steel tub or conventional plate girders, girder will be delivered in 3 pieces. Two pieces shall be spliced prior to erection.

Cost Summary	Construction	Right-of-way	Total
Baseline Concept	$103,823,991	$0	$103,823,991
Recommendation Concept	$100,702,011	$0	$100,702,011
Cost Avoidance/ (Added Value)	$3,121,979	$0	$3,121,979

FHWA Function Benefit

Safety	*Operations*	*Environment*	*Construction*	*Right-of-way*
			✓	

VE RECOMMENDATION NO. 10: INCREASE APPROACH SPAN LENGTH STRUCTURES	Idea No 4

Discussion/Sketches/Photos/Calculations

Technical Discussion/Sketches

The designer evaluated options including cable stayed bridges and back-to-back extradosed options as well as continuous trusses to explore how the number of water piers could be minimized.

When the tied arch option was selected the approach structures were informed by the span optimization report included in the project docs. Our recommendation pushes further on that study and seeks to eliminate some additional water and land piers in units 1 and 3. The design team did not evaluate this option.

In general, the substructure is significantly heavier than the superstructure. Thus, the loads on the piles are more driven by the substructure than the superstructure under both static and dynamic (seismic) loads. In fact, superstructure is isolated from the substructure for seismic loading.

We believe that pile cap sizes should be reduced. Earlier recommendation suggested to use batter piles to reduce the size of the pile cap. Up to 30 % reduction in pile cap appears feasible. This is about the same load increase as we expect from the increase in span length from 350 ft to 450 ft. the weight delta is derived from the AISC weight charts. (See AISC chart in Assumptions) Thus, in general, the increase in dead load is estimated to be about 125 kips per pile (Figure 1). (For a 4-pile system)

Dead loads (kips)					
span length		350 ft	450 ft	450 ft	delta
super		3089	4359	4359	1270
p. cap		2332	2332	1562	-770
col		2253	2253	2253	
		7674	8944	8175	501
4 piles	per pile	1918	2236	2044	125

Calculation table

But pile design is controlled by seismic design according to project documents. We feel that because of the use of the isolation bearing the increase in seismic shear from the superstructure with a longer span will be minimal. In any event, this is not the main driver of seismic forces. The main driver is the heavy substructure.

For this reason, we recommend that pile caps be made smaller by using battered piles. We also recommend using hollow rather than solid columns to reduce substructure weight.

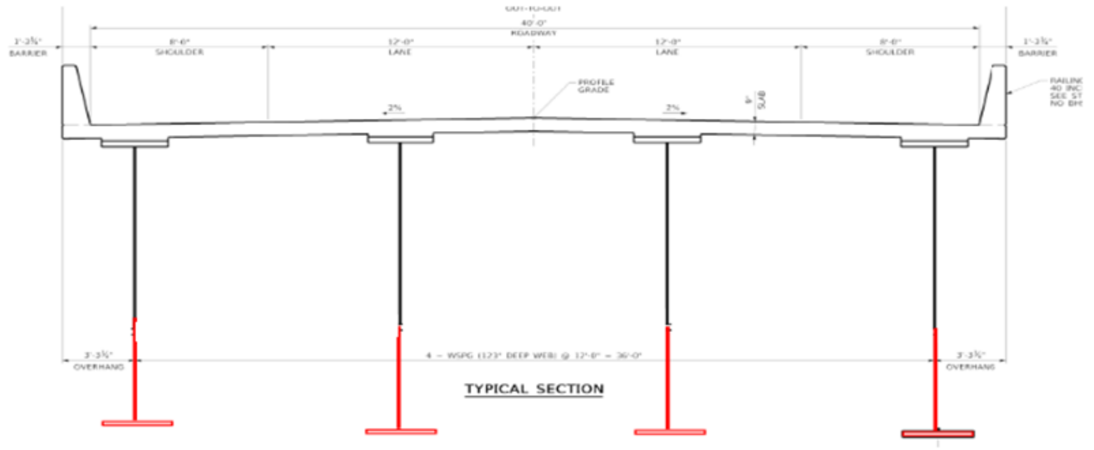
This will also reduce seismic demand and likely the above-mentioned additional force of 125 kips in the pile will be more than compensated.

Based on above reasoning, we propose to use 450 ft spans. We have proposed a span arrangement below and we see that a total of 2 piers in units 1 and 3 are eliminated. The ones that are left have smaller quantities

On the approach span two options for the 450 ft spans are proposed.

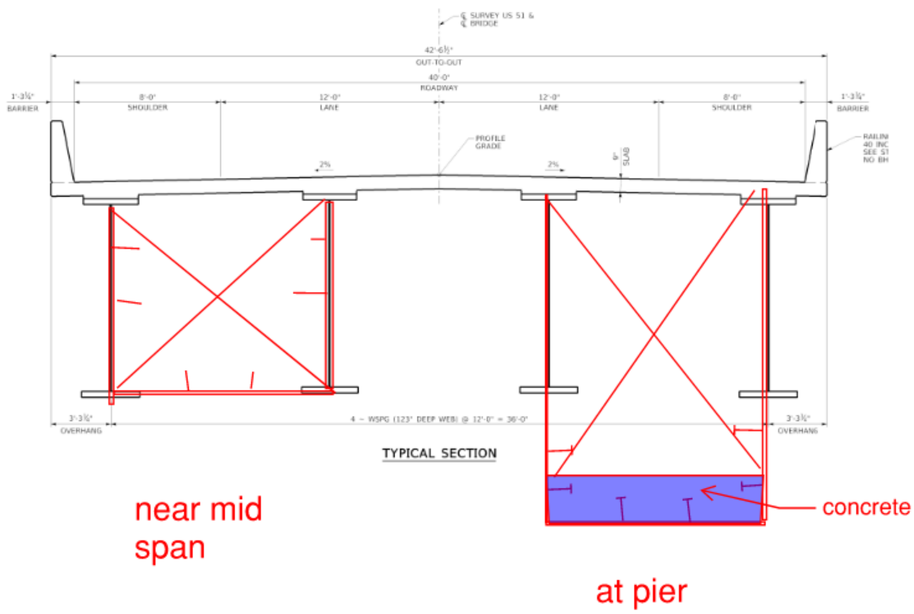
1. Modify the existing plate girder option by making it deeper. A haunched version of this can also be used. (Haunch piers)

VE RECOMMENDATION NO. 10: INCREASE APPROACH SPAN LENGTH STRUCTURES	Idea No 4



Option 1

2. Use twin haunched tub girders. This is a more robust system, but it offers the advantage in that plain concrete may be poured on the compression flanges and made composite with steel near the pier. This will reduce steel quantity.



Option 2

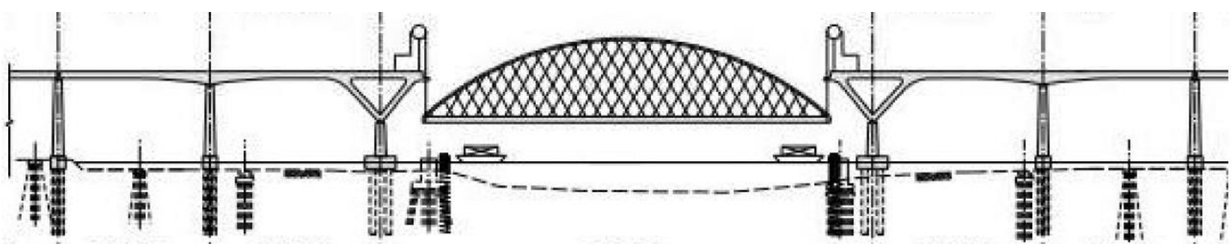
With increased span length the girders will be delivered in 3 pieces. They will need to be assembled in the staging area and then erected. It is expected that barge mounted cranes will be used to perform these operations.

The arch span may also be extended by using modified geometry on the flanking spans. The geometry will be like that used at Lake Champlain arch in upstate New York and shown below.

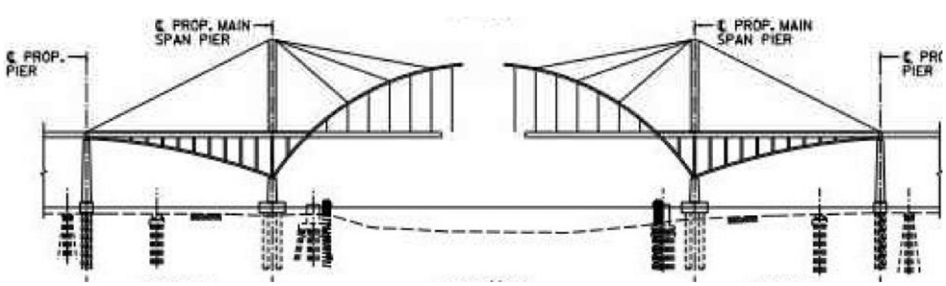
VE RECOMMENDATION NO. 10: INCREASE APPROACH SPAN LENGTH STRUCTURES	Idea No 4

Construction method employing whole span erection in one go as envisaged by the designers of the tied arch are still valid, in addition stick construction using temporary stays is also feasible.

1. Whole span lift with strand jacks:

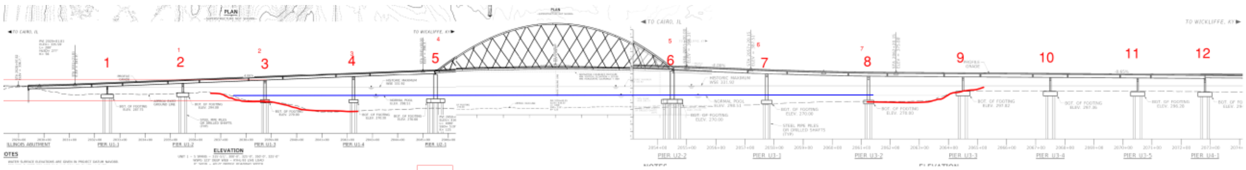


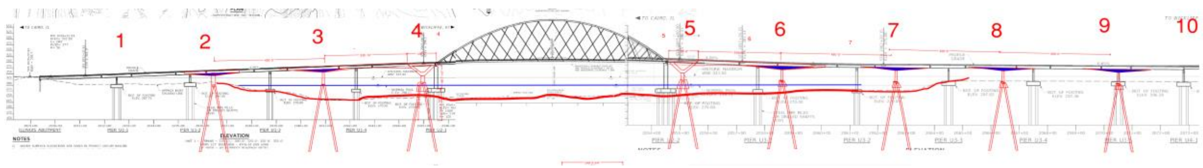
2.Top-down stick build with temporary stay cables:



The original vs revised span arrangement is as follows (Figure 5):

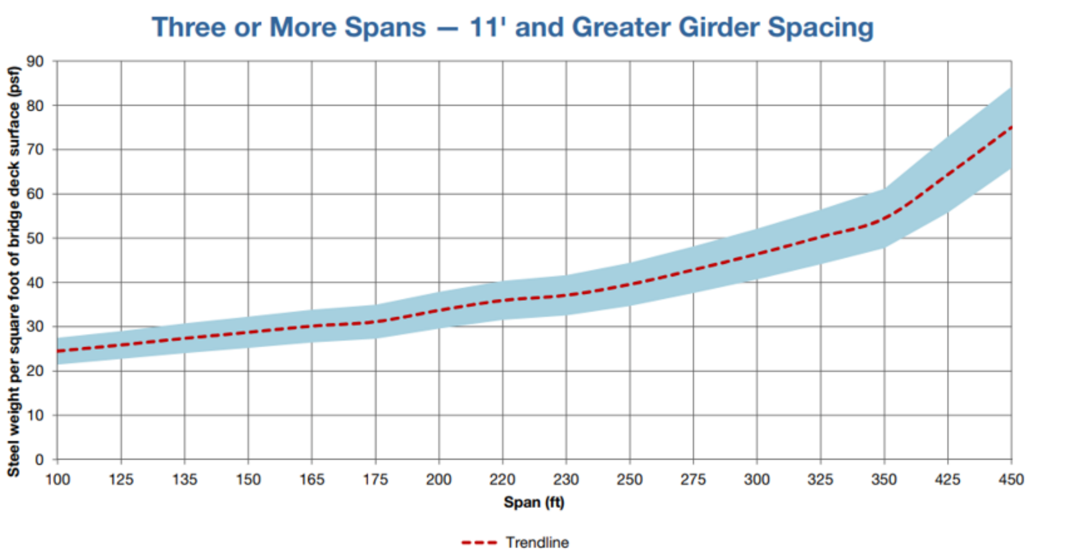
VE RECOMMENDATION NO. 10: INCREASE APPROACH SPAN LENGTH STRUCTURES	Idea No 4





Assumptions/Calculations

Chart used for estimating steel weight



The benefits of reduced pile cap sizes are not accounted for this rec.

VE RECOMMENDATION NO. 10: INCREASE APPROACH SPAN LENGTH STRUCTURES	Idea No 4

VE Study Cost Calculations

US 51 Bridge over Ohio River Replacement

Component	Unit	Baseline Concept Qty	Baseline Concept Cost/Unit	Baseline Concept Total	VE Recommended Concept Qty	VE Recommended Concept Cost/Unit	VE Recommended Concept Total
unit 1 strcutural steel	LB	6252942	$ 2.75	$ 17,195,591	7638402	$ 2.75	$ 21,005,606
unit 3 strcutural steel	LB	7106225	$ 2.75	$ 19,542,119	8680885	$ 2.75	$ 23,872,434
pier unit 1 (17,807,640/3)	LS	3	$ 5,935,880.00	$ 17,807,640	2	$ 5,935,880.00	$ 11,871,760
pier unit 3 (22181480/6)	LS	6	$ 3,696,913.33	$ 22,181,480	5	$ 3,696,913.33	$ 18,484,567
Concrete class A - unit 1	CY	2589	$ 900.00	$ 2,330,100	2013	$ 900.00	$ 1,811,700
Concrete class A - unit 2	CY	2425	$ 900.00	$ 2,182,500	1945	$ 900.00	$ 1,750,500
				$ -		$ -	$ -
				$ -		$ -	$ -
Subtotal Construction				*$ 81,239,429*			*$ 78,796,566*
Mark-Up (MOT, Mob., PE, CEI)	28%			$ 22,584,561			$ 21,905,445
Total Construction				**$ 103,823,991**			**$ 100,702,011**
Utility Costs				$ -		$ -	$ -
Right of Way Costs				$ -		$ -	$ -
TOTAL CAPITAL COST				***$ 103,823,991***			***$ 100,702,011***
COST CAPITAL SAVINGS / (VALUE ADDED)							**$ 3,121,979**

VE RECOMMENDATION NO. 10: INCREASE APPROACH SPAN LENGTH STRUCTURES	Idea No 4

VE RECOMMENDATION NO. 10	IDEA NO.		
Increase Span Length of Approach structures			
PERFORMANCE MEASURES Attributes and Rating Rationale for Recommendation	*Performance*	*Baseline*	*Recommendation*
Risk No change	*Rating*	5	5
	Weight	33.3	
	Contribution	166.5	167
Maintainability No change	*Rating*	5	5
	Weight	20.0	
	Contribution	100	100
Construction Impacts No change	*Rating*	5	5
	Weight	23.3	
	Contribution	116.5	117
Environmental Impacts Reduces the number of piers, thus impacting less the environment	*Rating*	5	6.5
	Weight	16.6	
	Contribution	83	108
Project Schedule Less piers to construct May require less cofferdams and take less time to set-up	*Rating*	5	6
	Weight	6.6	
	Contribution	33	40
	Total Performance	499	532
		Net Change in Performance	7%

7.4 Performance Assessment

As the VE team developed recommendations, the performance of each was compared to the baseline for potential value improvement. For this exercise, the baseline was given a score of 5. Table 10 shows the criteria used to evaluate the performance of the alternative concepts relative to the baseline concept.

Table 10. Performance Attribute Rating Scale

Rating	Performance Attribute Scales
10	Alternative concept is extremely preferred
9	Alternative concept is very strongly preferred
8	Alternative concept is strongly preferred
7	Alternative concept is moderately preferred
6	Alternative concept is slightly preferred
5	***Concepts are equally preferred***
4	Baseline concept is slightly preferred
3	Baseline concept is moderately preferred
2	Baseline concept is strongly preferred
1	Baseline concept is very strongly preferred
0	Baseline concept is extremely preferred

7.4.1 Performance Rating

The performance matrix (Table 11) permits the comparison of various recommendations against the baseline concept by organizing the data developed for the performance attributes into a matrix format to yield value indices.

The matrix is essential for understanding the performance and value of the baseline and VE concepts. Comparing the performance suggest which recommendations are potentially as good as, or better than, the baseline concept, in terms of overall value. Comparison at the value index level suggest which recommendations have the best functionality or provides the project with the best value.

The performance rating and rationale for each alternative generated by the VE team is located on the individual recommendation forms in Section 7.3.

Table 11. Performance Matrix

Attribute	Attribute Weight	Concept	Performance Rating	Total Performance
Risk	33.3	Baseline	5	166.5
		1	5	166.5
		2	8	266.4
		3	7.5	249.8
		4	7.5	249.8
		5	6.5	216.5
		6	5	166.5
		7	5	166.5
		8	5	166.5
		9	5	166.5
		10	5	166.5
Maintainability	20.0	Baseline	5	100.0
		1	5	100.0
		2	6	120.0
		3	6	120.0
		4	5	100.0
		5	5	100.0
		6	5	100.0
		7	5	100.0
		8	5	100.0
		9	7.5	150.0
		10	5	100.0
Construction Impacts	23.3	Baseline	5	116.5
		1	5	116.5
		2	5	116.5
		3	5	116.5
		4	5	116.5
		5	4.75	110.7
		6	5	116.5
		7	5	116.5
		8	7	163.1
		9	4	93.2
		10	5	116.5

Table 11. Performance Matrix

Attribute	Attribute Weight	Concept	Performance Rating	Total Performance
Environmental Impacts	16.6	Baseline	5	83.0
		1	5	83.0
		2	5	83.0
		3	5	83.0
		4	5	83.0
		5	5	83.0
		6	5	83.0
		7	5	83.0
		8	5	83.0
		9	5	83.0
		10	6.5	107.9
Project Schedule	6.6	Baseline	5	33.0
		1	5.5	36.3
		2	4.5	29.7
		3	5	33.0
		4	5.5	36.3
		5	5	33.0
		6	6.5	42.9
		7	6.5	42.9
		8	6	39.6
		9	5	33.0
		10	6	39.6

7.4.2 Compare Value

Understanding the relationship of cost, performance, and value of the project baseline and VE concepts is essential in evaluating VE recommendations. Comparing the performance and cost suggests which recommendations are potentially as good as or better than the project baseline concept in terms of overall value.

Table 12. Value Index

Recommendations		Performance (P)	% Change Performance	Cost (C) $ millions	Cost Change $ millions	% Change Cost	Value Index	% Value Improvement
	Baseline	500	—	$288.2		---	1.70	---
1	Facilitate Staging Locations	505	+1.0	$288.3	$0.08	+0.0	1.74	+2%
2	Use Soil Improvements Techniques	605	+21.0	$297.6	$9.36	+3.2	2.07	+22%
3	Conduct a Non-linear Time History Analysis	595	+19.0	$289.9	$1.70	+0.6	2.08	+22%
4	Pre-design by Load Testing	580	+16.0	$280.7	($7.57)	-2.6	2.09	+23%
5	Increase End Bearing Resistance of Foundations	539	+7.9	$271.0	($17.25)	-6.0	1.88	+11%
6	Use Isolation Bearings with Batter Piles	515	+3.0	$276.8	($11.39)	-4.0	1.84	+8%
7	Use Innovative Delivery Method	515	+3.0	$275.1	($13.18)	-4.6	1.85	+9%
8	Deliver and Remove Material by Rail - Build a Temporary Spur	555	+11.0	$288.2	$0.00	0.0	1.92	+13%
9	Use Concrete Pavement	528	+5.5	$283.6	($4.67)	-1.6	1.85	+9%
10	Increase Span Length of Approach structures	536	+7.3	$285.1	($3.12)	-1.1	1.86	+9%
	Total				($46.05)			

7.5 Design Considerations

The VE team generated the following design suggestions for the project design team's consideration. These items represent ideas that are general in nature and are listed below in Table 13. Additional details can be found in the evaluation form in Section 6.2. Fifteen ideas were initially brought forward as recommendations; however, after further evaluation, the VE team felt they should be presented to the design team for further investigation and design.

Table 13. Design Considerations

Idea No.	Description
5	Advance geotechnical investigations
8	Use friction reducers in the pile to reduce drag forces
13	Create a temporary structure to access river piers and construct from trestle structure
16	Use mixed type materials (Steel and Concrete) for areas as applicable
18	Use larger pile diameters
24	Create a SUP for pedestrians and bicyclist
29	Improve structure to account for tornado wind speeds
30	Shaping the towers more aerodynamically; edge beam shape or wind fairing
31	Install markers to footers in the navigational channels (perch footers)
32	Place the pile cap lower using a mudline footing
35	Add incentives for early completions
37	Use ITS to convey bridge conditions
38	Use DMS Sign to communicate bridge conditions
39	Install lighting throughout the bridge facility
41	Develop a cost loaded 4D schedule analysis to determine the best combination of piers / spans

7.6 Design Validations

Two ideas the VE team initially brought forward as recommendations were dropped from consideration after it was determined the baseline design was more economical and feasible. These validations are shown in Table 14; the write-up justifications can be found in Appendix E.

Table 14. Design Validations

Idea No.	Description
1	Use cable stay bridge type
2	Review and update seismic assumptions

Appendix A. Value Methodology Process

Value Methodology is a systematic process using a multidisciplinary team to improve the value of a project through the analysis of its functions. This process incorporates, to the extent possible, the values of design, construction, maintenance, contractor, state, local, and federal approval agencies, other stakeholders, and the public.

The primary objective of a Value Engineering (VE) study is value improvement. Value improvements might relate to scope definition, functional design, constructability, coordination (both internal and external), or the schedule for project development. Other possible value improvements are reduced environmental impacts, reduced public (traffic) inconvenience, or reduced project cost.

The VE team employed the eight-phase Value Methodology in analyzing the project. This process is recommended by SAVE International® and is composed of the following phases:

Pre-VE Study

Preparation Phase - Prior to the start of a VE study, the Project Manager, and the VE facilitator conduct the following activities:

- Initiate study – Identify study project and define study goals
- Organize study – Conduct Pre-VE study meeting and select team members
- Prepare data – Collect and distribute data and prepare cost models.

All the information gathered prior to the VE study is given to the team members for their use.

Workshop Phases

Information – The team reviews and defines the current conditions of the project and identifies the goals of the study.

Function Analysis – The team defines the project functions using a two-word active verb/ measurable noun context. The team reviews and analyzes these functions to determine which need improvement, elimination, or creation to meet the project's goals.

Creativity – The team employs creative techniques to identify other ways to perform the project's function(s).

Evaluation – The team follows a structured evaluation process to select those ideas that offer the potential for value improvement while delivering the project's function(s) and considering performance requirements and resource limits.

Development – The team develops the selected ideas into alternatives (or proposals) with a sufficient level of documentation to allow decision makers to determine if the alternative should be implemented.

Presentation – The VE facilitator develops a report and/or presentation that documents and conveys the adequacy of the alternative(s) developed by the team and the associated value improvement opportunity.

Post-Study

Implementation Phase - The project team is then charged with reviewing the report and may hold a Disposition Meeting with management and other stakeholders, to determine which recommendations will be implemented in the design. The project team then tracks their implementation into the plans.

Performance-Based Value Engineering

The following is a general discussion and overview of the Performance-Based VE process. Ideas that have been introduced and warrant further consideration, will be documented with their advantages and disadvantages; each idea will then be carefully evaluated against project-specific attributes.

Performance measures an integral part of the VE process. It provides the cornerstone of the VE process by giving a systematic and structured way of considering the relationship of a project's performance and cost as they relate to value. Project performance must be properly defined and agreed on by the stakeholders at the beginning of the VE study. The performance attributes and requirements that are developed are then used throughout the study to identify, evaluate, and document alternatives.

Introduction

Value engineering has traditionally been perceived as an effective means for reducing project costs. This paradigm only addresses one part of the value equation, oftentimes at the expense of overlooking the role that VE can play related to improving project performance. Project costs are relatively easy to quantify and compare through traditional estimating techniques. Performance is not so easily quantifiable.

The VE facilitator will lead the team and external stakeholders through the methodology, using the power of the process to distill subjective thought into an objective language that everyone can relate to and understand. The dialogue that develops forms the basis for the VE teams understanding of the performance requirements of the project and to what degree the current design concept is meeting those requirements. From this baseline, the VE team can focus on developing alternative concepts that will quantify both performance and cost and contribute to overall project value.

Performance-based VE yields the following benefits:

- Builds consensus among project stakeholders (especially those holding conflicting views)
- Develops a better understanding of a project's goals and objectives
- Develops a baseline understanding of how the project is meeting performance goals and objectives
- Identifies areas where project performance can be improved through the VE process
- Develops a better understanding of a VE alternative's effect on project performance
- Develops an understanding of the relationship between performance and cost in determining value
- Uses value as the true measurement for the basis of selecting the right project or design concept
- Provides decision-makers with a means of comparing costs and performance (i.e., costs vs. benefits) in a way that can assist them in making better decisions.

Methodology

The application of Performance-based VE consists of the following steps:

- Identify key project (scope and delivery) performance attributes and requirements for the project.
- Establish the hierarchy and impact of these attributes on the project.
- Establish the baseline of the current project performance by evaluating and rating the effectiveness of the current design concepts.
- Identify the change in performance of alternative project concepts generated by the study.
- Measure the aggregate effect of alternative concepts relative to the baseline project's performance as a measure of overall value improvement.

The primary goal of value engineering is to improve the value of the project. A simple way to think of value in terms of an equation is as follows:

$$Value = \frac{Performance}{Cost}$$

Assumptions

Before embarking on the details of this methodology, some assumptions need to be identified. The methodology described in the following steps assumes the project functions are well established. Project functions are defined as what the project delivers to its users and stakeholders; a good reference for the project functions can be found in the environmental document's purpose and need statement. Project functions are generally well defined prior to the start of the VE study. If project functions have been substantially modified, the methodology must begin anew (Step 1).

Step 1 – Determine the Major Performance Attributes

Performance attributes can generally be divided between project scope components (highway operations, environmental impacts, and system preservation) and project delivery components. It is important to make a distinction between performance *attributes* and performance *requirements*. Performance requirements are mandatory and binary in nature. All performance requirements MUST be met by any VE alternative concept being considered. Performance attributes possess a range of acceptable levels of performance. For example, if the project was the design and construction of a new bridge, a performance requirement might be that the bridge meets all current seismic design criteria. In contrast, a performance attribute might be project schedule, which means that a wide range of alternatives could be acceptable that had different durations.

The VE facilitator will initially request representatives from project team and external stakeholders identify performance attributes that they feel are essential to meeting the overall need and purpose of the project. Usually, four to seven attributes are selected. It is important that all potential attributes be thoroughly discussed. The information that comes out of this discussion will be valuable to both the VE team and the project owner. It is important that each attribute be discretely defined and be quantifiable in some form. Most performance attributes that typically appear in transportation VE studies have been standardized. This standardized list can be used "as is" or adopted with minor adjustments as required.

Typical standardized project performance attributes are shown below. Specific definitions of each attribute can be found below.

- Main Line Operations
- Local Operations

- Maintainability
- Construction Impacts
- Environmental Impacts
- Project Schedule

PERFORMANCE ATTRIBUTE AND DEFINITIONS	
Performance Attribute	**Description of Attribute**
Main Line Operations	An assessment of traffic operations and safety on the main line. Operational considerations include level of service relative to the 20-year traffic projections as well as geometric considerations such as design speed, sight distance, and lane and shoulder widths.
Local Operations	An assessment of traffic operations and safety on the local roadway infrastructure. Operational considerations include level of service relative to the 20-year traffic projections; geometric considerations such as design speed, sight distance, lane widths; bicycle and pedestrian operations and access, including shared use path.
Maintainability	An assessment of the long-term maintainability of the transportation facility(s). Maintenance considerations include the overall durability, longevity, and maintainability of pavements, structures, and systems; ease of maintenance; accessibility and safety considerations for maintenance personnel.
Construction Impacts	An assessment of the temporary impacts to the public during construction related to traffic disruptions, detours, and delays; impacts to businesses and residents relative to access, visual, noise, vibration, dust, and construction traffic. Temporary environmental impacts related to water quality, air quality, soil erosion, and local flora and fauna.
Environmental Impacts	An assessment of the permanent impacts to the environment, including ecological (i.e., flora, fauna, air quality, water quality, visual, noise); socioeconomic impacts (i.e., environmental justice, business, residents); impacts to cultural, recreational, and historic resources.
Project Schedule	An assessment of the total project delivery as measured from the time of the VE study to completion of construction.

Step 2 – Determine the Relative Importance of the Attributes

Once the group has agreed on the project’s performance attributes, the next step is to determine their relative importance in relation to each other. This is accomplished using an evaluative tool termed in this report as the “Performance Attribute Matrix.” This matrix compares the performance attributes in pairs, asking the question: “An improvement in which attribute will provide the greatest benefit to the project relative to purpose and need?”

A letter code (e.g., “A”) is entered into the matrix for each pair, identifying which of the two is more important. If a pair of attributes is of essentially equal importance, both letters (e.g., “A/B”) are entered into the appropriate box. This, however, should be discouraged, as it has been found that in practice a tie usually indicates that the pairs have not been adequately discussed. When all pairs have been discussed, the number of “votes” for each is tallied and percentages (which will be used as weighted multipliers later in the process) are calculated. It is common for one attribute to not receive any “votes.” If this occurs, the attribute is given a token “vote,” as it made the list in the first place and should be given some degree of importance.

An example of this exercise is shown below.

PERFORMANCE ATTRIBUTE MATRIX

[Project Name]

Which attribute is more important to the project?							**TOTAL**	**%**
Main Line Operations	A	B	A	A	A	A	5.0	**23.8%**
Local Operations		B	B	B	B	B/F	5.5	**26.2%**
Maintainability			C	C	E	F	2.0	9.5%
Construction Impacts				D	E	D/F	1.5	7.1%
Environmental Impacts					E	E	4.0	19.0%
Project Schedule						F	3.0	14.3%
						Total	21.0	100%

Without emphasis on preference

A = A is of greater importance

A/B = A and B are of equal importance

For the example project above, the project owner, design team, and stakeholders determined that Main Line Operations, followed by Environmental, gave the greatest improvement relative to the projects purpose and need, while Construction Impacts and Project Schedule gave the least improvement.

Step 3 – Establish the Performance Baseline for the Original Design

The next step in the process is to document the project-specific elements for the performance attributes developed in Step 1. This step establishes a baseline against which the VE alternative concepts can be compared. An example of project-specific elements is shown below.

Evaluation of Baseline Project		
Standard Performance Attribute	**Description of Attribute**	**Baseline Design Rating Rational**
Main Line Operations	An assessment of traffic operations and safety on the project. Operational considerations include level of service relative to the 20-year traffic projections as well as geometric considerations such as design speed, sight distance, lane widths, and shoulder widths.	Design Speed - __ MPH Bridge – __' Lanes, __' shoulders Roadway - __' Lanes, __' shoulders Bridge ___ Loading
Local Operations	An assessment of traffic operations and safety on the local roadway infrastructure. Operational considerations include level of service relative to the 20-year traffic projections; geometric considerations such as design speed, sight distance, lane widths; bicycle and pedestrian operations and access.	Revisions will need to be made to the existing streets and private approaches due to vertical alignment
Maintainability	An assessment of the long-term maintainability of the transportation facility(s). Maintenance considerations include the overall durability, longevity, and maintainability of pavements, structures, and systems; ease of maintenance; accessibility and safety considerations for maintenance personnel.	Baseline design assumes a replacement bridge. Bridge design – low slump overlay on a 7" deck Steel welded plate girder 100' - 150' - 250' - 250' - 150' - 100' spans
Construction Impacts	An assessment of the temporary impacts to the public during construction related to traffic disruptions, detours, and delays; impacts to businesses and residents relative to access, visual, noise, vibration, dust, and construction traffic; environmental impacts.	Maintain traffic across river Noise permit required Short term detour to construct tie-ins to existing highways
Environmental Impacts	An assessment of the permanent impacts to the environment including ecological (i.e., flora, fauna, air quality, water quality, visual, noise); socioeconomic impacts (i.e., environmental justice, business, residents); impacts to cultural, recreational, and historic resources.	In-water window Considered a navigable body of water Existing bridge is under consideration for historical significance
Project Schedule	An assessment of the total project delivery from the time as measured from the time of the study to completion of construction.	Advertisement date ____ Construction starts of ____ 26-month overall construction duration

Once the baseline definitions for the various attributes have been established, their total performance should be calculated by multiplying the attribute’s weight (which was developed in Step 2) by its rating. While one could assign a 0 to 10 rating for each attribute, using the definitions and scales developed in Step 1, a baseline rating of 5 is typically used as a mid-point so that alternatives can be evaluated – better than or worse than the baseline.

Total baseline performance is calculated by multiplying the attribute's weight (which was developed in Step 2) by its rating (5). The baseline design's total performance of 500 points can be calculated by adding all the scores for the attributes. This numerical expression of the original design's performance forms the baseline against which all alternative concepts will be compared.

Step 4 – Evaluate the Performance of the VE Alternative Concepts

Once the performance of the baseline has been established for the original design concept, it can be used to help the VE team develop performance ratings for individual VE alternative concepts as they are developed during the study. The Performance Measures Form is used to capture this information. This form allows a side-by-side comparison of the original design and VE alternative concepts to be performed.

It is important to consider the alternative concept's impact on the entire project (rather than on discrete components) when developing performance ratings for the alternative concept.

Proposals are evaluated against the baseline for all attributes to compare the potential for value improvement. As discussed in Step 3, the baseline is given a rating of 5. The following ratings were used to evaluate the performance of the alternative concepts relative to the baseline concept.

Rating	Performance Attribute Scale
10	Alternative concept is extremely preferred
9	Alternative concept is very strongly preferred
8	Alternative concept is strongly preferred
7	Alternative concept is moderately preferred
6	Alternative concept is slightly preferred
5	***Baseline***
4	Baseline concept is slightly preferred
3	Baseline concept is moderately preferred
2	Baseline concept is strongly preferred
1	Baseline concept is very strongly preferred
0	Baseline concept is extremely preferred

Step 5 – Compare the Performance Ratings of Alternative Concepts to the Baseline Project

As the VE team develops alternatives, the performance of each is rated against the original design concept (baseline). Changes in performance are always based on the overall impact to the total project. Once performance and cost data have been developed by the VE team, the net change in value of the VE alternatives can be compared to the baseline design concept. The resulting "Value Matrix" provides a summary of these changes and allows a way for the Project Team to assess the potential impact of the VE recommendations on total project value.

The VE team groups the VE alternatives into a strategy (or strategies) to provide the decision-makers a clear picture of how the alternatives fit together into possible solutions. At least one strategy is developed to present the VE team's consensus of what should be implemented. Additional strategies are developed as necessary to present other combinations to the decision-makers that should be considered. The strategy(s) of VE alternatives are rated and compared against the baseline concept. The performance ratings developed for the VE strategies are entered into the matrix, and the summary portion of the Value Matrix is completed. The summary provides details on net changes to cost, performance, and value, using the following calculations:

- % Performance Improvement = ∆ Performance VE Strategy/Total Performance Original Concept

Performance Attribute Ratings				
Attribute	**Attribute Weight**	**Concept**	**Performance Rating**	**Total Performance**
Main Line Operations	28.9	Baseline	5	144.5
		1	7	202.3
		2	7	202.3
		3	5	144.5
Local Operations	14.2	Baseline	5	71.0
		1	5	71.0
		2	5	71.0
		3	8	113.6
Maintainability	14.2	Baseline	5	71.0
		1	3	42.6
		2	6	85.2
		3	4.5	63.9
Environmental Impacts	16.6	Baseline	5	83.0
		1	6.5	107.9
		2	5	83.0
		3	4.5	74.7
Construction Impacts	14.2	Baseline	5	71.0
		1	4	56.8
		2	6	85.2
		3	5	71.0
Project Schedule	11.9	Baseline	5	59.5
		1	5	59.5
		2	5	59.5
		3	5	59.5

- Value Index = Total Performance/Total Cost (in Millions)
- % Value Improvement = ∆Value Index VE Strategy/Value Index Original Concept.

The following is an example of a Value Matrix worksheet.

Recommendation Summary									
Recommendations		**Performance (P)**	**% Change Performance**	**Cost (C) $ millions**	**Cost Change $ millions**	**% Change Cost**	**Value Index**	**% Value Improvement**
	Baseline	500	---	$46.1	---	---	10.85	---
1	Recommendation No. 1 - Title	540	+8.0%	$46.6	$0.5	+1.2%	11.58	+6.8%
2	Recommendation No. 2 - Title	586	+17.2%	$46.5	$0.4	+0.9%	12.60	+16.2%
3	Recommendation No. 3 - Title	527	+5.4%	$46.1	$0.0	+0.0%	11.43	+5.4%
			Total		$3.9			

Appendix B. VE Recommendation Approval Form

Project: US 51 Bridge Replacement over the Ohio River
VE Study Date: May 19, May 22-26, 2023

			FHWA Functional Benefit						
Recommendation		**Approved Y/N**	**Safety**	**Operations**	**Environment**	**Construction**	**Right-of-way**	**Estimated Cost Avoidance or Cost Added**	**Justification for Not Recommending or Potential Implementation Issues**
1	Facilitate Staging Locations					✓		$0.08	
2	Use Soil Improvements Techniques			✓		✓		$9.36	
3	Conduct a Non-linear Time History Analysis		✓	✓		✓		$1.70	
4	Pre-design by Load Testing		✓			✓		$7.57	
5	Increase End Bearing Resistance of Foundations		✓			✓		$17.31	
6	Use Isolation Bearings with Batter Piles		✓	✓		✓		$11.39	
7	Use Innovative Delivery Method				✓	✓		$13.18	
8	Deliver and Remove Material by Rail - Build a Temporary Spur			✓			✓	$0.00	
9	Use Concrete Pavement			✓				$4.67	
10	Increase Span Length of Approach structures			✓		✓		$3.12	
TOTALS			4	6	1	8	1	$46.05	

Justification for the value engineering workshop recommendations **not** approved or implemented is provided in the table above.

The completed VE Recommendation Approval form, including justification for any recommendations not approved or modified, will be sent to the State Value Engineering Coordinator/Manager by October 1 of each year so the results can be included in the annual Value Engineering Report to FHWA.

Signature – Project Manager

Date

Name (please print)

FHWA Functional Benefit Criteria

Each year, State DOTs are required to report on VE recommendations to FHWA. In addition to cost implications, FHWA requires the DOTs to evaluate each approved recommendation in terms of the project feature or features that recommendation benefits. If a specific recommendation can be shown to provide benefit to more than one feature described below, count the recommendation in *each category that is applicable*.

Safety: Recommendations that mitigate or reduce hazards on the facility.

Operations: Recommendations that improve real-time service and/or local, corridor, or regional levels of service of the facility.

Environment: Recommendations that avoid or mitigate impacts to natural and/or cultural resources.

Construction: Recommendations that improve work zone conditions or expedite the project delivery.

Right-of-way: Recommendations that lower the impacts or costs of right-of-way.

Appendix C. VE Study Memo, Agenda, and Attendees

Memo

Date: Monday, May 01, 2023

Project: US-51 Bridge Replacement between Wickliffe, KY and Cairo, IL

To: VE Team Members

From: Jose Theiler, PE, CVS®

Subject: Virtual Value Engineering Study

Congratulations!!! You have been chosen to participate in this Hybrid Value Engineering (VE) study because of your expertise and valuable contributions to the project.

This memo is to introduce some of the expectations for the upcoming VE study. I'm looking forward to working with you on this endeavor. My hope is that this memo will provide information about the project and expectations on working together.

If you have any questions, please contact me, Jose Theiler, at 561-386-3879 (cell), or e-mail: jose.theiler@hdrinc.com.

VE Study Dates and Location

The VE study will be held virtually on Friday May 19, 2023; and in person from Monday May 22 to Friday May 26, 2023 as follows:

Microsoft Teams meeting
Join on your computer, mobile app or room device
Click here to join the meeting
Meeting ID: 252 582 153 406
Passcode: 8FgaSp
Download Teams | Join on the web
Or call in (audio only)
+1 402-513-9026,,521527019# United States, Omaha
(833) 255-2803,,521527019# United States (Toll-free)
Phone Conference ID: 521 527 019#

What to Bring

Be sure to bring your normal tools of the trade (e.g., calculator, laptop computer, scale, etc.). Bring a creative and open mind. VE studies are a lot of work, but if you bring your creativity and sense of humor you will have a good time and a rewarding experience.

Ground Rules

1. A VE study follows a prescribed process that has been proven over many years to produce the best results. This process requires the team members be fully engaged and have an open mind to "step" outside of the box throughout the week.
2. To maintain our schedule and provide the best results to the project team, I ask that we follow some basic ground rules:

   a. We will use MS-Teams as a holding place for conversations, notes, documentation, etc. Follow the link to make sure you have access and become familiar with the site.
   b. Please be prepared to attend the entire duration of the workshop. You were selected to assist on this team based on your expertise. If you cannot be in attendance for the entire time, then please notify me prior to the study. When team members leave part way through, or come and go frequently, the VE team can lose its momentum and cohesiveness. We understand that conducting business virtually is different and typical interruptions or noise background is expected at times. Please minimize disruptions by muting your phone or asking for a break.
   c. Avoid multitasking during the study. Unless it is information to assist the team, please try to wait until breaks to return phone calls, check on messages, or sort through e-mails.
   d. Dress code. I want everyone to be comfortable. Some of us will attend from our homes; please dress appropriately (business casual).
   e. A laptop is required for the workshop. We will develop recommendations using templates in Word format and will exchange and share files throughout the workshop.
3. Our success will be evaluated based on the level of contribution that we bring to the project. Remember that the goal of any VE study is to add value to the project; saving money is just a byproduct. We want to make recommendations based on solid engineering judgment that will result in an improved project.

Value Engineering Job Plan

The VE team will employ the eight-phase VM job plan in analyzing the project. This process is recommended by SAVE International® and AASHTO, and is composed of the following phases:

Preparation Phase – Prior to the VE study, the Project Manager and the VE facilitator carry out the following activities:

- Initiate study – identify study project and define study goals
- Organize study – conduct pre-VE study meeting to establish team members, logistics and parameters to analyze the project
- Prepare data – Collect and distribute data and prepare cost models

Information Phase – The objective of this phase is to obtain a thorough understanding of the project's design criteria and objectives by reviewing the project's documents and drawings, cost estimates, and schedules.

As part of this phase, we will hold a 3-day CSRA (risk assessment); on the morning of the first day we will go over the following:

- Overview of the VE process
- Understanding of study objectives
- Project Overview and Briefing by the Design team
    - Provide insight on project history, design concepts, environmental issues, etc.
    - Discuss any design concerns and new concepts involved with the project.
    - All appropriate project disciplines should be discussed.
    - Discuss/identify any risks or issues that the VE team should concentrate on.
    - Provide VE team with any specific project constraints.
    - Q&A – Presenters answers questions from the VE team.
- Risk Elicitation: a risk elicitation session will follow for three days. The purpose is to identify and quantify the risks of the project. This information may provide an opportunity for the VE team to develop response strategies in the form of recommendations.

Function Analysis Phase – Identifying each of the key functions of the project is the most important phase of value engineering, as it is the basis for unlocking the creativity of team members. As part of this phase, the team performs the following tasks with the assistance of the VE Facilitator:

- Defines project and risk functions and assigns them to key project components.
- Classifies functions as either “basic” or “secondary.”
- Sequence functions to understand their relationships using the Function Analysis System Technique (FAST).
- Establishes performance measures.
- Creates the project’s cost model.

Creativity Phase – During this phase the team will employ creative techniques such as team brainstorming to develop a number of alternative concepts that satisfy the project’s basic and supporting functions and mitigate project risks.

Evaluation Phase – The purpose of this phase is to evaluate the alternative concepts developed by the VE team during the brainstorming sessions. To that purpose, the team discusses advantages and disadvantages, and uses a number of tools to determine the qualitative and quantitative merits of each concept.

Mid-point Review With Management Team: At this point, the VE team holds a meeting with the project team, management, and other stakeholders, to validate the direction of the team and that ideas moving forward to the development phase do not step outside the boundaries set forth by project constraints.

Development Phase – Those concepts that ranked highest in the evaluation are further developed into VE recommendations. Recommendation narratives, additional advantages and disadvantages, drawings, calculations, and life cycle cost analysis are prepared for each recommendation.

Presentation Phase – The VE team presents their finding during an oral presentation to the owner and the project team. Following the workshop, a written report is submitted that summarizes the study, its findings, and recommendations.

Implementation Phase – The project team is then charged with reviewing the report and may hold a Disposition Meeting with management and other stakeholders, to determine which recommendations will be implemented in the design. The project team then tracks their implementation into the plans.

I’m looking forward to working with you on this VE study and I really appreciate each of you blocking time out of your busy schedules to participate. Please don’t hesitate to call or e-mail me if you have any questions.

Sincerely,

Jose Theiler, PE CVS®
East Region Manager of
Project Risk Management and Value Engineering
HDR Engineering, Inc
440 S. Church Street, Suite 1000
Charlotte, NC 28202-2075
M 561.386.3879
jose.theiler@hdrinc.com

Agenda

Day 1	**Friday, May 19, 2023** **Objective for the day: Learn about VE and the Project**	
8:30	**Connect to MS Teams Meeting**	**All audiences** Project owner, PMs, designers, VE team
8:35 *Information Phase*	• **Roll call** • **VE Process Overview:** an instructional presentation on the principles of value engineering and their application to the project	**All audiences facilitated by** Jose Theiler, PE, CVS
9:00 *Information Phase*	**Project Overview** • Purpose and need of the project • Goals and objectives of the project • Constraints • Basis of design • Virtual site visit • Questions and answers	**All audiences facilitated by** Project team/designer
10:00	**Break**	
10:10 *Information Phase*	**Define/Review Performance Attributes**	**All audiences facilitated by** Jose Theiler, PE, CVS
10:40 *Information Phase*	**Risk Elicitation**	**All audiences facilitated by** Jose Theiler, PE, CVS
11:00	**Adjourn**	

Day 2	Monday, May 22, 2023 Objective for the day: Function Analysis	
1:00 *Information Phase*	**Recap Information Phase**	**All audiences facilitated by** Jose Theiler, PE, CVS
1:30 *Information Phase*	**Project / site visit observations**	**VE team facilitated by** Jose Theiler, PE, CVS
02:00 *Function Analysis Phase*	**Function Analysis** • Review project cost model • Define key project functions using "verb + noun" expressions	
3:30	**Break**	
03:45 *Function Analysis Phase*	**Function Analysis** • Define key project functions using "verb + noun" expressions • Build a FAST diagram	
05:00	**Adjourn**	

Day 3	Tuesday, May 23, 2023 Objective for the day: Function Analysis, Brainstorming Ideas, Evaluate Ideas	
08:00 *Function Analysis Phase*	**Creative Phase** • Brainstorm alternative ways to perform key functions • Brainstorm ways to improve value of key functions	**VE team facilitated by** Jose Theiler, PE, CVS
9:30	**Break**	
9:45 *Creative Phase*	**Creative Phase** • Brainstorm alternative ways to perform key functions • Brainstorm ways to improve value of key functions	**VE team facilitated by** Jose Theiler, PE, CVS
11:00 *Creative Phase*	**Evaluate Ideas** • Discuss advantages and disadvantages for each idea • Score ideas based on predetermined criteria to develop further into recommendations	**VE team facilitated by** Jose Theiler, PE, CVS
12:00	**Lunch**	
01:00 *Creative Phase*	**Evaluate Ideas** • Discuss advantages and disadvantages for each idea • Score ideas based on predetermined criteria to develop further into recommendations	**VE team facilitated by** Jose Theiler, PE, CVS
03:45	**Break**	
4:00	**Mid-point review (Optional)** • Update leadership on progress	**All audiences facilitated by** Jose Theiler, PE, CVS
05:00	**Adjourn**	

Day 4	**Wednesday, May 24, 2023** **Objective for the day: Begin Developing**	

08:00
Development Phase
	Develop Ideas into Recommendations
	• Individual/team assignments
	• Development of recommendations:
	  ○ Test design feasibility
	  ○ Design analysis
	  ○ Technical narratives
	  ○ Further discussion on advantages and disadvantages
	• Cost analysis (life cycle cost comparison)
		VE team facilitated by
		Jose Theiler, PE, CVS

10:00	**Break**	
11:45 *Development Phase*	**Check in Progress**	**VE team facilitated by** Jose Theiler, PE, CVS
12:00	**Lunch**	
01:00 *Development Phase*	**Development Continues**	**Facilitator, Value Engineer, PMs, Managers**
4:00 *Development Phase*	**Check in Progress**	**VE team facilitated by** Jose Theiler, PE, CVS
05:00 PM	**Adjourn**	

Day 5	**Thursday, May 25, 2023** **Objective for the day: Continue Development of Recommendations and the Close-out Presentation**	
8:00 *Development Phase*	**Development Continues**	**Facilitator, Value Engineer, PMs, Managers**
11:00 *Development Phase*	**Check in Progress**	**VE team facilitated by** Jose Theiler, PE, CVS
12:00	**Lunch**	
01:00 *Development Phase*	**Finalize recommendations** Peer review of recommendations	**VE team facilitated by** Jose Theiler, PE, CVS
02:00 *Development Phase*	**Evaluate performance attributes of recommendations**	**VE team facilitated by** Jose Theiler, PE, CVS
05:00	**Adjourn**	

Day 6	Friday, May 26, 2023 **Objective for the day: Deliver Close-out Presentation**	
8:00 *Presentation Phase*	**Review and Rehearse Presentation**	**VE team facilitated by** Jose Theiler, PE, CVS
10:15	**Break**	
10:30 *Presentation Phase*	**Presentation of VE Findings** • Team presents recommendations to management • Questions and answers	**All audiences:** Project owner, management, stakeholders, designers, etc.
12:00	**Adjourn**	

VE Study Attendees
US 51 Bridge Replacement

NAME						ORGANIZATION – POSITION/DISCIPLINE	EMAIL	PHONE
19	22	23	24	25				
				✓	C.Y Yong	MBI	cyong@mbakerintl.com	
✓					Chittenden, Devin	HDR	devin.chittenden@hdrinc.com	(270) 969-0212
✓					Eldridge, Brad	FHWA		
✓					Gregory, Brad	HMB	bgregory@hmbpe.com	
✓	✓	✓	✓	✓	Guess, Jonathan	HDR	jonathan.guess@hdrinc.com	(270) 538-1503
✓					Hagerman, Wes	HDR	wes.hagerman@hdrinc.com	(859) 629-4860
✓					Hart, Austin	KYTC		
					Hart, Austin P (KYTC-D01)	KYTC	austin.hart@ky.gov	
✓		✓	✓	✓	Johnson, Christopher	HDR	christopher.johnson@hdrinc.com	(704) 915-7810
✓					Kauzlarich, Joseph M	HMB		
✓	✓	✓	✓	✓	Keaney, Brian	HDR	brian.keaney@hdrinc.com	(919) 740-9686
✓				✓	Klenke, Anna	MBI	anna.klenke@mbakerintl.com	
✓					Kramer, Steve	HMB		
✓					Kuntz, Chris C (KYTC-D01)	KYTC	chris.kuntz@ky.gov	

VE Study Attendees
US 51 Bridge Replacement

19	22	23	24	25	NAME	ORGANIZATION – POSITION/DISCIPLINE	EMAIL	PHONE
✓					Leathers, Michael	HMB		
✓					Looper, Jason	KYTC		
					Looper, Jason W (KYTC-D01)	KYTC	jason.looper@ky.gov	
✓	✓	✓	✓	✓	Malik, Raheel	HDR	raheel.malik@hdrinc.com	(415) 609-4129
✓	✓	✓	✓	✓	Messmer, Anthony	HDR	anthony.messmer@hdrinc.com	(360) 480-3040
✓					Nelsen, Carrie L	IDOT	carrie.nelsen@illinois.gov	
✓					Papakos, Tatiana	MBI	tatiana.papakos@mbakerintl.com	
✓					Pietz, Kenny	HDR	kenny.pietz@hdrinc.com	(843) 296-9887
✓				✓	Poat, Kyle M (KYTC-D01)	KYTC	kyle.poat@ky.gov	
✓				✓	Provance, Shannon	HDR	shannon.provance@hdrinc.com	(270) 538-1521
✓					Rawlins, Patsy	KYTC		
✓					Schaefer, Jeff	HDR	jeff.schaefer@hdrinc.com	(502) 909-3247
✓				✓	Stein, Charles W	IDOT	charles.stein@illinois.gov	
✓	✓	✓	✓	✓	Stewart, Katy R (KYTC)	KYTC	katy.stewart@ky.gov	

VE Study Attendees
US 51 Bridge Replacement

NAME						ORGANIZATION – POSITION/DISCIPLINE	EMAIL	PHONE
19	22	23	24	25				
√				√	Stith, Jason	MBI	jason.stith@mbakerintl.com	
√				√	Stover, Aaron	MBI	astover@mbakerintl.com	
√	√	√	√	√	Theiler, Jose	HDR	jose.theiler@hdrinc.com	(561) 386-3879
√					Tilley, James	KYTC		
√				√	Wilson, Everett L (KYTC-D01)	KYTC	everett.wilson@ky.gov	

Appendix D. Project Estimate

PROJECT : *US-51 over Ohio River Bridge Replacement*
TASK : *Cost Estimation* PROJECT NO : *173028*
SUBJECT : *ASF Closeout Forms*
CALCULATED BY : *BTP* DATE : *3/24/2023* CHECKED BY : DATE :

Michael Baker INTERNATIONAL

TIED ARCH

Description:

Total Cost Estimate Summary for Tied Arch Option.

Total Cost - Tied Arch Option

Direct Costs

	Item Cost	Deck Area (SQ FT)
Unit 1 Approach =	$ 46,059,400.00	68,553.770
Unit 2 Main Span =	$ 104,190,800.00	38,287.800
Unit 3 Approach =	$ 51,756,300.00	77,909.290
Unit 4 Approach =	$ 40,023,500.00	57,823.870
Unit 5 Approach =	$ 21,532,600.00	31,140.500
Demolition =	$ 5,000,000.00	
Roadway =	$ 15,000,000.00	
Total Direct Costs (2022) =	**$ 283,562,600.00**	**273,715.230**

Cost per Deck Area = $ 1,035.98 / SQ FT

Other Costs

Contingency (20%) = $ 56,712,520.00
Mobilization (6.5%) = $ 22,117,882.80

OTAL ESTIMATED COSTS (2022) = $ 362,393,002.80

KENTUCKY TRANSPORTATION CABINET
DEPARTMENT OF HIGHWAYS
DIVISION OF STRUCTURAL DESIGN
SUMMARY OF BRIDGE DESIGN DATA

TC 66-101
Rev. 11/05

COUNTY	Ballard
ROAD	US 51, Great River Rd
STATUS REPORT ITEM	01-1140.00
STATE PROJECT NO.	none
FEDERAL PROJECT NO.	NHPP BR 0601-204
CROSSING	Ohio River
DESIGNER	Michael Baker International Design Section
DRAWING NO.	XXXXXX
STATION	2029+38.55
SKEW	0.0 deg
DESIGN LOAD	KY-HL93
ROAD ALIGNMENT	Straight
BRIDGE ROADWAY	40.000 ft.
BRIDGE WIDTH	42.542 ft.
TOTAL LENGTH	1611.450 ft.
DECK AREA	68553.77 ft.^2
BRIDGE TYPE	WSPG 123" Web

ABUTS

	1	2
ABUT. TYPE	ABP	
ABUT. HEIGHT	18.0 ft	

COMPARISON of Estimate vs. Final Bid				
Final Plan Total	$46,059,400.00	Contractor UNDER By:	100.0	%
Final Bid Total	$-	$ 46,059,400.00		

SPANS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
311.5 ft	300.0 ft	325.0 ft	350.0 ft	325.0 ft										
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

PIERS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
C1P	C1P	C1P	C1P											
31.5 ft	37.3 ft	89.1 ft	138.0 ft											
16	17	18	19	20	21	22	23	24	25	26	27	28	29	

FRAMING	Continuous
MATERIAL	WSPG 123" Web
SPECIAL FEATURES	Tied Arch Option, Unit 1

		PRELIMINARY PLANS ESTIMATE						BID	Letting: Unknown		Awarded: Unknown		
Item	Units	Unit Price	Superstructure		Substructure		Bridge	Unit Price	Superstructure		Substructure		Bridge
Concrete Class A	CY	900			2489	2,240,073	2,240,073				2489		
Concrete Class AA	CY	1,250	2082	2,602,988			2,602,988		2082				
Steel Reinforcement	LB	1.70			497102	845,073	845,073				497102		
Steel Reinforcement Epoxy Coated	LB	1.80	572657	1,030,800			1,030,800		572657				
Structural Steel	LB	2.75	6252942	17,195,600			17,195,600		6252942				
Total for Additional Items				2,637,163		19,507,640	22,144,803						
TOTAL COST				23,466,550		22,592,800	46,059,400						
Cost per Deck Area				350		330	672						

ADDITIONAL ITEMS		PRELIMINARY PLANS ESTIMATE						BID	Letting: Unknown		Awarded: Unknown		
Item	Units	Unit Price	Superstructure		Substructure		Bridge	Unit Price	Superstructure		Substructure		Bridge
Pier Foundations	LS	17807640			1.0	17,807,640	17,807,640				1		
Abutment Ground Improvements	LS	1500000			1	1,500,000	1,500,000				1		
Slope Ground Improvements	LS	200000.00			1.0	200,000	200,000				1.0		
Latex Concrete Overlay	CY	1700.00	249.0	423300.00			423,300		249.0				
Bearings	EA	25000.00	20.0	500,000			500,000		20.0				
Modular Expansion Joint	LF	6000.00	43.0	258,000			258,000		43.0				
RAIL SYSTEM SINGLE SLOPE - 40 IN	LF	125.00	3222.9	402,863			402,863		3222.9				
Drilled Shaft - 60in (Common)	LF	1350.00	780.0	1,053,000			1,053,000		780.0				
Total for Additional Items				2,637,163		19,507,640	22,144,803						

SUMMARY OF BRIDGE DESIGN DATA

COUNTY	Ballard
ROAD	US 51, Great River Rd
STATUS REPORT ITEM	01-1140.00
STATE PROJECT NO.	none
FEDERAL PROJECT NO.	NHPP BR 0601-204
CROSSING	Ohio River
DESIGNER	Michael Baker International Design Section
DRAWING NO.	XXXXXX
STATION	2045+50
SKEW	0.0 deg
DESIGN LOAD	KY-HL93
ROAD ALIGNMENT	Straight
BRIDGE ROADWAY	40.000 ft.
BRIDGE WIDTH	42.542 ft.
TOTAL LENGTH	900.000 ft.
DECK AREA	38287.80 ft.^2
BRIDGE TYPE	Single Span Tied Arch

ABUTS

	1	2
ABUT. TYPE	L2WP	L2WP
ABUT. HEIGHT	110.0 ft	110.0 ft

COMPARISON of Estimate vs. Final Bid			
Final Plan Total	$104,190,800.00	Contractor UNDER By:	100.0 %
Final Bid Total	$-	$ 104,190,800.00	

SPANS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
900.0 ft														
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

PIERS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
16	17	18	19	20	21	22	23	24	25	26	27	28	29	

FRAMING	Simple Span
MATERIAL	Single Span Tied Arch
SPECIAL FEATURES	Tied Arch Option, Unit 2

		PRELIMINARY PLANS ESTIMATE						BID	Letting: Unknown			Awarded: Unknown	
Item	Units	Unit Price	Superstructure		Substructure		Bridge	Unit Price	Superstructure		Substructure		Bridge
Concrete Class A	CY	1,650			4404	7,266,039	7,266,039				4404		
Concrete Class AA	CY	1,250	945	1,181,775			1,181,775		945				
Steel Reinforcement	LB	1.70			880732	1,497,244	1,497,244				880732		
Steel Reinforcement Epoxy Coated	LB	1.80	259990	468,000			468,000		259990				
Total for Additional Items				47,999,238		45,778,501	93,777,739						
TOTAL COST				49,649,013		54,541,800	104,190,800						
Cost per Deck Area				1,300		1,430	2,721						

ADDITIONAL ITEMS			PRELIMINARY PLANS ESTIMATE					BID	Letting: Unknown			Awarded: Unknown	
Item	Units	Unit Price	Superstructure		Substructure		Bridge	Unit Price	Superstructure		Substructure		Bridge
Pier Foundations	LS	27278501			1.0	27,278,501	27,278,501				1		
Arch Alternate - Barges and Workboats	LS	11000000			1	11,000,000	11,000,000				1		
Trestle	LS	2500000.00			1.0	2,500,000	2,500,000				1.0		
Contingency Trestle	LS	5000000.00			1.0	5,000,000	5,000,000				1.0		
Concrete Overlay - Latex	CY	1700.00	139.0	236,300			236,300		139.0				
RAIL SYSTEM SINGLE SLOPE - 40 IN	LF	125.00	1800.0	225,000			225,000		1800.0				
Bearings	EA	100000.00	4.0	400,000			400,000		4.0				
Arch Alternate - Network Cables	LS	7220390.00	1.0	7,220,390			7,220,390		1.0				
Arch Alternate - Structural Steel GR70	LB	5.25	6339470.0	33,282,218			33,282,218		6339470.0				
Arch Alternate - Structural Steel GR50	LB	5.00	1275466.0	6,377,330			6,377,330		1275466.0				
Modular Expansion Joint	LF	6000.00	43.0	258,000			258,000		43.0				
Total for Additional Items				47,999,238		45,778,501	93,777,739						

KENTUCKY TRANSPORTATION CABINET
DEPARTMENT OF HIGHWAYS
DIVISION OF STRUCTURAL DESIGN
SUMMARY OF BRIDGE DESIGN DATA

TC 66-101
Rev. 11/05

COUNTY	Ballard
ROAD	US 51, Great River Rd
STATUS REPORT ITEM	01-1140.00
STATE PROJECT NO.	none
FEDERAL PROJECT NO.	NHPP BR 0601-204
CROSSING	Ohio River
DESIGNER	Michael Baker International Design Section
DRAWING NO.	XXXXXX
STATION	2054+50
SKEW	0.0 deg
DESIGN LOAD	KY-HL93
ROAD ALIGNMENT	Straight
BRIDGE ROADWAY	40.000 ft.
BRIDGE WIDTH	42.542 ft.
TOTAL LENGTH	1831.350 ft.
DECK AREA	77909.29 ft.^2
BRIDGE TYPE	WSPG 123" Web

ABUTS

	1	2
ABUT. TYPE		
ABUT. HEIGHT		

COMPARISON of Estimate vs. Final Bid				
Final Plan Total	$51,756,300.00	Contractor UNDER By:	100.0	%
Final Bid Total	$-	$ 51,756,300.00		

SPANS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
325.0 ft	350.0 ft	325.0 ft	300.0 ft	300.0 ft	231.4 ft.									
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

PIERS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
C1P	C1P	C1P	C1P	C1P										
124.9 ft	108.1 ft	66.1 ft	61.4 ft	57.2 ft										
16	17	18	19	20	21	22	23	24	25	26	27	28	29	

FRAMING	Continuous
MATERIAL	WSPG 123" Web
SPECIAL FEATURES	Tied Arch Option, Unit 3, Superelevation Transition

		PRELIMINARY PLANS ESTIMATE						BID	Letting: Unknown		Awarded: Unknown		
Item	Units	Unit Price	Superstructure		Substructure		Bridge	Unit Price	Superstructure		Substructure		Bridge
Concrete Class A	CY	900			2425	2,182,365	2,182,365				2425		
Concrete Class AA	CY	1,250	2366	2,957,500			2,957,500		2366				
Steel Reinforcement	LB	1.70			484969	824,447	824,447				484969		
Steel Reinforcement Epoxy Coated	LB	1.80	650715	1,171,300			1,171,300		650715				
Structural Steel	LB	2.75	7106225	19,542,200			19,542,200		7106225				
Total for Additional Items				1,896,938		23,181,480	25,078,418						
TOTAL COST				25,567,938		26,188,300	51,756,300						
Cost per Deck Area				330		340	664						

ADDITIONAL ITEMS			PRELIMINARY PLANS ESTIMATE					BID	Letting: Unknown		Awarded: Unknown		
Item	Units	Unit Price	Superstructure		Substructure		Bridge	Unit Price	Superstructure		Substructure		Bridge
Pier Foundations	LS	22181480			1.0	22,181,480	22,181,480				1		
Slope Ground Improvements	LS	1000000			1	1,000,000	1,000,000				1		
Concrete Overlay - Latex	CY	1700.00	283.0	481100.00			481,100		283.0				
Bearings	EA	25000.00	28.0	700000.00			700,000		28.0				
Modular Expansion Joint	LF	6000.00	43.0	258,000			258,000		43.0				
RAIL SYSTEM SINGLE SLOPE - 40 IN	LF	125.00	3662.7	457,838			457,838		3662.7				
Total for Additional Items				1,896,938		23,181,480	25,078,418						

KENTUCKY TRANSPORTATION CABINET
DEPARTMENT OF HIGHWAYS
DIVISION OF STRUCTURAL DESIGN
SUMMARY OF BRIDGE DESIGN DATA

TC 66-101
Rev. 11/05

COUNTY	Ballard
ROAD	US 51, Great River Rd
STATUS REPORT ITEM	01-1140.00
STATE PROJECT NO.	none
FEDERAL PROJECT NO.	NHPP BR 0601-204
CROSSING	Ohio River, E Cairo Rd, CN RR, IC RR
DESIGNER	HMB Design Section
DRAWING NO.	XXXXXX
STATION	2072+81.35
SKEW	0.0 deg
DESIGN LOAD	KY-HL93
ROAD ALIGNMENT	Curved
BRIDGE ROADWAY	40.000 ft.
BRIDGE WIDTH	42.542 ft.
TOTAL LENGTH	1359.229 ft.
DECK AREA	57823.87 ft.^2
BRIDGE TYPE	WSPG 96" Web

ABUTS

	1	2
ABUT. TYPE	C1P	
ABUT. HEIGHT	49.7 ft	

COMPARISON of Estimate vs. Final Bid				
Final Plan Total	$40,023,500.00	Contractor UNDER By:	100.0	%
Final Bid Total	$-	$ 40,023,500.00		

SPANS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
190.0 ft	245.0 ft	245.0 ft	245.0 ft	245.0 ft	189.2 ft									
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

PIERS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
C1P	C1P	C1P	C1P	C1P										
50.9 ft	46.1 ft	45.5 ft	43.0 ft	38.6 ft										
16	17	18	19	20	21	22	23	24	25	26	27	28	29	

FRAMING	Continuous
MATERIAL	WSPG 96" Web
SPECIAL FEATURES	All Options, Unit 4, Full Superelevation, Curved

		PRELIMINARY PLANS ESTIMATE						BID	Letting: Unknown			Awarded: Unknown	
Item	Units	Unit Price	Superstructure		Substructure		Bridge	Unit Price	Superstructure		Substructure		Bridge
Concrete Class A	CY	900			7303	6,572,340	6,572,340				7303		
Concrete Class AA	CY	1,250	1554	1,942,875			1,942,875		1554				
Steel Reinforcement	LB	1.70			1460535	2,482,910	2,482,910				1460535		
Steel Reinforcement Epoxy Coated	LB	1.80	427433	769,400			769,400		427433				
Structure Excavation Common	CY	150			6144	921,600	921,600				6144		
Structural Steel	LB	2.75	4764480	13,102,400			13,102,400		4764480				
Total for Additional Items				1,799,890		12,432,000	14,231,890						
TOTAL COST				17,614,565		22,408,900	40,023,500						
Cost per Deck Area				310		390	692						

ADDITIONAL ITEMS			PRELIMINARY PLANS ESTIMATE					BID	Letting: Unknown			Awarded: Unknown	
Item	Units	Unit Price	Superstructure		Substructure		Bridge	Unit Price	Superstructure		Substructure		Bridge
Drilled Shaft - 96IN (Common)	LF	2000			6216.0	12,432,000	12,432,000				6216		
Modular Expansion Joint	LF	6000	42.5	255000.00			255,000		43				
Concrete Overlay - Latex	CY	1700.00	267.7	455090.00			455,090		267.7				
Disc Expansion Bearing	EA	25000.00	30.0	750000.00			750,000		30.0				
RAIL SYSTEM SINGLE SLOPE - 40 IN	LF	125.00	2718.4	339,800			339,800		2718.4				
Total for Additional Items				1,799,890		12,432,000	14,231,890						

KENTUCKY TRANSPORTATION CABINET
DEPARTMENT OF HIGHWAYS
DIVISION OF STRUCTURAL DESIGN
SUMMARY OF BRIDGE DESIGN DATA

TC 66-101
Rev. 11/05

COUNTY	Ballard
ROAD	US 51, Great River Rd
STATUS REPORT ITEM	01-1140.00
STATE PROJECT NO.	none
FEDERAL PROJECT NO.	NHPP BR 0601-204
CROSSING	Ohio River
DESIGNER	Civil Design, Inc. Design Section
DRAWING NO.	XXXXXX
STATION	2086+40.58
SKEW	0.0 deg
DESIGN LOAD	KY-HL93
ROAD ALIGNMENT	Straight
BRIDGE ROADWAY	40.000 ft.
BRIDGE WIDTH	42.542 ft.
TOTAL LENGTH	732.000 ft.
DECK AREA	31140.50 ft.^2
BRIDGE TYPE	WSPG 103" Web

ABUTS

	1	2
ABUT. TYPE	C1P	ABP
ABUT. HEIGHT	39.6 ft	18.0 ft

COMPARISON of Estimate vs. Final Bid				
Final Plan Total	$21,532,600.00	Contractor UNDER By:	100.0	%
Final Bid Total	$-	$ 21,532,600.00		

SPANS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
220.0 ft	292.0 ft	220.0 ft												
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

PIERS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
C1P	C1P													
36.0 ft	30.0 ft													
16	17	18	19	20	21	22	23	24	25	26	27	28	29	

FRAMING	Continuous
MATERIAL	WSPG 103" Web
SPECIAL FEATURES	All Options, Unit 5, Superelevation Transition

		PRELIMINARY PLANS ESTIMATE						**BID**	Letting: Unknown			Awarded: Unknown	
Item	Units	Unit Price	Superstructure		Substructure		Bridge	Unit Price	Superstructure		Substructure		Bridge
Concrete Class A	CY	900			962	866,178	866,178				962		
Concrete Class AA	CY	1,250	946	1,182,500			1,182,500		946				
Steel Reinforcement	LB	1.70			192272	326,862	326,862				192272		
Steel Reinforcement Epoxy Coated	LB	1.80	260045	468,100			468,100		260045				
Structural Steel	LB	2.75	1929580	5,306,400			5,306,400		1929580				
Total for Additional Items				1,291,017		12,091,500	13,382,517						
TOTAL COST				8,248,017		13,284,600	21,532,600						
Cost per Deck Area				270		430	691						

ADDITIONAL ITEMS			**PRELIMINARY PLANS ESTIMATE**					**BID**	Letting: Unknown			Awarded: Unknown	
Item	Units	Unit Price	Superstructure		Substructure		Bridge	Unit Price	Superstructure		Substructure		Bridge
Bearings	EA	25000	16	400,000			400,000		16				
RAIL SYSTEM SINGLE SLOPE - 40 IN	LF	125	1463.3	182916.67			182,917		1463				
Pier Foundations	LS	9538500.00			1.0	9,538,500	9,538,500				1.0		
Abutment Ground Improvements	LS	1500000.00			1.0	1,500,000	1,500,000				1.0		
Modular Expansion Joint	LF	6000.00	86.0	516,000			516,000		86.0				
Concrete Overlay - Latex	CY	1700.00	113.0	192,100			192,100		113.0				
Drilled Shaft - 60in (Common)	LF	1350.00			780.0	1,053,000	1,053,000				780.0		
Total for Additional Items				1,291,017		12,091,500	13,382,517						

US 51 - CAIRO BRIDGE
BALLARD CO
ITEM NO. 01-1140

	US 51 Mainline and Approaches	
PRELIMINARY CONSTRUCTION COST ESTIMATE		
Project Construction Total	**$14,000,000**	
	KY	**IL**
Roadways Costs (30% Contingency)	**$10,200,000**	**$3,800,000**
INTERSECTION TYPE		
Select Type (use drop down menu to select Rndbt, T, or Cont. Rt)	**Roundabout**	
EARTHWORK		
Embankment	195,000 CY	55,000 CY
Excavation	70,000 CY	20,000 CY
Borrow	125,000 CY	35,000 CY
Embankment Stabilization	$ 4,000,000	$ 1,000,000
EARTHWORK SUBTOTAL ($10.00 / CY)	**$ 5,960,000**	**$ 1,560,000**
PAVEMENT / MISC		
Project Length	9,850 ft	
Asphalt ($115/TON)	$ 897,000	$ 575,000
Aggregate ($25/TON)	$ 950,000	$ 675,000
Guardrail ($20/LF)	$ 8,000	$ 6,750
Drainage (LS)	$ 5,000	$ 50,000
Striping ($2/LF)	$ 52,000	$ 25,000
PAVEMENT / MISC SUBTOTAL	**$ 1,912,000**	**$ 1,331,750**
RIGHT OF WAY		
Parcels Affects	6	2
Perm ROW (Acres)	15.86	1.66
Cost ($8,000/Acre)	$ 127,000	$ 13,500
Temp ROW (Acres)	7.78	1.36
Cost ($700/Acre)	$ 5,000	$ 1,000
Admin / Court Costs	$ 115,000	$ 15,000
Relocations		
Moorings Removed ($500,000 Each)	0	0
Moorings Moved ($200,000 Each)	1	
Length of Moorings Lost ($500 / LF)	800	800
Relocation Cost	$ 600,000	$ 400,000
RIGHT OF WAY SUBTOTAL	**$ 847,000**	**$ 429,500**
UTITITIES		
Railroad Flaggers ($1,300 / Day)	$ 182,000	$ -
UTILITIES SUBTOTAL	**$ 182,000**	**$ -**

Appendix E. Design Validations

DESIGN VALIDATION NO. 1: USE CABLE STAYED BRIDGE TYPE	Idea No(s) 1, 2, 14, 20

Baseline Concept

The baseline concept is to use a 900-foot steel network tied-arch main span.

Recommendation Concept

The VE team discussed the following ideas to consider the use of a 1200-foot steel composite cable stayed bridge:

- Use lifecycle cost analysis to determine bridge type
- Reassess the anchor piers for cable stay options and improve size.
- Reconsider relative durability associated with concrete deck / overlay maintenance

Advantages	Disadvantages
• Increased navigation opening – lower probability of vessel impacts • More space for fleeting operations (less piers in water) • Reduces number of piers in the water • Reduces need for construction mobilization and demobilization during flood season (fewer piers) • May reduce substructure costs • May reduce maintenance costs • May reduce scour – fewer piers in the water • May reduce construction duration • Life-cycle cost improves complete costing of the bridge • Life-cycle cost improves the selection of the bridge	• May require wind fairings • May require more wind analysis

Cost Summary	Construction	Lifecycle Costs	Total
Baseline Concept	$428,130,000	$5,216,080	$433,346,081
Recommendation Concept	$449,863,668	$5,390,609	$455,254,278
Cost Avoidance/ (Added Value)	$(21,733,668)	$(174,529)	$(21,908,197)

FHWA Function Benefit

Safety	*Operations*	*Environment*	*Construction*	*Right-of-way*

DESIGN VALIDATION NO. 1: USE CABLE STAYED BRIDGE TYPE	**Idea No(s) 1, 2, 14, 20**

Discussion/Sketches/Photos/Calculations

Technical Discussion/Sketches

The overall cost difference, which is the highest-weighted parameter for bridge type selection, between the base concept tied-arch and the 1200-foot steel cable-stayed alternate is approximately 10% of total project cost ($369M / $335= 1.10). This may be a small/negligible difference at this level of design if life cycle costs are not considered.

Recommend adding life-cycle costs to the scoring matrix or replacing capital costs with life-cycle costs in the scoring matrix.

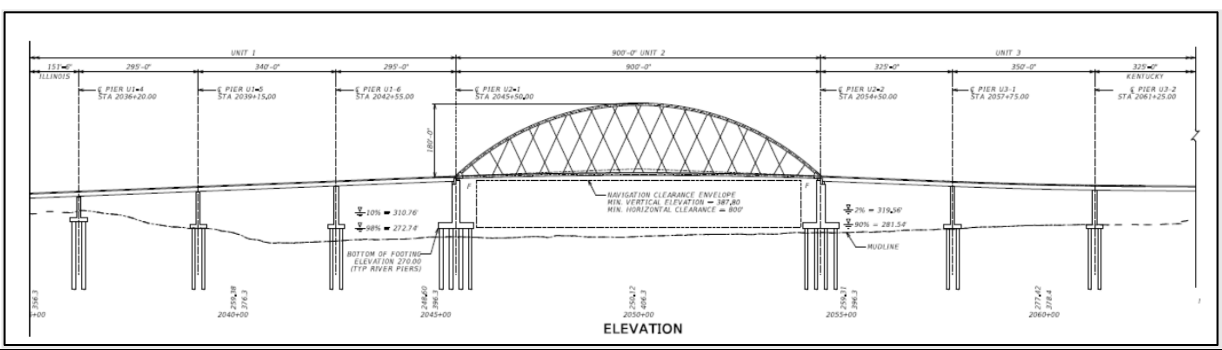
	Approach	Summary			Contingency	Mob/Demob	
	Span Alternative	Substructure Costs	Superstructure Costs	Total Costs	20%	6.50%	**Project Bridge Estimate**
Arch	Long	$ 138,700,000	$ 123,500,000	$ 262,200,000	$ 52,400,000	$ 20,400,000	**$ 335,000,000**
Truss	Short	$ 170,100,000	$ 132,200,000	$ 302,300,000	$ 60,500,000	$ 23,600,000	**$ 386,000,000**
	Medium	$ 159,400,000	$ 141,500,000	$ 300,900,000	$ 60,200,000	$ 23,500,000	**$ 385,000,000**
	Long	$ 131,000,000	$ 152,600,000	$ 283,600,000	$ 56,700,000	$ 22,100,000	**$ 362,000,000**
Steel CS	Medium	$ 206,900,000	$ 99,600,000	$ 306,500,000	$ 61,300,000	$ 23,900,000	**$ 392,000,000**
	Long	$ 175,500,000	$ 113,100,000	$ 288,700,000	$ 57,700,000	$ 22,500,000	**$ 369,000,000**
Concrete CS	Medium	$ 208,500,000	$ 96,100,000	$ 304,600,000	$ 60,900,000	$ 23,800,000	**$ 389,000,000**
	Long	$ 177,100,000	$ 109,600,000	$ 286,700,000	$ 57,300,000	$ 22,400,000	**$ 366,000,000**

<u>Confirm Capital Costs:</u>

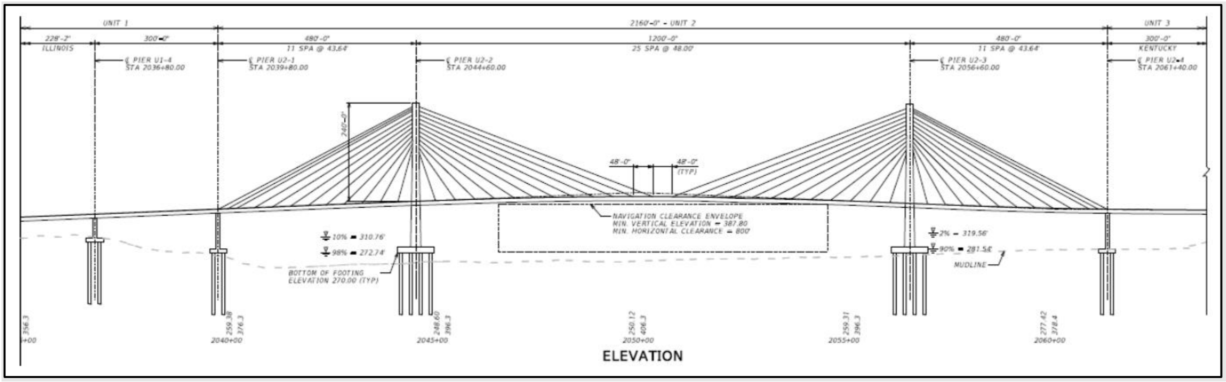
Confirm ground improvement was considered at the anchor pier locations, and re-asses anchor pier foundation sizes if ground improvement was not considered. Revise anchor pier cost estimate if appropriate.

<u>Consider Life-Cycle Costs:</u>

The square footage of steel elements of the cable-stayed bridge is 36% greater than the tied-arch, but exposure of some of the tied-arch components is greater than the cable-stayed bridge (arch ribs, rib bracing, tie-girder), leading to more frequent painting. Also consider a premium for painting access to some of the tied-arch components. The arch ribs and lateral bracing are over traffic and more exposed to wind, compared to the steel floor system of the cable-stayed bridges. Containment systems are more difficult/costly to place over traffic and more difficult/costly to attach in locations with increased wind exposure.



DESIGN VALIDATION NO. 1: USE CABLE STAYED BRIDGE TYPE	Idea No(s) 1, 2, 14, 20



Consider overlay replacement and deck replacement in life cycle costs and reconsider the durability assumptions regarding concrete deck replacement and overlay maintenance for cable-stayed bridges. The baseline tied-arch will have the same overlay maintenance requirements as a cable-stayed bridge, or the tied-arch should recognize replacement costs of the concrete deck at least once during its lifetime. Alternatively, both options should be treated as having the same durability/maintenance for the concrete deck/overlay. Also note the cable-stayed bridge concrete deck, underneath the overlay, should perform better than a tied-arch concrete deck because the cable-stayed concrete deck is in compression. This is qualitative, and difficult to quantify, but the cable-stayed bridge concrete deck will perform better, compared to the tied-arch, as the overlay ages and begins to fail (lower probability for deck replacement than tied-arch). Recommend revising structure comparison matrix to assume same durability (or lower for the cable-stayed) for cable-stayed and tied-arch in addition to recognizing this in life-cycle costs. Currently the discussion in the Main Span Concept Evaluation Memo states that the cable-stayed deck will require more overlay maintenance than the baseline tied-arch.

<u>Other Benefits / Discussion:</u>

The 1200-foot steel cable-stayed bridge will provide a much larger navigation opening and fewer piers in the water. This will result in lower probability of significant (design level) vessel impacts. While this loading may not be controlling over seismic loading, the 1200-foot cable-stayed bridge will be a more resilient structure in this regard, and subject to lower probability of significant repairs associated with vessel impacts.

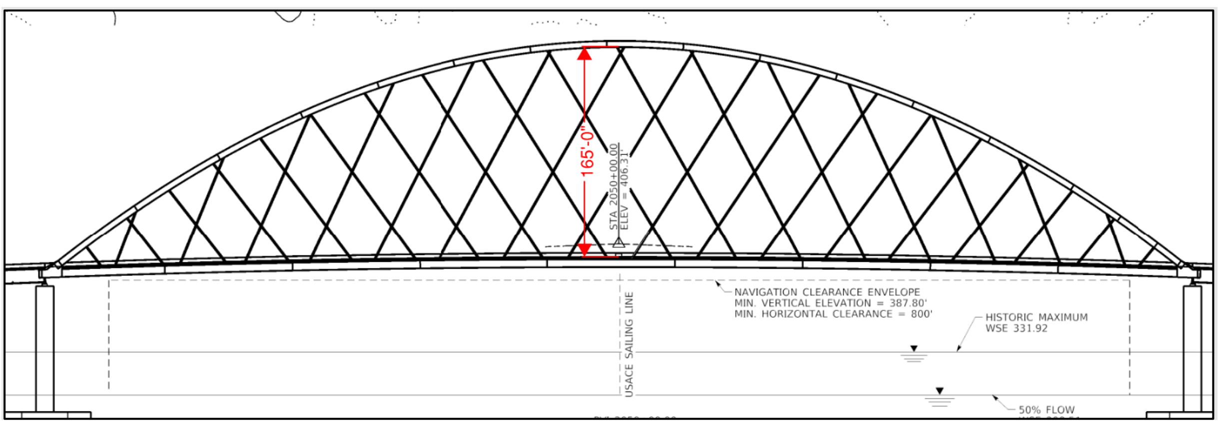
The 1200-foot steel cable-stayed bridge will provide more clear space for the fleeting operations along the banks of the river. This will reduce probability of “nuisance” vessel impacts that do not result in significant structural damage but do result in maintenance costs. While difficult to quantify, this is also a life-cycle maintenance cost difference between the cable-stayed alternate and the baseline tied-arch alternate.

Recommend reconsidering inspectability score in the structure comparison matrix. The baseline tied-arch alternate is approximately 165 feet above deck at the center. Like the cable-stayed alternate, this will require rope access and/or man lifts with very tall reach capacity to inspect cables. These manlifts may not be readily available. Suggest recognizing a smaller difference between these two options in the structure comparison matrix (currently set at 1 for the tied-arch and 3 for the cable-stayed alternate).

DESIGN VALIDATION NO. 1: USE CABLE STAYED BRIDGE TYPE

Idea No(s)
1, 2, 14, 20

		Estimated Construction Cost (millions)				DESIGN RISK	CONSTRUCTION RISK			OWNER RISK				
ALTERNATIVE	MAIN SPAN	Main Span Cost	Approach Span Cost	Units 1-3 Total Cost	60%	EMBANKMENT SPAN FLEXIBILITY	NUMBER WATER PIERS (INCLUDING APPROACHES)	CONSTRUCTION COMPLEXITY	25%	RELATIVE DURABILITY	10%	INSPECTABILITY	5%	Total
A1 - Tied Arch	900'	$100	$94	$194	1.00	No Flexibility	6	Low	1	Medium	2	Low	1	1.10
T1 – 3 Span Truss	450' - 900' - 450'	$168	$65	$233	1.75	No Flexibility	6	Medium-High	2.5	High	1	High	1	1.83
T2 – 5 Span Truss	350' - 665' - 900' - 665' - 350'	$218	$23	$241	2.00	Flexible	4	High	3	High	1	Medium-High	1.5	2.13
CS1 – 1200' Concrete Cable Stayed	480' - 1200' - 480'	$183	$55	$238	2.00	Some Flexibility	4	Medium	2	Medium	2	Low	3	2.05
CS2 – 1500' Steel Cable Staved	600' - 1500' - 600'	$209	$27	$236	2.00	Flexible	3	High	3	Low	3	Low	3	2.40
CS3 – 900' Steel Cable Stayed	360' - 900' - 360'	$147	$65	$212	1.25	No Flexibility	6	Medium-Low	1.5	Low	3	Low	3	1.58
CS4 – 1200' Steel Cable Stayed	480' - 1200' - 480'	$169	$45	$214	1.25	Some Flexibility	4	Medium-Low	1.5	Low	3	Low	3	1.58



The cable-stayed structure may require more wind analysis than the baseline tied-arch, including additional wind tunnel testing. This may also result in recommendations for wind fairings or other bridge shaping recommendations to reduce wind loads and/or eliminate aeroelastic instability. Note an unbraced (compared to braced) tied-arch may also require these items if chosen. The Main Span Concept Evaluation Memo states that the 1500-foot cable-stayed option drew concerns aeroelastic stability concerns due to its width/length ratio. However, this was not stated for the 1200-foot cable-stayed bridge alternate. Recommend the project team do additional desktop modeling (low cost) to vet this concern for the 1200-foot cable-stayed bridge alternate.

DESIGN VALIDATION NO. 1: USE CABLE STAYED BRIDGE TYPE	Idea No(s) 1, 2, 14, 20

Consider scour repair for in-water piers in life-cycle cost estimate. Scour is significant at this bridge location. Consider maintenance repair of scour at each pier in life-cycle costing. The baseline tied-arch alternate has more in-water piers than the 1200-foot steel cable-stayed alternate.

The 1200-foot cable-stayed alternate will have fewer piers. This will reduce the need for construction mobilization and demobilization during flood season (fewer piers). This may decrease schedule, cost of longer construction timeline, and risk-based cost included in a contractor's bid.

Assumptions/Calculations

Assume 1200-foot steel cable stay alternate anchor pier foundations are 30% of foundation costs listed in estimate clip below; or 0.30 x $72M = $21.6M. Assume half of anchor pier foundation costs may be eliminated by re-assessing foundation design and accounting for better soil conditions associated with ground improvement. 0.50 x $21.6M = $10.8M, round down to $10M total for both anchor pier foundations ($5M per anchor pier).

Assume tied-arch rib, rib bracing, and tie girder are painted twice in its lifetime at 35 and 55 years. Assume tied-arch floor system is painted once in its lifetime at 35 years. Assume steel cable-stayed floor system is painted once in its lifetime at 35 years. Painting is assumed to be 19 $/sf of painted surface, based on input from KYTC for bridge painting projects (range of 18 $/sf – 20 $/sf was provided by KYTC). A premium of 1.15 is applied to the tied-arch rib and rib bracing. Assumed painted areas and costs are as follows:

Arch ribs: (6 ft + 3.5 ft) x 2 sides x (230 ft + 110 ft + 135 ft) x 2 halves x 2 ribs x 19 $/sf x 1.15 = $788,785

Arch rib bracing: (6 ft + 3.5 ft) x 2 sides x 46.25 ft long x 10 braces (est) x 19 $/sf x 1.15 = $192,007

Arch tie-girders: (6 ft + 3.75 ft) x 2 sides 900 ft long x 2 ties x 19 $/sf = $669,900

Arch floor beams: (4.25ft + 4.25ft + 2.67ft + 2.67ft +2.67ft) x 2 sides x 46.25ft long x 60 floor beams (est 15-foot spacing) x 19 $/sf = $870,490

Arch stingers: (33/12 ft + 33/12 + 11.5/12 ft + 11.5/12 ft + 11.5/12) x 2 sides x 900 ft long x 5 stringers x 19 $/sf = $716,063

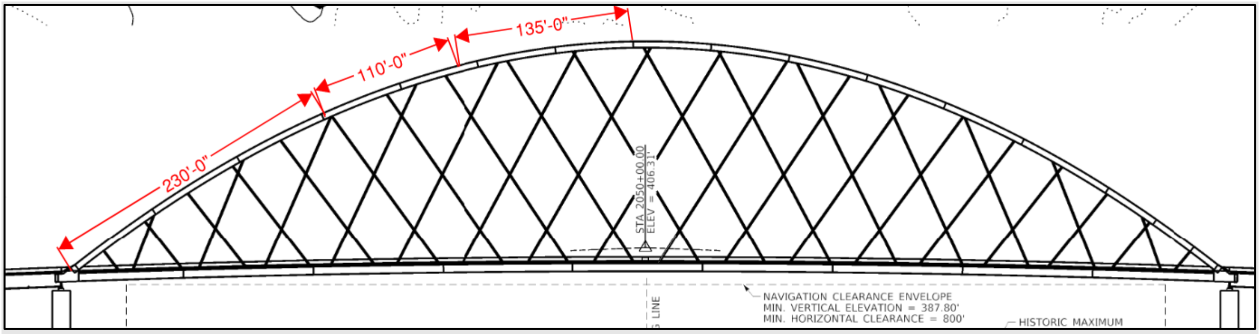
Total Arch Paint = $3,234,244

Cable stay edge girders: (4.5ft + 4.5ft + 1.67ft + 1.67ft + 1.67ft) x 2 x 2160ft long x 2 girders x 19 $/sf = $1,149,120

Cable stay floor beams: (3 ft +3 ft + 2 ft + 2 ft + 2 ft) x 40 ft long x 135 floor beams (spaced at 16ft) x 19 $/sf = $1,231,120

Total Cable Stay Paint = $2,380,320

DESIGN VALIDATION NO. 1: USE CABLE STAYED BRIDGE TYPE	Idea No(s) 1, 2, 14, 20



Assume deck overlay is replaced twice in the life of the steel cable-stayed alternate. Overlay removal / replacement is assumed to be 1700 $/CY, taken from the estimate below. Total cost of one overlay is $603,500 in today's dollars. Assume overlay is removed / replaced at year 35 and year 55.

SUMMARY OF BRIDGE DESIGN DATA

COUNTY	Ballard
ROAD	US 51, Great River Rd
STATUS REPORT ITEM	01-1140.00
STATE PROJECT NO.	none
FEDERAL PROJECT NO.	NHPP BR 0601-204
CROSSING	Ohio River
DESIGNER	Michael Baker International Design Section
DRAWING NO.	XXXXXX
STATION	2039+20
SKEW	0.0 deg
DESIGN LOAD	KY-HL93
ROAD ALIGNMENT	Straight
BRIDGE ROADWAY	40.000 ft.
BRIDGE WIDTH	42.542 ft.
TOTAL LENGTH	2160.000 ft.
DECK AREA	91890.00 ft.^2
BRIDGE TYPE	3 Span Steel Cable Stayed

ABUTS	1	2
ABUT. TYPE	NP	NP
ABUT. HEIGHT	92.4 ft	108.8 ft

COMPARISON of Estimate vs. Final Bid			
Final Plan Total	$175,578,000.00	Contractor UNDER By:	100.0 %
Final Bid Total	$-	$ 175,578,000.00	

SPANS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	480.0 ft	1200.0 ft	480.0 ft												
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

PIERS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Tower	Tower													
	139.2 ft	130.1 ft													
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	

FRAMING	Continuous Edge Girder
MATERIAL	3 Span Steel Cable Stayed
SPECIAL FEATURES	Steel Cable Stay Option, Unit 2

		PRELIMINARY PLANS ESTIMATE						BID	Letting: Unknown			Awarded: Unknown	
Item	Units	Unit Price	Superstructure		Substructure		Bridge	Unit Price	Superstructure		Substructure		Bridge
Concrete Class A	CY	1,650			8233	13,584,483	13,584,483				8233		
Steel Reinforcement	LB	1.70			3851031	6,546,752	6,546,752				3851031		
Steel Reinforcement Epoxy Coated	LB	1.80	779969	1,404,000			1,404,000		779969				
Structural Steel	LB	4.65	7700048	35,805,300			35,805,300		7700048				
Total for Additional Items				19,846,750		98,390,639	118,237,389						
TOTAL COST				57,056,050		118,521,900	175,578,000						
Cost per Deck Area				630		1,290	1,911						

ADDITIONAL ITEMS			PRELIMINARY PLANS ESTIMATE					BID	Letting: Unknown			Awarded: Unknown	
Item	Units	Unit Price	Superstructure		Substructure		Bridge	Unit Price	Superstructure		Substructure		Bridge
Pylon Concrete - High Strength	CY	2350			4603.8	10,818,836	10,818,836				4604		
Pier Foundations	LS	72421803			1	72,421,803	72,421,803				1		
Steel CS Alternate - Barges and Workboats	LS	12650000.00			1.0	12,650,000	12,650,000				1.0		
Trestle	LS	2500000.00			1.0	2,500,000	2,500,000				1.0		
Concrete Overlay - Latex	CY	1700.00	355.0	603,500			603,500		355.0				
Lateral Bumpers	EA	50000.00	4.0	200,000			200,000		4.0				
Bearings	EA	100000.00	8.0	800,000			800,000		8.0				
Cables	LS	11800000.00	1.0	11,800,000			11,800,000		1.0				
Precast Concrete Deck Panels	CY	1800.00	2836.3	5,105,250			5,105,250		2836.3				
Modular Expansion Joint	LF	6000.00	43.0	258,000			258,000		43.0				
Side Mounted Rail Barrier	LF	250.00	4320.0	1080000.00			1,080,000		4320.0				
Total for Additional Items				19,846,750		98,390,639	118,237,389						

Assume baseline tied-arch deck is replaced once in its lifetime. This maintains base concept that an overlay is not maintained on the baseline tied-arch to the same level as a cable-stayed alternate. Deck replacement is assumed to be $2,144,075 in today's dollars per the project estimate below for the baseline tied-arch (1,181,775+468,000+236,300+2*258,000=2,402,075). Assume deck is replaced at year 55. Note this could be expanded to the approach structures since it is assumed that the overlay will be maintained to the same level on the approach structures adjacent to the main span. However, this cost was not accounted for in this recommendation at this time.

DESIGN VALIDATION NO. 1: USE CABLE STAYED BRIDGE TYPE

Idea No(s)
1, 2, 14, 20

BRIDGE TYPE: Single Span Tied Arch — SPECIAL FEATURES: Tied Arch Option, Unit 2

		PRELIMINARY PLANS ESTIMATE						BID	Letting: Unknown			Awarded: Unknown	
Item	Units	Unit Price	Superstructure		Substructure		Bridge	Unit Price	Superstructure		Substructure		Bridge
Concrete Class A	CY	1,650			4404	7,266,039	7,266,039				4404		
Concrete Class AA	CY	1,250	945	1,181,775			1,181,775		945				
Steel Reinforcement	LB	1.70			880732	1,497,244	1,497,244				880732		
Steel Reinforcement Epoxy Coated	LB	1.80	259990	468,000			468,000		259990				
Total for Additional Items				47,999,238		45,778,501	93,777,739						
TOTAL COST				49,649,013		54,541,800	104,190,800						
Cost per Deck Area				1,300		1,430	2,721						

ADDITIONAL ITEMS			PRELIMINARY PLANS ESTIMATE					BID	Letting: Unknown			Awarded: Unknown	
Item	Units	Unit Price	Superstructure		Substructure		Bridge	Unit Price	Superstructure		Substructure		Bridge
Pier Foundations	LS	27278501			1.0	27,278,501	27,278,501				1		
Arch Alternate - Barges and Workboats	LS	11000000			1	11,000,000	11,000,000				1		
Trestle	LS	2500000.00			1.0	2,500,000	2,500,000				1.0		
Contingency Trestle	LS	5000000.00			1.0	5,000,000	5,000,000				1.0		
Concrete Overlay - Latex	CY	1700.00	139.0	236,300			236,300		139.0				
RAIL SYSTEM SINGLE SLOPE - 40 IN	LF	125.00	1800.0	225,000			225,000		1800.0				
Bearings	EA	100000.00	4.0	400,000			400,000		4.0				
Arch Alternate - Network Cables	LS	7220390.00	1.0	7,220,390			7,220,390		1.0				
Arch Alternate - Structural Steel GR70	LB	5.25	6339470.0	33,282,218			33,282,218		6339470.0				
Arch Alternate - Structural Steel GR50	LB	5.00	1275466.0	6,377,330			6,377,330		1275466.0				
Modular Expansion Joint	LF	6000.00	43.0	258,000			258,000		43.0				
Total for Additional Items				47,999,238		45,778,501	93,777,739						

TA Unit 2 Closeout - 20230217_REV1.xlsm 3/25/20 Zoom TC 66-101 (Bridge Est.)

The cost of additional desktop study by the wind consultant (RWDI) is assumed to be $6,000. This is based on recent estimates for similar work on cable-stayed bridge by RWDI.

DESIGN VALIDATION NO. 1: USE CABLE STAYED BRIDGE TYPE

Idea No(s) 1, 2, 14, 20

VE Study Life-Cycle Costs Calculations

US 51 Bridge over Ohio River Replacement

		Baseline Concept			VE Recommended Concept		
Component	**Unit**	**Quantity**	**Cost/Unit**	**Total**	**Quantity**	**Cost/Unit**	**Total**
Arch bridge	LS	1	$ 335,000,000.00	$ 335,000,000		$ 335,000,000.00	$ -
Steel Cable Stay	LS		$ 362,000,000.00	$ -	1	$ 362,000,000.00	$ 362,000,000
Oversized Anchor Pier	LS		$ 10,000,000.00	$ -	-1	$ 10,000,000.00	$ (10,000,000)
Cable Stay Aeroelastic Desktop Study	LS	0		$ -	1	$ 6,000.00	$ 6,000
				$ -	1	$ -	$ -
Subtotal Construction				$ 335,000,000			$ 352,006,000
Mark-Up (MOT, Mob., PE, CEI)	28%			$ 93,130,000			$ 97,857,668
Total Construction				**$ 428,130,000**			**$ 449,863,668**
Utility Costs				$ -		$ -	$ -
Right of Way Costs				$ -		$ -	$ -
TOTAL CAPITAL COST				**$ 428,130,000**			**$ 449,863,668**
COST CAPITAL SAVINGS / (VALUE ADDED)							**$ (21,733,668)**

Life Cycle Cost Analysis

				Baseline Concept	**Alternative Concept**
Life Cycle Period	75 Years				
Discount Rate	3.6% https://www.whitehouse.gov/wp-content/uploads/2018/12/M-19-05.pdf				
A. Initial Costs				$ 428,130,000	$ 449,863,668
B. Annual Costs	**Total Capital Cost Savings / (Value Added)**				**$ (21,733,668.00)**
1. Annual Maintenance:	Inspections			$ 50,000	$ 60,000
2. Annual Energy:					
3. Other:					
	Total Annual Costs:			$ 50,000	$ 60,000
	Present Value Factor (P/A):			73.9834	73.9834
	Present Value of Annual Costs:			$ 3,699,171	$ 4,439,005
C. Single Future Expenditures	**Amount**	**Year**	**PV Factor**	**Present Value**	**Present Value**
Arch Repainting Rbs, Tie Girder, Rib Bracing - 1st cycle	$ 1,647,699.00	35	0.2900	$ 477,844	
Cable Stay Repainting - 1st cycle	$ 2,380,320.00	35	0.2900		$ 690,310
Arch Repainting Floorbeams, Stringers - 1st cycle	$ 1,586,552.00	35	0.2900	$ 460,111	
Cable Stay Overlay Replacement - 1st cycle	$ 603,500.00	35	0.2900		$ 175,019
Arch Repainting Rbs, Tie Girder, Rib Bracing - 2nd cycle	$ 1,647,699.00	55	0.1430	$ 235,554	
Cable Stay Overlay Replacement - 2nd cycle	$ 603,500.00	55	0.1430		$ 86,276
Arch Concrete Deck replacement - 1st cycle	$ 2,402,075.00	55	0.1430	$ 343,400	
			1.0000		$ -
Residual Value		40	0.2430	$ -	$ -
	Present Value of Future Single Expenditures and Residual Value:			$ 1,516,910	$ 951,605
D. TOTAL PRESENT VALUE COST (A+B+C)				$ 433,346,081	$ 455,254,278
TOTAL LIFE CYCLE SAVINGS / (VALUE ADDED):					$ (21,908,197)

After the above analysis with listed assumptions, it is concluded that it is a fair assessment that the tied-arch will rate more favorably on the evaluation matrix than the cable stayed bridge.

DESIGN VALIDATION NO. 2: REVIEW & UPDATE SEISMIC ASSUMPTIONS	Idea No. 6

Baseline Concept

The baseline concept is to employ a Performance-based Seismic Design with two level design; FEE = 500 year-return-period and SEE = 1,000 year-return-period.

Recommendation Concept

Review seismic assumptions and use of seismic standards (reduce requirements)

Advantages	Disadvantages
May reduce foundation costs May improve overall design and performance	None discussed

Cost Summary	Construction	Right-of-way	Total
Baseline Concept	$0	$0	$0
Recommendation Concept	$0	$0	$0
Cost Avoidance/ (Added Value)	$0	$0	$0

FHWA Function Benefit

Safety	*Operations*	*Environment*	*Construction*	*Right-of-way*
			✓	

DESIGN VALIDATION NO. 2: REVIEW & UPDATE SEISMIC ASSUMPTIONS	Idea No. 6

Discussion/Sketches/Photos/Calculations

Technical Discussion/Sketches

Reviewed the proposed seismic design criteria to investigate ways to reduce costs. No reduction in costs found.

A performance-based seismic design with two-level (SEE and FEE) design is proposed. The bridge is considered "essential" about seismic performance. This is the highest level of seismic performance and is anticipated to result in a structure that will facilitate immediate use by emergency vehicles post upper-level design earthquake (SEE), as shown in the following clip from the AASHTO LRFD Bridge Design Specifications, 9th Edition.

1.3.5—Operational Importance

The Owner may declare a bridge or any structural component and connection thereof to be of operational priority.

C1.3.5

Such classification should be done by personnel responsible for the affected transportation network and knowledgeable of its operational needs. The definition of operational priority may differ from Owner to Owner and network to network. Guidelines for classifying critical or essential bridges are as follows:

- Bridges that are required to be open to all traffic once inspected after the design event and be usable by emergency vehicles and for security, defense, economic, or secondary life safety purposes immediately after the design event.
- Bridges that should, as a minimum, be open to emergency vehicles and for security, defense, or economic purposes after the design event, and open to all traffic within days after that event.

Seismic design of critical/essential bridges is not currently within the scope of the scope of the AASHTO LRFD Bridge Design Specifications and/or the AASHTO Guide Specifications for Seismic design.

The proposed SEE = 1,000 year-return-period

The proposed FEE = 500-year-return-period

Assumptions/Calculations

A performance-based seismic design criteria is appropriate for bridges classified as essential bridges, as the scope of these bridges is not currently covered by the AASHTO LRFD Bridge Design Specifications and/or the AASHTO Guide Specifications for Seismic design.

The proposed SEE return period is consistent with AASHTO, and the proposed FEE return period is reasonable and not expected to control the design.

Overall conclusion is that the proposed seismic design criteria is reasonable, thus validating the current design.

Appendix F. Closing Presentation

VALUE ENGINEERING STUDY

US 51 Bridge Replacement over the Ohio River
Wickliffe, Kentucky to Cairo, Illinois

KYTC Item No. 01-1140.00

May 19, May 22-26, 2023

SAFETY FIRST

- ✓ Emergency exits
- ✓ Meeting point
- ✓ CPR
- ✓ The number for "911"
- ✓ Tornado?

VE TEAM

Katy R Stewart (KYTC)

Anthony Messmer (HDR)

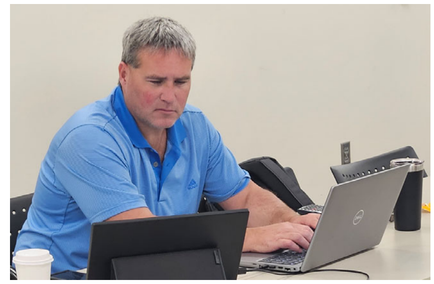
Brian Keaney (HDR)

Christopher Johnson (HDR)

Jonathan Guess (HDR)

Jose Theiler (HDR)

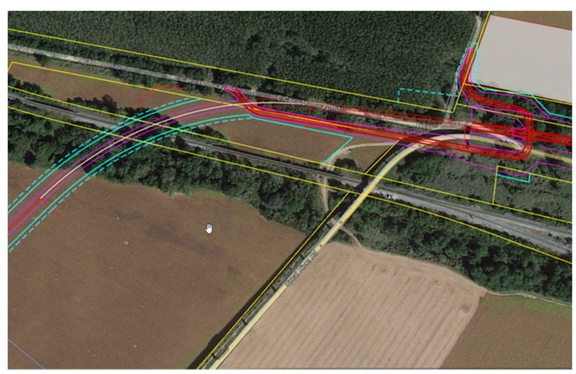
Raheel Malik (HDR)

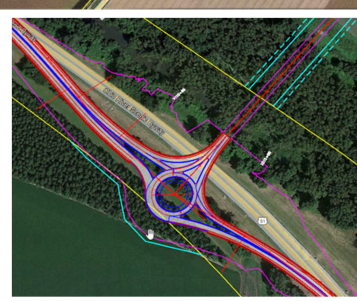


PROJECT INFORMATION

- Improve cross river mobility
- Improve safety
  - Address narrow lane widths
  - Widen shoulders
  - Improve geometry
  - Accommodate truck traffic
  - Accommodate bicycle

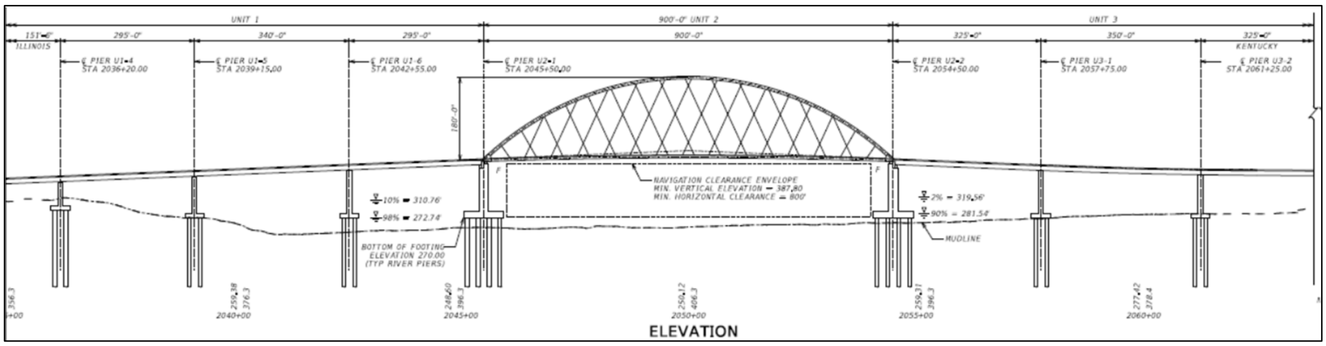
- 980 feet upstream of the existing bridge
- Project length: 1.94 miles





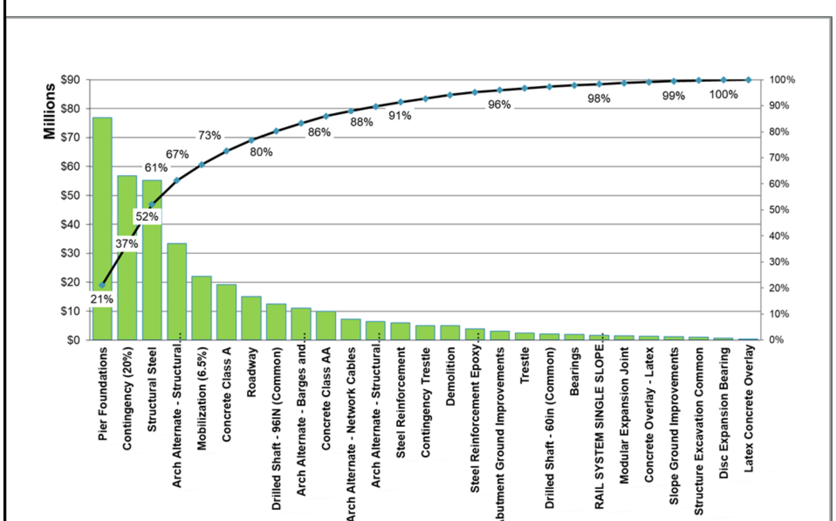
PROJECT INFORMATION

Arch Bridge Concept

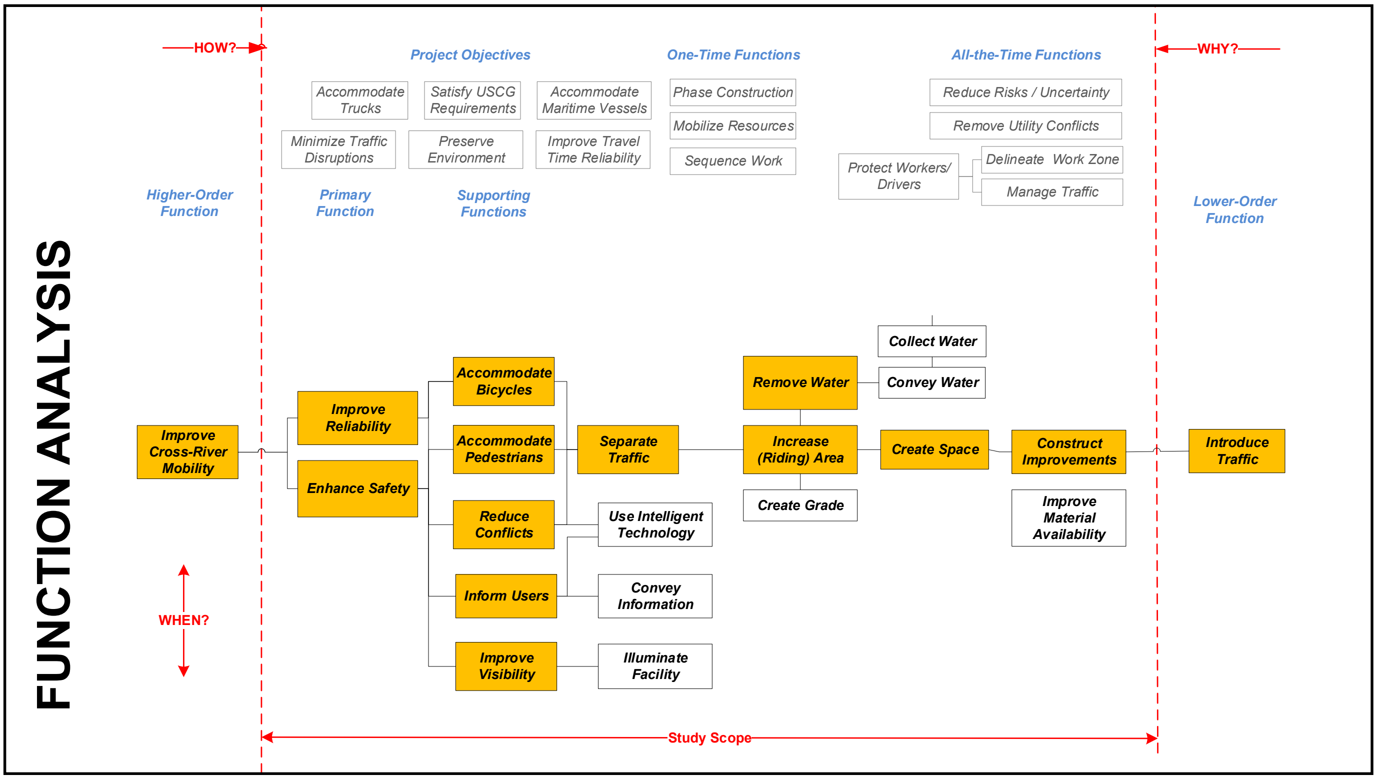


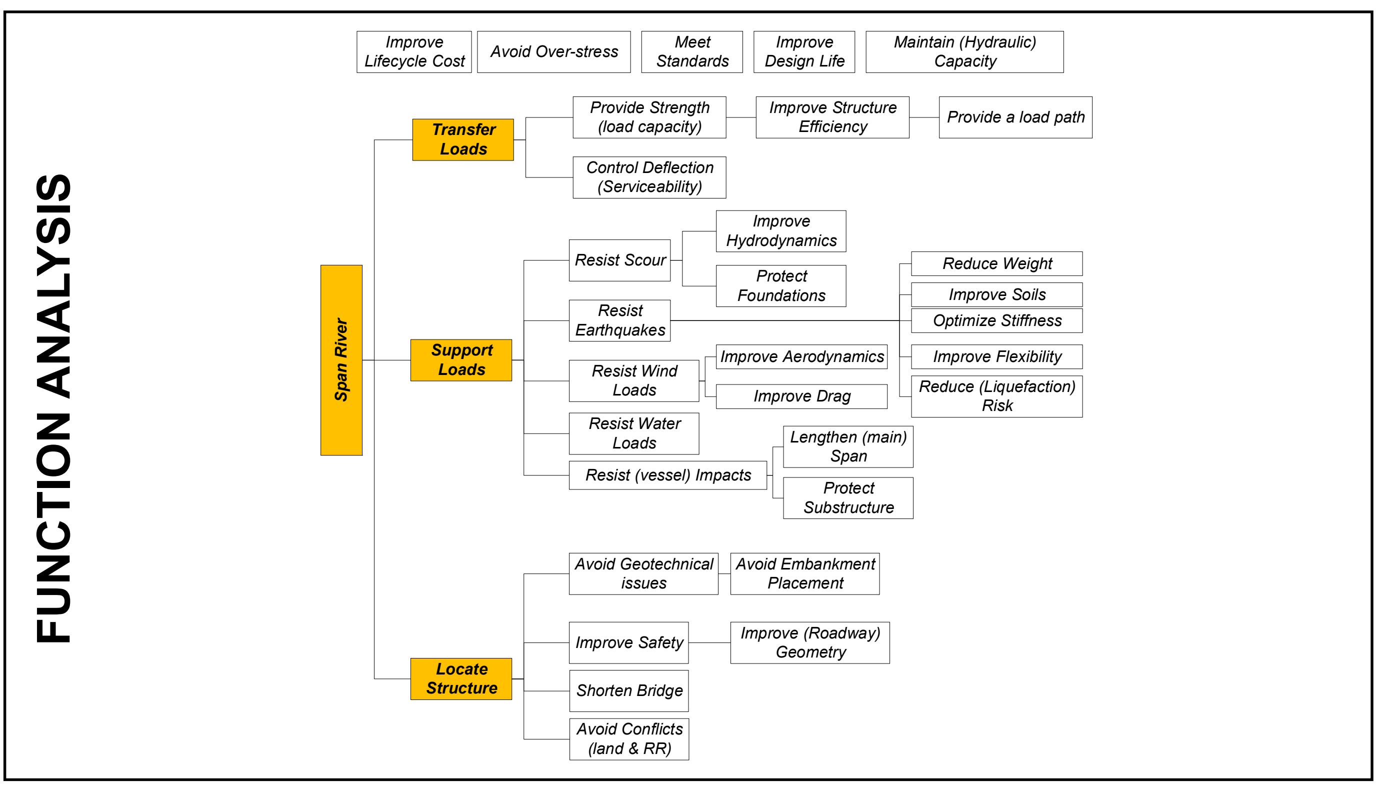
- Length of complex bridge – 900’
- Navigation clear span length – 822’
- Side span length – 300’
- Number of piers – 6
- Recommended pier type – Pipe Piles
- Costs - $362M

COST MODEL

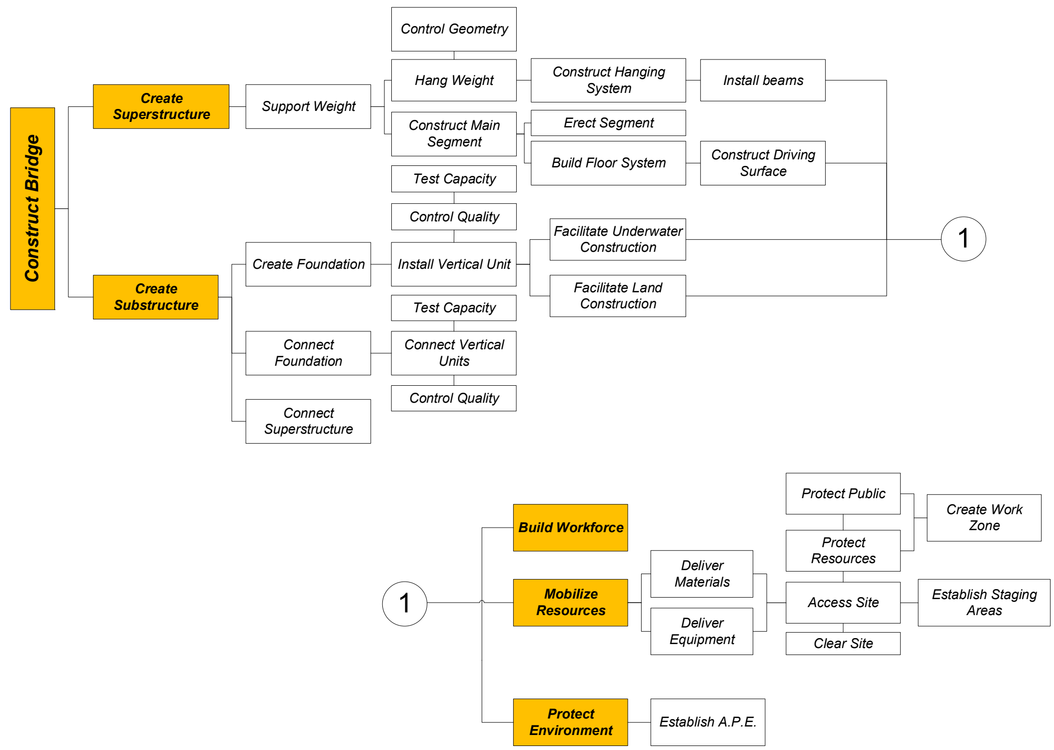


Description	Amount	
Pier Foundations	$	76,806,121.00
Contingency (20%)	$	56,712,480.00
Structural Steel	$	55,146,600.00
Arch Alternate - Structural Steel GR70	$	33,282,218.00
Mobilization (6.5%)	$	22,117,867.20
Concrete Class A	$	19,126,995.00
Roadway	$	15,000,000.00
Drilled Shaft - 96IN (Common)	$	12,432,000.00
Arch Alternate - Barges and Workboats	$	11,000,000.00
Concrete Class AA	$	9,867,638.00
Arch Alternate - Network Cables	$	7,220,390.00
Arch Alternate - Structural Steel GR50	$	6,377,330.00
Steel Reinforcement	$	5,976,536.00
Contingency Trestle	$	5,000,000.00
Demolition	$	5,000,000.00
Steel Reinforcement Epoxy Coated	$	3,907,600.00
Abutment Ground Improvements	$	3,000,000.00
Trestle	$	2,500,000.00
Drilled Shaft - 60in (Common)	$	2,106,000.00
Bearings	$	2,000,000.00
RAIL SYSTEM SINGLE SLOPE - 40 IN	$	1,608,418.00
Modular Expansion Joint	$	1,545,000.00
Concrete Overlay - Latex	$	1,364,590.00
Slope Ground Improvements	$	1,200,000.00
Structure Excavation Common	$	921,600.00
Disc Expansion Bearing	$	750,000.00
Latex Concrete Overlay	$	423,300.00
Total Cost	**$**	**362,392,683**


FUNCTION ANALYSIS
HOW?
WHY?
WHEN?
Project Objectives
One-Time Functions
All-the-Time Functions
Accommodate Trucks
Satisfy USCG Requirements
Accommodate Maritime Vessels
Minimize Traffic Disruptions
Preserve Environment
Improve Travel Time Reliability
Phase Construction
Mobilize Resources
Sequence Work
Reduce Risks / Uncertainty
Remove Utility Conflicts
Protect Workers/ Drivers
Delineate Work Zone
Manage Traffic
Higher-Order Function
Primary Function
Supporting Functions
Lower-Order Function
Improve Cross-River Mobility
Improve Reliability
Enhance Safety
Accommodate Bicycles
Accommodate Pedestrians
Reduce Conflicts
Inform Users
Improve Visibility
Separate Traffic
Use Intelligent Technology
Convey Information
Illuminate Facility
Remove Water
Collect Water
Convey Water
Increase (Riding) Area
Create Grade
Create Space
Construct Improvements
Improve Material Availability
Introduce Traffic
Study Scope


FUNCTION ANALYSIS
Improve Lifecycle Cost
Avoid Over-stress
Meet Standards
Improve Design Life
Maintain (Hydraulic) Capacity
Span River
Transfer Loads
Provide Strength (load capacity)
Improve Structure Efficiency
Provide a load path
Control Deflection (Serviceability)
Support Loads
Resist Scour
Improve Hydrodynamics
Protect Foundations
Resist Earthquakes
Reduce Weight
Improve Soils
Optimize Stiffness
Improve Flexibility
Reduce (Liquefaction) Risk
Resist Wind Loads
Improve Aerodynamics
Improve Drag
Resist Water Loads
Resist (vessel) Impacts
Lengthen (main) Span
Protect Substructure
Locate Structure
Avoid Geotechnical issues
Avoid Embankment Placement
Improve Safety
Improve (Roadway) Geometry
Shorten Bridge
Avoid Conflicts (land & RR)

FUNCTION ANALYSIS



OBJECTIVE OF THE VE STUDY

The objective of the VE team is to **VALIDATE or IMPROVE** on the various concepts for the **US 51 Bridge Replacement over the Ohio River** project**,** through the application of the VE job plan.

$$Value = \frac{Performance}{Cost}$$

EVALUATION PROCESS – TIER 1

Function: Mobilize Resources					
23	Deliver and remove material using the RR. Build temporary spur.	• Provides a means of access • May improve schedule duration • Reduces contractor risks • Provides means to remove materials (demo)	• RR agreement • Means and methods	*3*	Move forward to Development Phase

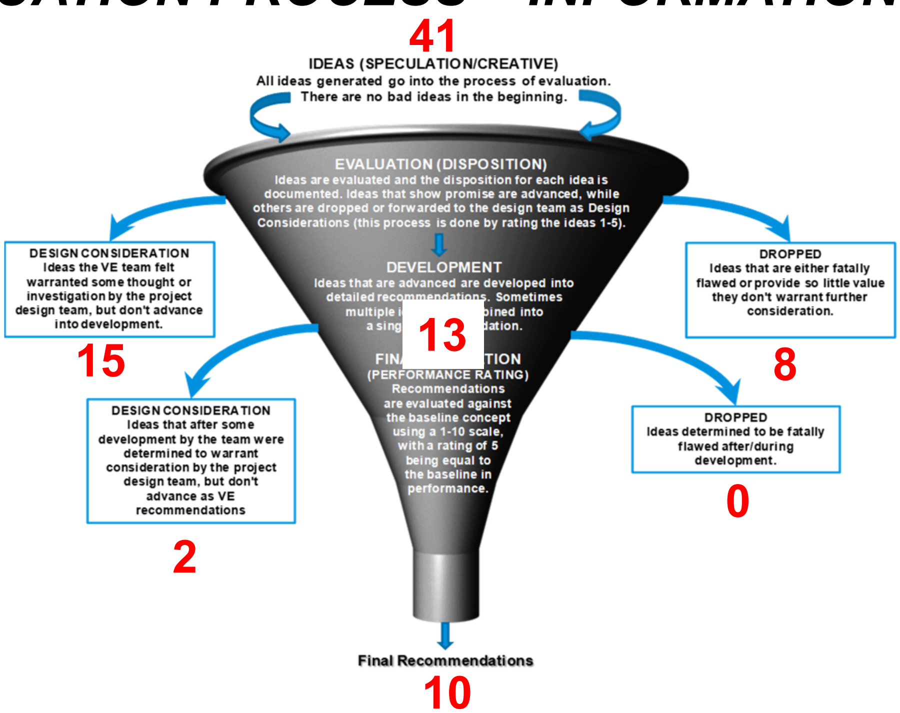
0-Unacceptable Impact / Fatal Flaw

1-Poor Opportunity

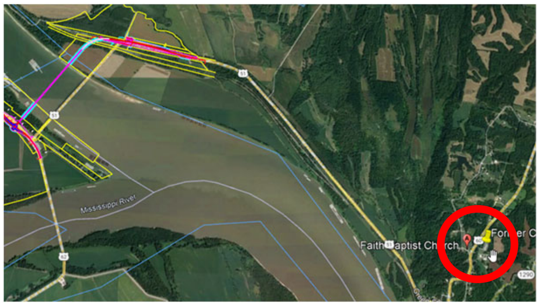
2-Good idea for design team to pursue

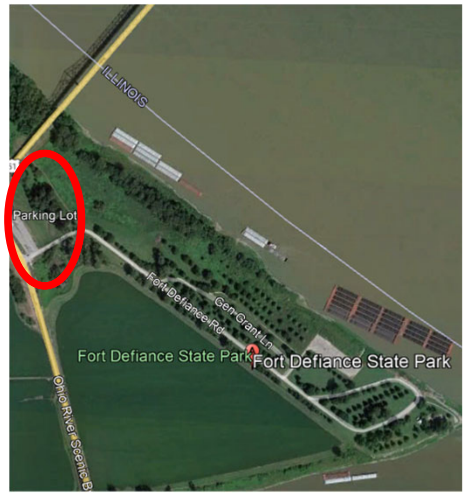
3-Good Opportunity

EVALUATION PROCESS – INFORMATION FLOW



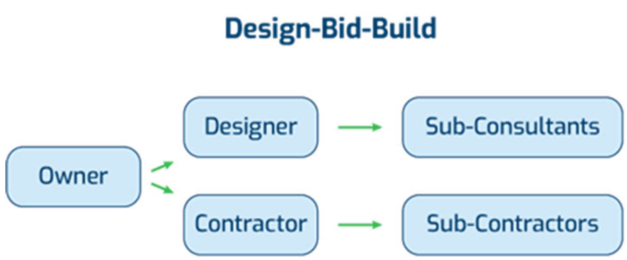
FACILITATE STAGING LOCATIONS





Recommendation

USE INNOVATIVE DELIVERY METHOD (D/B OR PDB/CMAR)



Owner must manage two separate contracts: owner becomes Middleman, settling disputes between the designer and the contractor. Designer and contractor can easily blame one another for cost overruns and other problems.

Baseline

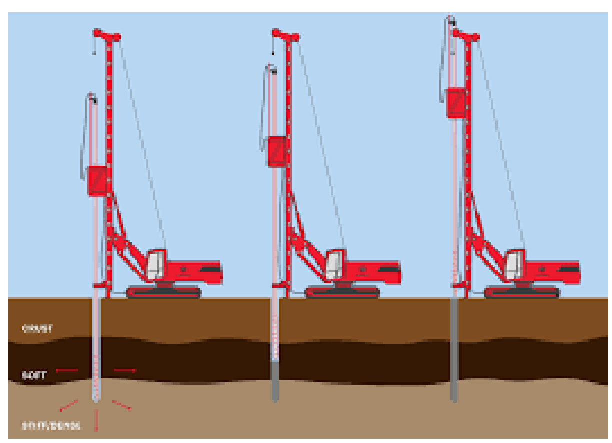
USE INNOVATIVE DELIVERY METHOD (D/B OR PDB/CMAR)

Design-Build Project Delivery

Owner manages only one contract with a single point of responsibility; designer and contractor are on the same team, providing unified recommendations. Changes are addressed by design-build entity, not used as excuses.

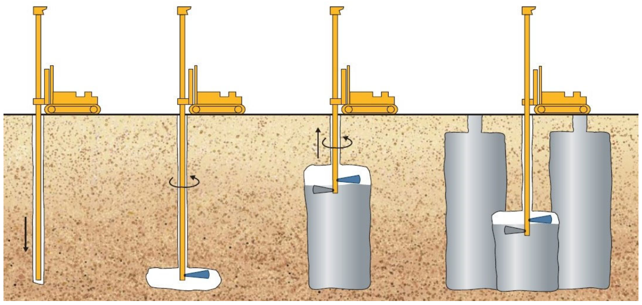
Recommendation

USE SOIL IMPROVEMENTS TECHNIQUES



Baseline

USE SOIL IMPROVEMENTS TECHNIQUES



Recommendation

PRE-DESIGN BY LOAD TESTING

Baseline

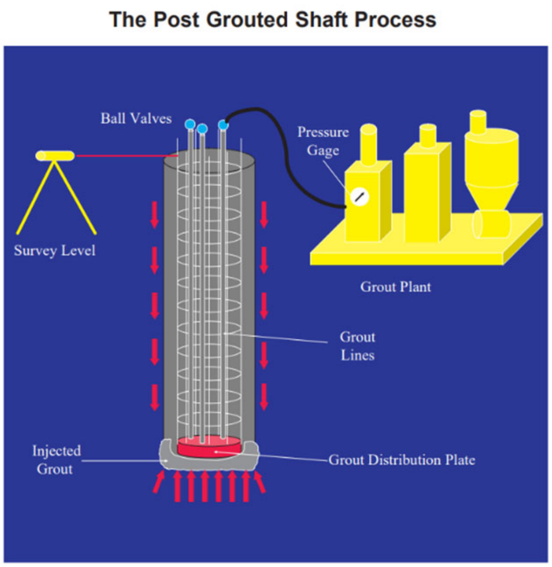
PRE-DESIGN BY LOAD TESTING

Recommendation

INCREASE END BEARING RESISTANCE OF FOUNDATIONS

Baseline

INCREASE END BEARING RESISTANCE OF FOUNDATIONS



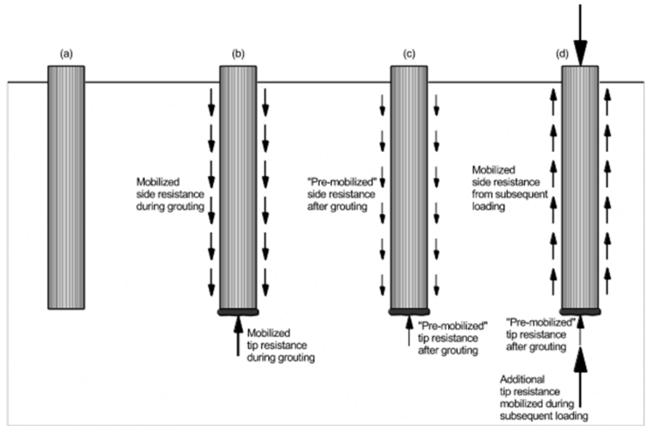
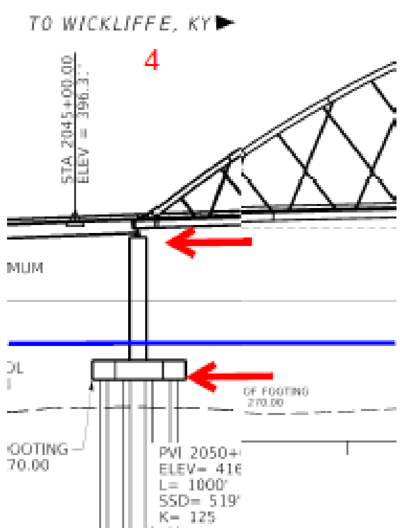


Figure 2.1: Schematic illustrating mobilization of resistance for PGDS: (a) constructed drilled shaft prior to post-grouting; (b) grouting at the shaft tip mobilizes negative side resistance and positive tip resistance; (c) mobilized resistance following post-grouting, including any relaxation of mobilized load that may occur following grouting; and (d) top-down loading reverses side resistance and mobilizes remaining tip resistance (adapted from Brown et al., 2010).

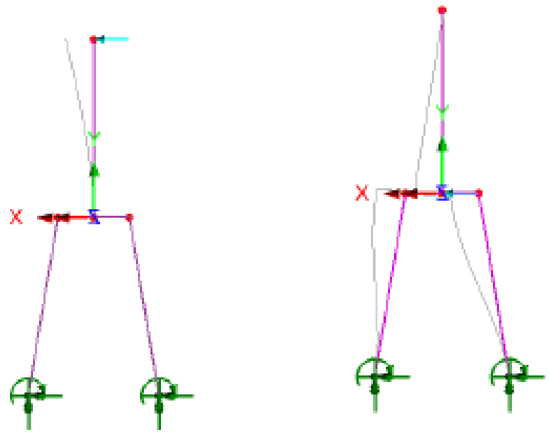
Recommendation

USE ISOLATION BEARINGS WITH BATTER PILES



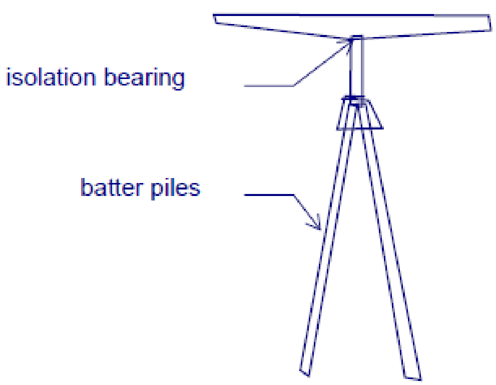
Baseline

USE ISOLATION BEARINGS WITH BATTER PILES



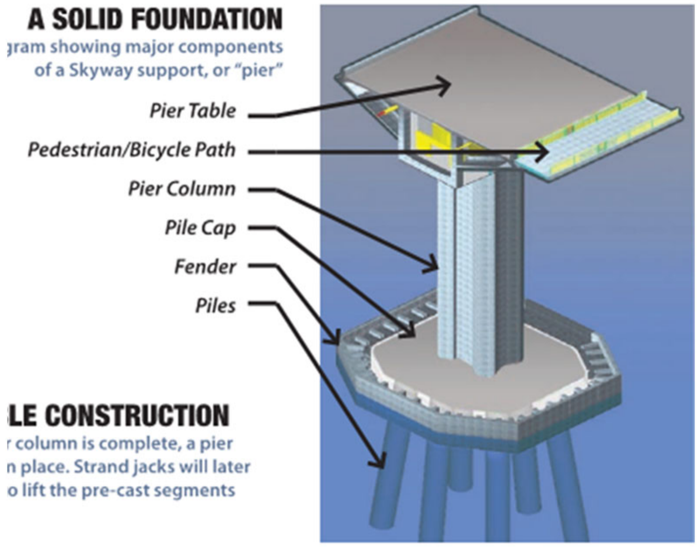
Recommendation

USE ISOLATION BEARINGS WITH BATTER PILES



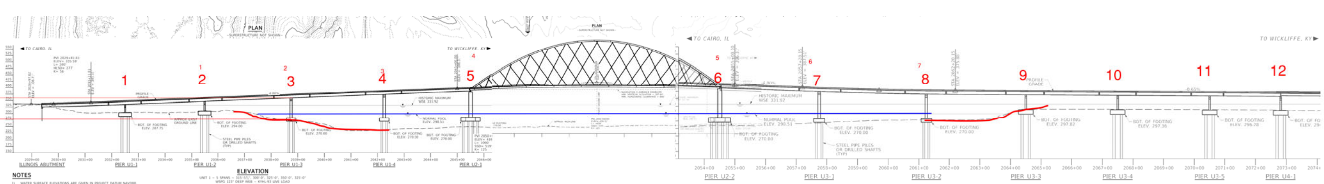
Recommendation

USE ISOLATION BEARINGS WITH BATTER PILES



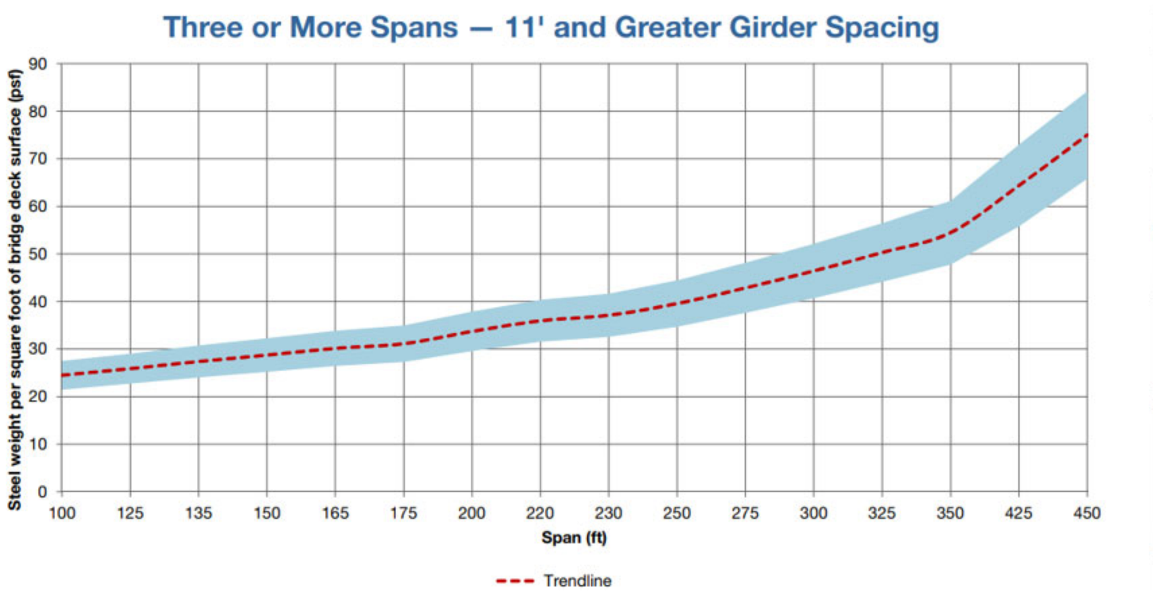
Recommendation

INCREASE APPROACH SPAN LENGTH



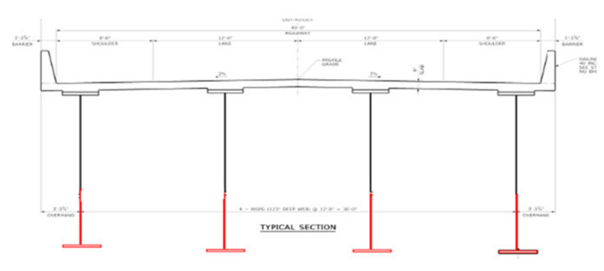
Baseline

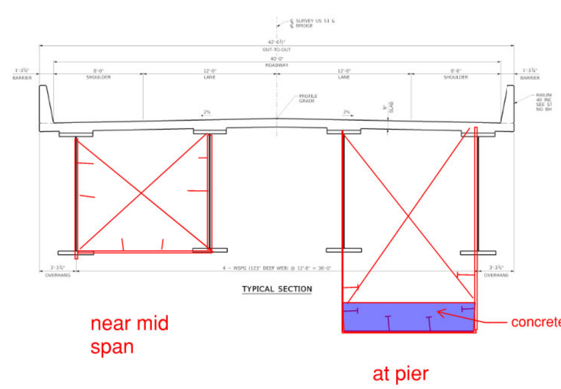
INCREASE APPROACH SPAN LENGTH



Recommendation

INCREASE APPROACH SPAN LENGTH





Recommendation

INCREASE APPROACH SPAN LENGTH

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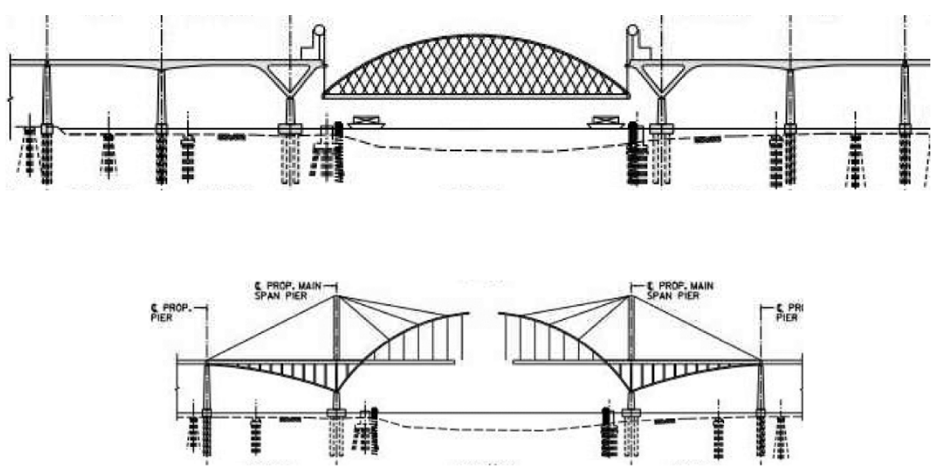
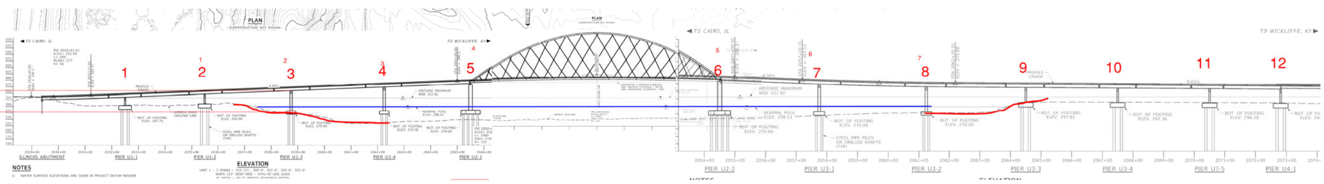
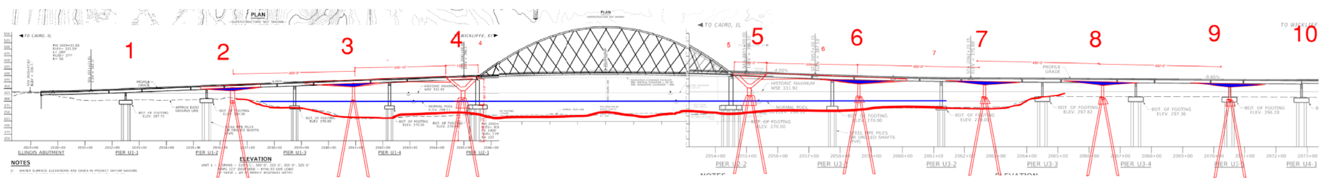


Recommendation

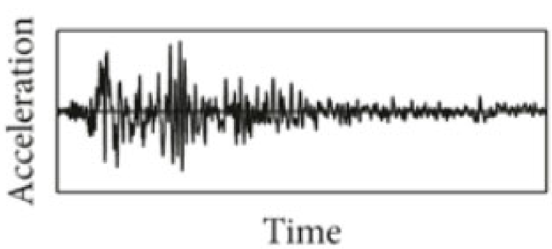
INCREASE APPROACH SPAN LENGTH





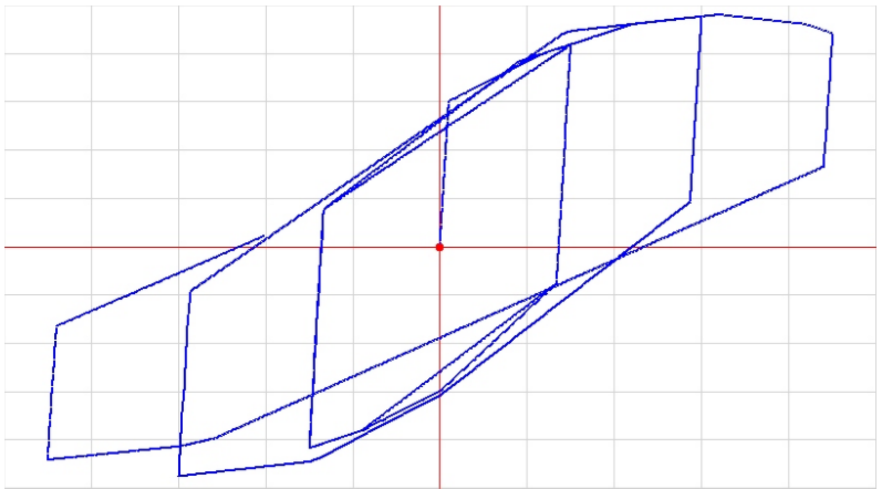
Recommendation

CONDUCT A NON-LINEAR TIME HISTORY ANALYSIS



Baseline

CONDUCT A NON-LINEAR TIME HISTORY ANALYSIS



Recommendation

USE CONCRETE PAVEMENT

Baseline

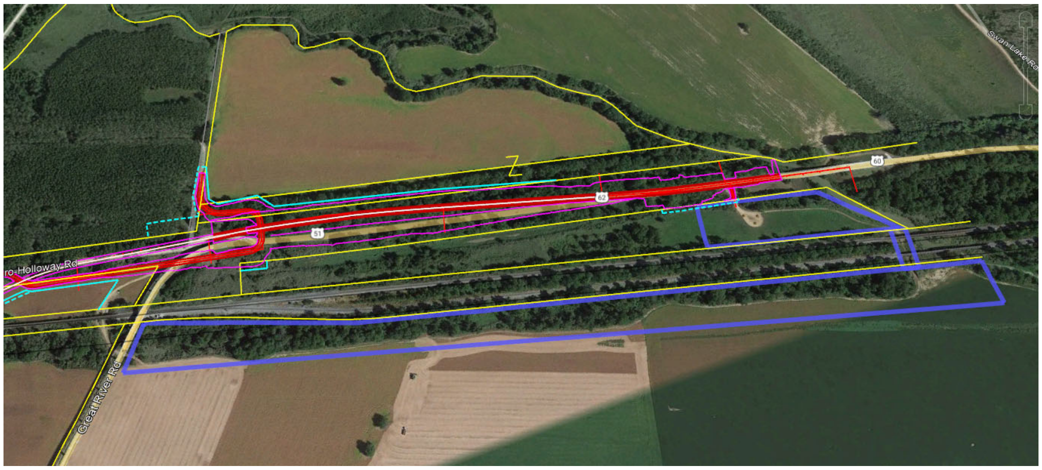
USE CONCRETE PAVEMENT

Recommendation

DELIVER AND REMOVE MATERIAL BY RAIL - BUILD A TEMP SPUR

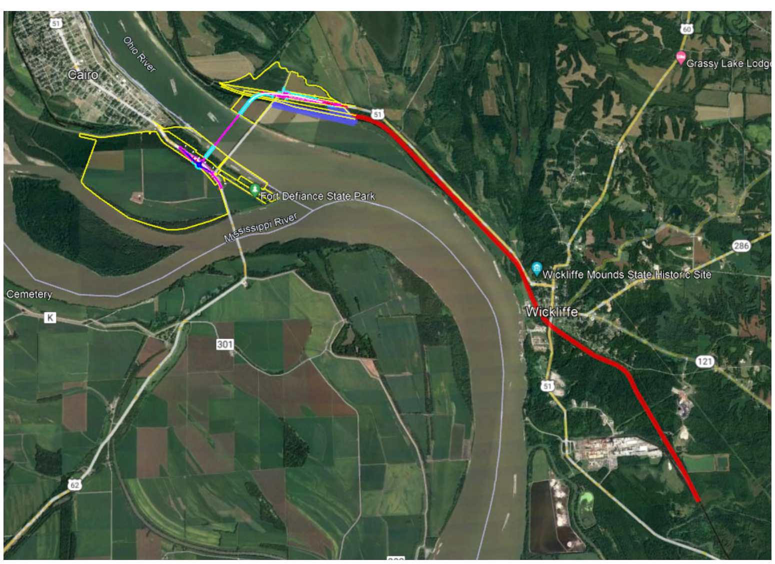
Baseline

DELIVER AND REMOVE MATERIAL BY RAIL - BUILD A TEMP SPUR



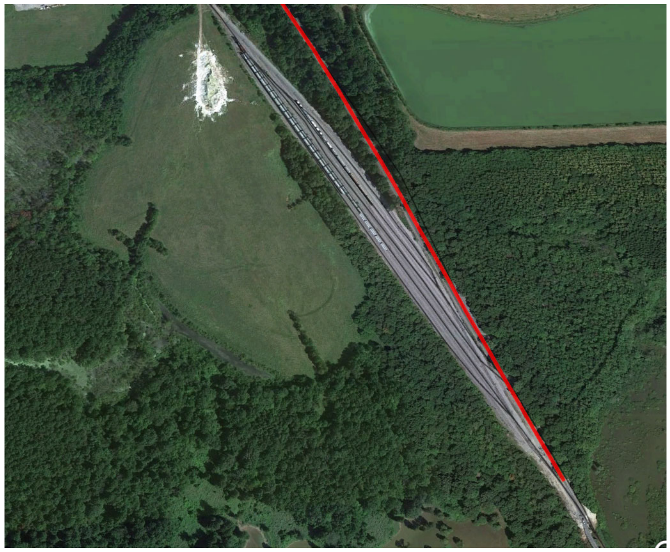
Recommendation

DELIVER AND REMOVE MATERIAL BY RAIL - BUILD A TEMP SPUR



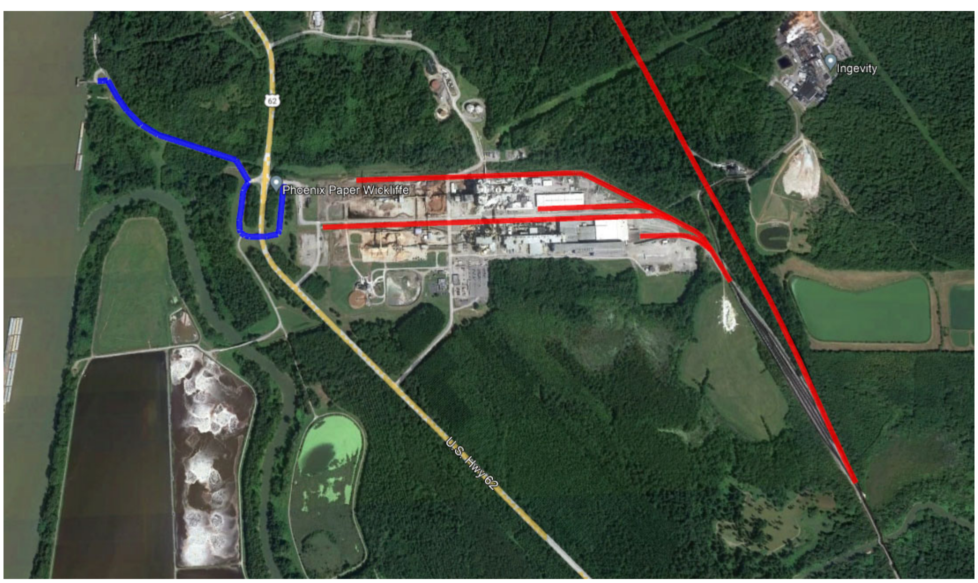
Recommendation

DELIVER AND REMOVE MATERIAL BY RAIL - BUILD A TEMP SPUR



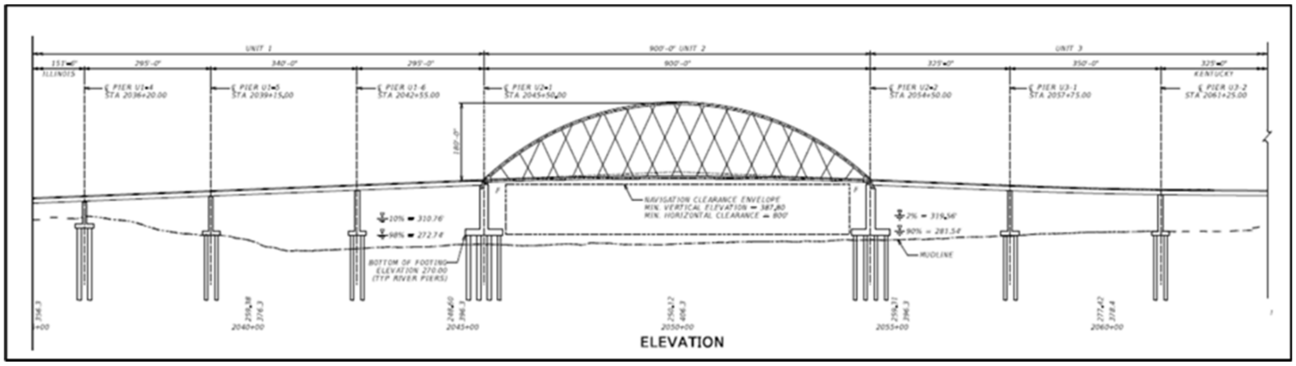
Recommendation

DELIVER AND REMOVE MATERIAL BY RAIL - BUILD A TEMP SPUR



Recommendation

USE CABLE STAYED BRIDGE TYPE



Design Validation

DESIGN CONSIDERATIONS

Idea #	Idea Description
5	Advance geotechnical investigations
8	Use friction reducers in the pile to reduce drag forces
13	Create a temporary structure to access river piers and construct from trestle structure
16	Use mixed type materials (Steel and Concrete) for areas as applicable
18	Use larger pile diameters
24	Create a SUP for pedestrians and bicyclist
29	Improve structure to account for tornado wind speeds

DESIGN CONSIDERATIONS

Idea #	Idea Description
30	Shaping the towers more aerodynamically; edge beam shape or wind fairing
31	Install markers to footers in the navigational channels (perch footers)
32	Place the pile cap lower using a mudline footing
35	Add incentives for early completions
37	Use ITS to convey bridge conditions
38	Use DMS Sign to communicate bridge conditions
39	Install lighting throughout the bridge facility
41	Develop a cost loaded 4D schedule analysis to determine the best combination of piers / spans

DESIGN CONSIDERATIONS TIER 2

Value engineering has traditionally been perceived as an effective means for reducing project costs.

This paradigm only addresses one part of the value equation, oftentimes at the expense of overlooking the role that VE can play regarding improving project performance.

Performance-based VE

$$Value = \frac{Worth}{Cost} = \frac{Performance}{Cost}$$

PERFORMANCE ATTRIBUTES – PAIRED COMPARISON

Paired Comparison							Total points	% of Total
Risk	A	A	A	A	A		6.0	30%
Maintainability		B	B/C	B/D	B		4.0	20%
Construction Impacts			C	C	C		4.5	23%
Environmental Impacts				D	D		3.5	18%
Project Schedule					E		2.0	10%
						Total	20.0	100%

Performance Attributes – Paired Comparison

$$Value = \frac{Worth}{Cost} = \frac{Performance}{Cost}$$

VE RECOMMENDATION NO. 1	IDEA NO.		
UTILIZE TURBINE INTERCHANGE			
PERFORMANCE MEASURES Attributes and Rating Rationale for Recommendation	*Performance*	*Baseline*	*Recommendation*
Main Line Operations Improves system vs service movements Increase ramp speed Increase throughput at ramps Lowers sawgrass through operational speed Provides all movements at interchange	*Rating*	5	7
	Weight	28.5	
	Contribution	142.5	199.5
Local Operations No Change	*Rating*	5	5
	Weight	23.8	
	Contribution	119	119
Maintainability More bridges to maintain Higher bridges to increase complex inspection	*Rating*	5	4
	Weight	19.0	
	Contribution	95	76
Construction Impacts Eliminates the Punch Through Pile driving closer to home Increase overnight detours and closures	*Rating*	5	4.5
	Weight	7.1	
	Contribution	35.5	32
Environmental Impacts Reducing the Quite Waters Park ROW and ENV impact May increase noise by bringing traffic closer to neighborhoods Improves all connections satisfying stakeholder wishes	*Rating*	5	6.72
	Weight	14.2	
	Contribution	71	95.4
Project Schedule No Change	*Rating*	5	5
	Weight	7.1	
	Contribution	35.5	35.5
	Total Performance	499	557
	Net Change in Performance		12%

Summary

	Recommendations	Performance (P)	% Change Performance	Cost (C) $ millions	Cost Change $ millions	% Change Cost	Value Index	% Value Improvement
	Baseline	500	---	$288.2	---	---	1.70	---
1	Facilitate Work Zone Locations	505	+1.0%	$288.3	$0.08	+0.0%	1.75	+3%
2	Use Soil Improvements Techniques	605	+21.0%	$297.6	$9.35	+3.2%	2.03	+19%
3	Conduct a Non-linear Time History Analysis	595	+19.0%	$289.9	$1.70	+0.6%	2.05	+21%
4	Pre-design by Load Testing	580	+16.0%	$280.7	($7.57)	-2.6%	2.07	+22%
5	Use Concrete-filled Steel Pipe Piles	539	+7.9%	$288.2	$0.00	0.0%	1.87	+10%
6	Use Isolation Bearings with Batter Piles	515	+3.0%	$276.8	($11.39)	-4.0%	1.86	+9%
7	Use Innovative Delivery Method (D/B)	515	+3.0%	$275.1	($13.18)	-4.6%	1.87	+10%
8	Deliver and Remove Material by Rail - Build a Temp Spur	555	+11.0%	$288.2	$0.00	0.0%	1.93	+14%
9	Use Concrete Pavement	528	+5.5%	$283.6	($4.67)	-1.6%	1.86	+9%
10	Increase Span Length of Approach structures	536	+7.3%	$285.1	($3.12)	-1.1%	1.88	+11%
	Total				($28.81)			

QUESTIONS

Jose Theiler, PE, CVS
Christopher Johnson, VMA, PMP