Main River Bridge Structure Type Study
Step 2 – Recommendation Memo
May 21, 2010

The objective of Step 2 of the Bridge Type Selection Process was to develop and evaluate the 6 Bridge Type Alternatives selected from Step 1 and to recommend the Final 3 Bridge Alternatives to advance into Step 3. This memo documents the results of the work completed during Step 2 of the Bridge Type Selection Process and presents the Final 3 Bridge Alternatives recommended for further study in Step 3. The recommended Final 3 Bridge Alternatives are:

- Alternative 1: Arch Bridge – simply supported arch with inclined arch ribs
- Alternative 3: Cable-stayed Bridge – two towers, three vertical legs/tower
- Alternative 6: Cable-stayed Bridge – one tower, two vertical legs/tower

The basis for this recommendation is described below.

Through a series of design meetings with the Federal Highway Administration (FHWA), Kentucky Transportation Cabinet (KYTC), and Ohio Department of Transportation (ODOT) during Step 2, the 6 Bridge Type Alternatives were further refined for conformance to the purpose and needs of the project. The 6 Bridge Type Alternatives were presented to a combined meeting of the Project Aesthetic Committee (PAC) and Project Advisory Committee on April 15, 2010. During this meeting, the project team presented the 6 Bridge Type Alternatives consisting of two arch bridges and four cable-stayed bridges. As part of the presentation, the project team discussed how each the 6 Bridge Type Alternatives met the key design criteria that were established for the project bridge type selection process. The key design criteria are: construction costs, constructability, maintenance and durability, and major rehabilitation feasibility. In addition, the presentation discussed how each Bridge Type Alternative met the five key visual and aesthetic criteria developed by the PAC during Step 1.

The project team then solicited feedback from the two committees as to which 6 Bridge Type Alternatives best met the five key visual and aesthetic criteria. During the meeting, the project team presented various bridge components incorporated into the 6 Bridge Type Alternatives and requested additional feedback on them to aid in the Step 3 bridge design process. The 6 Bridge Type Alternatives were posted on the project website to solicit public comments as well. A press release was issued by the project sponsors in order to notify the public of the opportunity to provide feedback.

During the April 15th meeting, the key visual and aesthetic criteria matrix was collaboratively completed by the two committees. The April 15th meeting minutes and the completed criteria matrix can be found in Attachment A. A one-week comment period followed the April 15th meeting, which provided the committee members and the public an opportunity to comment on the 6 Bridge Type Alternatives. Comments were received via email, faxes, phone calls, and postings to the project website. Comments received from the committee members after the meeting are included in Attachment B. Comments received from the public are included in Attachment C.

As a member of the Project Advisory Committee, the Cincinnati USA Regional Chamber conducted a member survey of the 6 Bridge Type Alternatives. The Chamber received 1,362 responses from their members over a two-day period. The member's bridge preference results are shown in Table A.

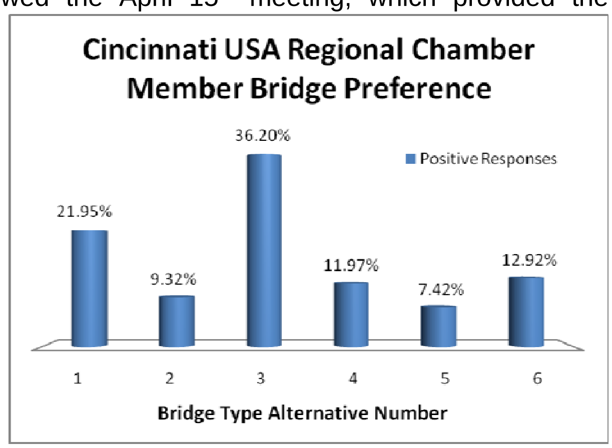

Table A

The Cincinnati USA Regional Chamber comments are in Attachment D.

The public comments received were analyzed and used to quantify trends for the public's preferences and concerns regarding the overall project and for the various bridge concepts. Table B is a visual representation of those trends. Those comments which liked all or none of the bridge concepts, or which did not indicate a preference (neutral) are not included in Table B. In general, up to three positive or three negative comments from each commenter were included in the analysis. Showing a preference for one concept over another was not considered a negative comment for the less preferred concept, unless a specifically negative comment was made about that concept. The bar chart in Table B provides a summary of public opinions on the bridge concepts, and was used as one source of input for the recommendation of the Final 3 Bridge Alternatives.

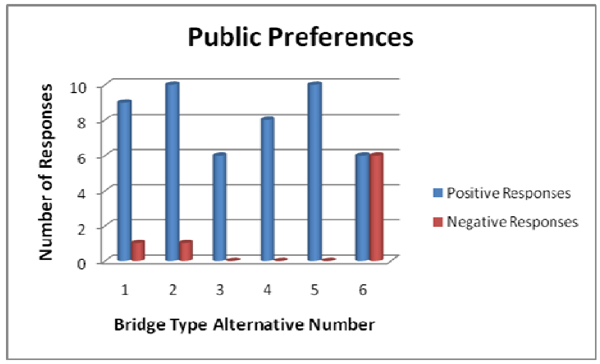

Table B

As part of the Step 2 process, additional structural analysis was performed for each of the 6 Bridge Type Alternatives. The purpose of this analysis was to better define the structural elements sizes and perform a more refined optimization of the structural design. The result of the additional structural analysis was used to determine how each of the 6 Bridge Type Alternatives meets the Key Design Criteria for the project. These efforts enable a more reliable estimate of probable costs for the 6 Bridge Type Alternatives. A comparison of the 6 Bridge Type Alternatives with regards to the Key Design Criteria are included in the Comparison of Alternatives section of this memo. Aesthetics are discussed in Attachment E. The reasoning behind the selection of these particular Bridge Type Alternatives is provided in the Recommendation section of this memo.

COMPARISON OF ALTERNATIVES

The following section describes and compares the 6 Bridge Type Alternatives with respect to construction cost, constructability/construction time, maintenance and durability, major rehabilitation feasibility, and maintenance of traffic. Properly designed and maintained, all 6 Bridge Type Alternatives would have a design life of 100 years.

To compare construction costs between the 6 Bridge Type Alternatives, a bridge segment length of 2,200 feet was utilized for each alternative. The bridge segment length includes the main bridge and the appropriate approach spans. Construction costs are based on 2010 costs inflated to the median construction date for each bridge alternative with an anticipated start of construction date of January 2015. The construction costs are based on quantity takeoffs of the major bridge components developed as part of the conceptual engineering analysis of the 6 Bridge Type Alternatives. For the 6 Bridge Type Alternatives, quantities were developed for major steel and concrete members.

Foundation costs were calculated as a percentage (20%) of the total cost of the bridge. A contingency of 30% was utilized to include additional bridge components not calculated and any other unknowns. An inflation rate of 32.9% was used for Alternative 1 based on a three year estimated construction schedule with a median construction date of June 2016. An inflation rate of 36.7% was used for Alternatives 2, 3, 4, 5, and 6 based on a four year estimated construction schedule with a median construction date of January 2017. The ODOT FY10'-11' Business Plan Inflation Calculator was used to calculate the inflation rates.

Alternative 1 Arch Bridge: Simply Supported Arch with Inclined Arch Ribs

Construction Cost:		
	KY:	$ 430 M
	OH:	$ 60 M
	Total:	$ 490 M

Constructability/Construction Time: The main span arch can be assembled in several ways: on falsework in the river, by cantilever using temporary towers and cables, or offsite, then floated in and lowered onto the piers. Falsework construction will narrow the navigation channel and will interrupt barge traffic. Cantilever construction will not interrupt river traffic, but is a relatively complicated and costly construction method for this bridge type. The offsite construction/float-in method of construction may be erected on a number of temporary piers next to the river bank between the existing Brent Spence Bridge and the Cincinnati Southern Bridge. The float-in of the main span will affect river traffic for one day or less. For the purposes of the cost estimate and the estimated schedule, the float-in construction method is assumed and is expected to take approximately 2.5 to three years. If the contractor proposes using a different construction method, the construction schedule will be similar to the other alternatives.

The arch span may be seated on bearings. The constructability of these extremely large bearings requires investigation. If the bearings are too large to be manufactured, the arch span would need to be seated directly on top of the piers. This integral connection requires investigation as well. The arch bridges (Alternatives 1 and 2) will require three arch planes due to the size and weight of the bridge. The three arch planes will allow for bridge loads to be distributed more efficiently into the foundations.

Construction Schedule:		
	Foundation:	11 – 12 Months
	Pier/Tower:	6 Months
	Superstructure:	10 – 15 Months
	Finishing:	3 Months
	Total:	2 .5 - 3 Years

Maintenance and Durability: This Arch Bridge will present normal maintenance and durability issues - paint and the deck overlay will require replacement approximately every 20 years. Special attention will be needed for the top and bottom chords as these will each be fracture critical members, which will function as ties throughout the life of the structure. The steel tie chords and the arch ribs will require inspection within the member itself, which will be difficult. It is expected that strands will be used for the hanger members because of the heavy anticipated loads. The material and corrosion protection of the hangers will be similar to that of the stay cables of the cable-stayed bridges. The strands are sealed by polyethylene (PE) sheathing and pipes. Direct visual inspection of the strand steel is impossible. Special attention during inspection will need to be paid to the hangers, including using specialist inspectors and non-destructive testing. Hangers may be made of galvanized bridge strands, which is a type of wire rope. Regular cleaning of the bottom socket area to prevent corrosion of the bridge strand is critical to the longevity of the hangers. Painting hangers will be required when the galvanizing layer is worn out.

Major Rehabilitation Feasibility: The concrete deck slab may require replacement once over the course of the lifespan of the bridge, an operation which is feasible for this alternative. It is expected that hangers will require replacement once or twice in the life span of the bridge. For the bridges with three planes of trusses between the decks, such as this alternative, the deck truss rehabilitation is expected to be at least 50% more expensive than for the two deck truss plane bridges, due to the greater number of structural members.

If the bearing option is adopted, jacking points will be built in for bearing replacement and the whole or part of the bearing will be designed to be replaceable.

Maintenance of Traffic: MOT during maintenance or rehabilitation activities will be an issue for three-plane arch/truss alternatives, especially on the lower deck. It is expected that both the main span and the approaches will have a center deck truss. The center deck truss prevents movement of traffic from one side of the bridge to the other. Therefore, the maintenance and rehabilitation work will require lane closures or a median crossover on the approaches to the main bridge.

Alternative 2 Arch Bridge: Continuous Arch with Vertical Arch Ribs

Construction Cost:

KY:	$ 570 M
OH:	$ 60 M
Total:	$ 630 M

Constructability/Construction Time: The possible construction methods of the main span are similar to that of Alternative 1. Though the main span portion of the arch can be assembled offsite, floated in, and then connected to the cantilevered arches, the arched back spans are expected to be constructed on falsework. Connecting the floated-in span to the superstructure will block river traffic for approximately one or two days, which is longer than for the simply-supported arch (Alternative 1). This alternative will take longer to build than Alternative 1 due the construction of the inclined back span supports. The total construction time for this alternative is expected to be approximately 3.5 to four years.

Construction Schedule:

Foundation:	11 – 12 Months
Pier/Tower:	9 Months
Superstructure:	19 – 24 Months
Finishing:	3 Months
Total:	3 .5 - 4 Years

Maintenance and Durability: The painting, deck overlay replacement and inspection requirements are similar to that of Alternative 1. Additionally, since the arch ribs extend below the deck and could be within reach of the river flood water surface, these ribs would have to be protected from vessel collision and may require additional protection from vandal and/or terrorist threats. This protection is expected to take the form of concrete fill within the steel arch ribs up to an elevation deemed acceptable based on vessel collision and/or security analysis. Despite the protection offered by the concrete fill, vehicle traffic may be interrupted in the event of a vessel impact so emergency inspections can occur. Protection by dolphins or fenders is not feasible due to the large elevation fluctuations of the Ohio River between drought and flood stages.

Major Rehabilitation Feasibility: The deck replacement, hanger replacement, rib and deck truss repair requirements are similar to that of Alternative 1.

Maintenance of Traffic: The MOT during maintenance or rehabilitation activities is similar to that of Alternative 1.

Alternative 3 Cabled Stayed Bridge: Two Towers, Three Vertical Legs/Tower

Construction Cost:

KY:	$ 470 M
OH:	$ 100 M
Total:	$ 570 M

Constructability/Construction Time: The cantilever construction, which would be used for all cable-stayed alternatives, would pose very little hindrance to river traffic. Once the needle tower construction reaches the elevation of the first or second cable, the construction of the deck trusses/decks can proceed simultaneously with the construction of the needle towers, which is assumed in the construction schedule below. The total estimated time in the schedule is less than the sum of the individual item schedules, which indicates the time savings due to the overlap of the construction of the pylons and superstructure.

The deck truss members, floorbeams, and precast concrete deck panels will be delivered to the bridge site by barges. They may be partially assembled on the barges in order to optimize crane operations. The assemblies will be lifted by floating cranes or by gantries placed on the deck. Each assembly lift will require approximately one hour, and the barges should not completely block river traffic. The total construction time for this alternative is expected to be approximately 3.5 to four years.

<u>Construction Schedule:</u>

Foundation:	11 – 12 Months
Pier/Tower:	14 Months
Superstructure:	20 – 25 Months
Finishing:	3 Months
Total:	3.5 - 4 Years

<u>Maintenance and Durability:</u> With the exception of the deck, this bridge will present normal maintenance and durability issues, the steel deck truss members and the floorbeams will require repainting approximately every 20 years. Because the deck of a cable-stayed bridge is typically deemed non-replaceable, the deck will require a high level of durability and special roadway maintenance procedures to prolong its life span. One way to protect the concrete deck is keep the deck overlay in good repair and to replace the deck overlay when necessary. Using non-corrosive de-icing chemicals in the winter will be beneficial but more costly than standard roadway salts. Stainless steel reinforcement may be considered to reduce importance of the deck overlay and non-corrosive de-icing chemicals so that the maintenance cost and inconvenience can be reduced. The stay cables are comprised of strands. The strands are sealed by PE sheathing and pipes. Direct visual inspection of the strand steel will be impossible; therefore special attention to the stay cables during inspection will be required, including using specialist inspectors and non-destructive testing.

<u>Major Rehabilitation Feasibility:</u> Deck replacement is prohibitively difficult, if not impossible, for this and all other cable-stayed alternatives. Stay cable replacement may be required in the future. All cable-stayed bridges are required by code to be designed so that the stay cables can be replaced one at a time. Stay cable replacement is a major special operation, which requires stay cable specialist contractors. The deck truss rehabilitation is similar to the arch alternatives.

<u>Maintenance of Traffic:</u> The MOT during maintenance or rehabilitation activities is similar to that of Alternative 1.

<u>Alternative 4 Cabled Stayed Bridge: Two Towers, Three Inclined Legs/Tower</u>

<u>Construction Cost:</u>

KY:	$ 500 M
OH:	$ 110 M
Total:	$ 610 M

The cost for Alternative 4 is higher than that of Alternative 3 due to the additional cost incurred for the construction of the inclined pylons.

<u>Constructability/Construction Time:</u> The constructability is similar to Alternative 3, except with inclined tower construction. Special temporary measures, either falsework or post-tensioning, are required to construct the inclined tower. The total construction time for this alternative is expected to be approximately 3.5 to four years.

Construction Schedule:

Foundation:	11 – 12 Months
Pier/Tower:	16 Months
Superstructure:	18 – 23 Months
Finishing:	3 Months
Total:	3.5 - 4 Years

Maintenance and Durability: Deck and stay cable maintenance is similar to Alternative 3.

Major Rehabilitation Feasibility: Deck and stay cable replacement is similar to Alternative 3. Deck truss rehabilitation is similar to the arch alternatives.

Maintenance of Traffic: The MOT during maintenance or rehabilitation activities is similar to that of Alternative 1.

Alternative 5 Cabled Stayed Bridge: Two Towers, Two Inclined Legs/Tower

Compared to the other Bridge Type Alternatives, Alternatives 5 and 6 only have two deck truss planes. As a result of this, the roadway profile will be different than the other bridges in both vertical grade and vertical distance between the two bridge decks. With the deeper floorbeams required for Alternatives 5 and 6, the lower bridge deck will be approximately six feet higher in elevation than the other alternatives. The upper bridge deck will be approximately 12 feet higher in elevation than the other alternatives.

Construction Cost:		
	KY:	$ 520 M
	OH:	$ 120 M
	Total:	$ 640 M

The higher cost for Alternative 5 versus Alternative 4 is due to a higher unit cost for the deeper floorbeams which affect the main bridge span and the approach spans. The approach spans for Alternative 5, like the main span, will have two deck truss planes and will require deeper floorbeams and heavier deck trusses than in the three-truss alternatives.

Constructability/Construction Time: The constructability is similar to Alternative 3, except with two cable planes and with inclined tower construction. The construction of the inclined tower is similar to Alternative 4. The members of the deck trusses and floorbeams will be larger than those of Alternatives 3 and 4. The total construction time for this alternative is expected to be approximately 3.5 to four years.

Construction Schedule:		
	Foundation:	11 – 12 Months
	Pier/Tower:	15 Months
	Superstructure:	19 – 24 Months
	Finishing:	3 Months
	Total:	3.5 - 4 Years

Maintenance and Durability: Deck and stay cable maintenance is similar to that of Alternative 3.

Major Rehabilitation Feasibility: Deck and stay cable replacement is similar to that of Alternative 3. Deck truss rehabilitation is similar to the arch alternatives.

Maintenance of Traffic: Because there is no center deck truss or cable plane, MOT during maintenance or rehabilitation activities can be performed by closing one roadway completely and moving all traffic to the other roadway. A median crossover can occur on the main bridge or on the approaches to the main bridge.

Alternative 6 Cabled Stayed Bridge: One Tower, Two Vertical Legs/Tower

Compared to the other bridge alternatives, Alternatives 5 and 6 only have two deck truss planes. As a result of this, the roadway profile will be different than the other bridges in both vertical grade and vertical distance between the two bridge decks. With the deeper floorbeams required for Alternatives 5 and 6, the lower bridge deck will be approximately six feet higher in elevation than the other alternatives. The upper bridge deck will be approximately 12 feet higher in elevation than the other alternatives.

Construction Cost:		
	KY:	$ 460 M
	OH:	$ 160 M
	Total:	$ 620 M

Constructability/Construction Time: The constructability is similar to Alternative 3, except with two cable planes and a single, taller tower. The members of the deck trusses and floorbeams will be larger than that of Alternatives 3 and 4. Superstructure erection will start when the tower construction reaches the first or second cable. The total construction time for this alternative is expected to be approximately 3.5 to four years.

Unlike the other cable-stayed alternatives with two sets of towers, the single, taller tower alternative in this alternative may have additional cost implications associated with it due to the superstructure erection being dependent on the single tower on the critical path for construction.

Construction Schedule:	Foundation:	11 – 12 Months
	Pier/Tower:	19 Months
	Superstructure:	15 – 20 Months
	Finishing:	3 Months
	Total:	3.5 - 4 Years

Maintenance and Durability: Deck and stay cable maintenance is similar to that of Alternative 3.

Major Rehabilitation Feasibility: Deck and stay cable replacement is similar to that of Alternative 3. Deck truss rehabilitation is similar to the arch alternatives.

Maintenance of Traffic: Since there is no center deck truss or cable plane, MOT during maintenance or rehabilitation activities can be performed by closing one roadway completely and moving all traffic to the other roadway. A median crossover can occur on the main bridge or on the approaches to the main bridge.

RECOMMENDATION

It is recommended that Alternative 1, Alternative 3, and Alternative 6 be the Final three Bridge Alternatives selected to proceed to preliminary design during Step 3 of the Bridge Type Selection Process. The reasons for the selection of these particular Bridge Type Alternatives are discussed below.

Alternative 1 is recommended to proceed through Step 3 of the Bridge Type Selection Process because it offers the lowest construction cost ($490M) of all Bridge Type Alternatives, and it was well regarded by the public via the input received from the project website and the Cincinnati Chamber of Commerce poll. The construction of the Ohio River Crossing is on the overall project's critical path for construction. Alternative 1 has the shortest construction time (2.5 to 3 years compared to 3.5 to 4 years for the other five Bridge Type Alternatives); which is another strong advantage.

Alternative 2 is not recommended to advance further in the Bridge Type Selection Process because its construction cost ($630M) is the second highest of the 6 Bridge Type Alternatives, and its arch ribs will present a vessel navigation hazard for barges during floods. Pier protection such as fenders or dolphins will be impractical and unsightly due to the variability of the river height. If the arch ribs are damaged, mitigation measures would be expensive and negatively impact river traffic. Additionally, construction of the main span will interrupt river traffic for longer than that of Alternative 1. The construction time of 3.5 to 4 years is similar to the other four Bridge Type Alternatives, with the exception of Alternative 1.

Alternative 3 is recommended to proceed through Step 3 of the Bridge Type Selection Process because it offers the second lowest construction cost ($570M), which is the lowest of the cable-stayed alternatives, and Alternative 3 was well regarded by the public via the input received from the Project Aesthetics Committee and Project Advisory Committee, the project website, and, especially, the Cincinnati Chamber of Commerce poll. From the drivers' point of view, the three needle towers are well proportioned and the vertical towers are more traditional and straightforward than the inclined tower Bridge Type Alternatives.

Alternative 4 is not recommended to advance in the Bridge Type Selection Process because its inclined needle towers are not visible from either Cincinnati or Covington from the drivers' point of view; and it would be more difficult and expensive to construct than Alternative 3. Even though the construction cost ($610M) is similar to Alternative 6, this alternative does not offer the advantages of Alternative 6 as described below.

Alternative 5 is not recommended to proceed further in the Bridge Type Selection Process because its construction cost ($640M) is the highest of all the Bridge Type Alternatives. Additionally, compared to Alternative 6, the twin needle towers appear too short and poorly proportioned from the drivers' point of view.

Alternative 6 is recommended to proceed through Step 3 of the Bridge Type Selection Process because it is the most visible of the Bridge Type Alternatives, especially from Cincinnati and Covington and it would serve as a landmark for the region. From the drivers' point of view, the tall and well proportioned twin-needle towers would serve as a gateway entrance to Cincinnati and Covington. This alternative was highly regarded by the public via the input received from the Cincinnati Chamber of Commerce poll and, especially, the Project Aesthetics Committee and Project Advisory Committee. While the construction cost ($620M) is the third highest of all the Bridge Type Alternatives, it is only 1.6% ($10M) higher than the fourth highest, which is a negligible difference.