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Value Engineering and Cost Saving Innovations: CSX Mobile River Lift Bridge

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VALUE ENGINEERING AND COST SAVING INNOVATIONS: CSX MOBILE RIVER BRIDGE

Abstract

After bids came in 73% higher than the Engineer's Estimate, the U.S. Coast Guard selected HNTB to perform a Value Engineering Review of a movable rail bridge over the Mobile River in Alabama. HNTB used their extensive experience on movable bridges to examine the foundations, superstructure, constructability as well as the mechanical and electrical systems to develop cost savings throughout structure.

This paper will discuss the original structure configuration, Contractor's input regarding the erection, staging, closures to rail and marine traffic associated with the original design, and main details of the redesign which resulted in cost savings.

The paper will discuss the cost effective redesign performed by HNTB to lower the estimated construction cost of the bridge without sacrificing any of the design requirements.

Topics discussed in the paper will be as follows:

- High cost details of original bridge
- Cost effective alternatives
- Details of alternate design
- Cost comparison of the two alternate structures

Project Background

Existing Bridge (See Figure 1)

The existing structure is a single track, 330 foot (2 @ 165 feet) center bearing swing span that provides one clear channel of 146'-7" over the Mobile River. To the east of the swing span, the structure has 800 feet of timber approach trestle and one 208 foot variable depth truss span. To the west there are two 208 foot variable depth truss spans and an 80 foot long through girder span. The superstructure is supported on un-reinforced concrete piers with soil bearing footings. Due to river geometry, the structure has been hit numerous times causing interruptions in rail and navigation traffic, along with an extensive amount of repairs. Pier 4 had previously been struck shearing the pier horizontally and requiring extensive repairs. The navigational clearance was determined to be inadequate by the United States Coast Guard and thus the agency requested CSX, the owner, to replace the movable span to provide more navigation clearance, funded under the Truman Hobbs Act (CFR 33, 2008).

Figure 1. Elevation of Existing Bridge

Original Design for Replacement Structure (See Figure 2)

The criteria for the replacement structure was to provide a 56 foot 5 inch vertical clearance over a 300 foot wide channel. A 365 foot through-truss, span-drive vertical lift bridge was determined to be the optimum solution by another consultant. The design incorporated a new pier behind Pier 4 and the existing Pier 2 was strengthened for the new lift span. Drilled shafts were used for the foundation of the new Pier 4A and strengthened Pier 2. The towers for the lift span were each to be four leg trussed steel elements. The rear tower legs would be supported on their own new separate piers. All piers were to be constructed utilizing cofferdams. A 42 foot tower span would be placed within each tower to span between the front and rear tower legs. To accommodate the towers for the lift span, the two fixed truss spans on either side of the swing span required modification to shorten their overall length. Existing Pier 4 with a recently replaced fender system was to remain and be utilized for pier protection. A new fender system was to be installed at Pier 2.

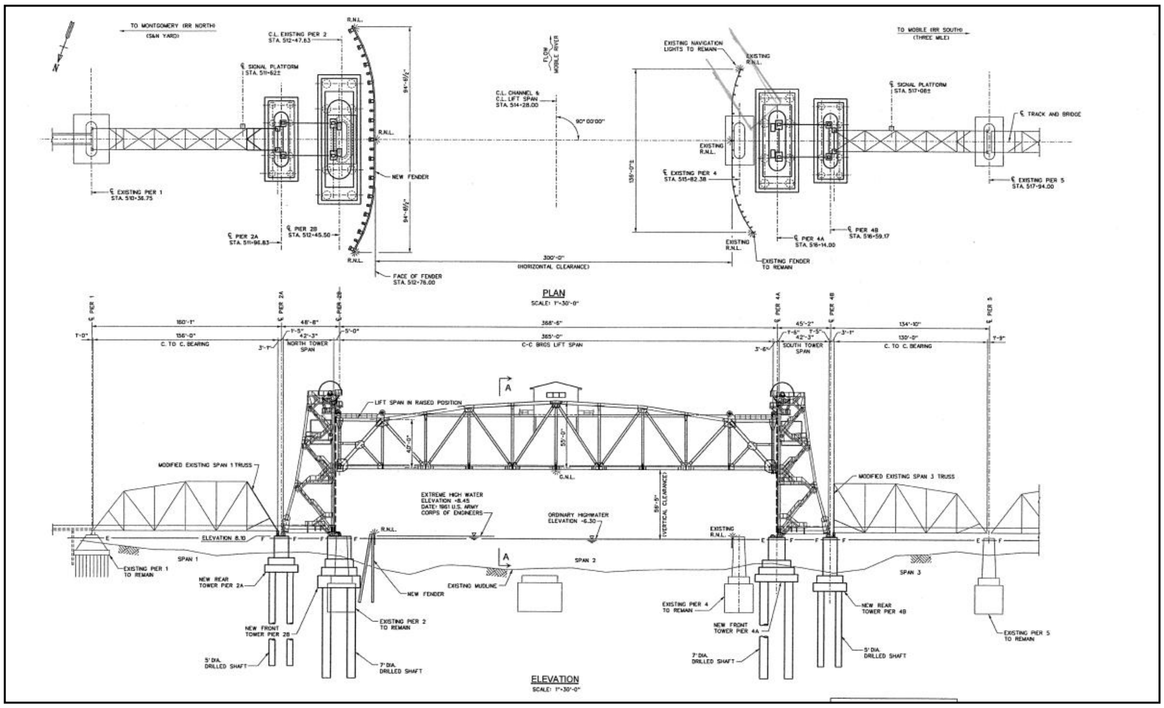

Figure 2. General Plan and Elevation of Proposed Replacement Structure (CSX Plans, 2006)

Bids and Resulting Efforts

Bid tabulations

The project was advertised on February 24, 2006. Questions were raised during bidding including a letter from one of the prospective bidders indicating certain requirements in the contract specifications made the cost of the project higher than anticipated. Three bids were received on May 4, 2006 with the low bid at $30 million above the Engineer’s Estimate. (See Figure 3) Since the variation was too great to award, the bids were rejected. The Coast Guard then contacted three consultants to solicit bids to perform a Value Engineering of the project in an effort to find cost saving suggestions. HNTB Corporation was selected for the assignment.

BID TABULATION

PROJECT: Replace Exsting Swing Span with Vertical Lift Span

Item No.	Bid Item Description	Bid Quantities		Estimated Bid		Contractor 1		Contractor 2		Contractor 3	
		Est'd Qty.	Unit	Unit Price	Total Amount	Unit Price	Total Amount	Unit Price	Total Amount	Unit Price	Total Amount
2	Mobilization	1	L.S.	$1,629,000	$1,778,542.20	$6,990,000.00	$6,990,000.00	$7,830,000.00	$7,830,000.00	$9,000,000.00	$9,000,000.00
2A	Partnering	1	L.S.	$0.00	$0.00	$96,500.00	$96,500.00	$60,000.00	$60,000.00	$56,000.00	$56,000.00
3	Environmental Protection	1	L.S.	$10,000	$10,918.00	$140,000.00	$140,000.00	$150,000.00	$150,000.00	$50,000.00	$50,000.00
4A	Drilled Shaft (7' dia)	1,952	L.F.	$1,365	$2,909,079.26	$1,374.00	$2,682,048.00	$2,730.00	$5,328,960.00	$2,320.00	$4,528,640.00
4B	Drilled Shaft (5' dia)	1,328	L.F.	$740	$1,072,933.70	$701.00	$930,928.00	$2,255.00	$2,994,640.00	$1,240.00	$1,646,720.00
4C	Drilled Shaft 7' Casing	432	L.F.	$196	$92,444.89	$1,200.00	$518,400.00	$1,460.00	$630,720.00	$1,600.00	$691,200.00
4D	Drilled Shaft 5' Casing	448	L.F.	$143	$69,945.08	$1,076.00	$482,048.00	$1,040.00	$465,920.00	$705.00	$315,840.00
4E	Exploratory Borings	295	L.F.		$0.00	$202.00	$59,590.00	$150.00	$44,250.00	$200.00	$59,000.00
4F	Protection of Existing Structures	1	L.S.		$0.00	$45,000.00	$45,000.00	$100,000.00	$100,000.00	$975,000.00	$975,000.00
4G	Statnamic Axial Load Test	1	EA.	$70,000	$76,426.00	$500,000.00	$500,000.00	$1,000,000.00	$1,000,000.00	$135,000.00	$135,000.00
5A	Structural Excavation	6,700	C.Y.	$40	$292,602.40	$149.00	$998,300.00	$100.00	$670,000.00	$72.00	$482,400.00
5B	Cofferdams	4	EA.	$508,750	$2,221,813.00	$2,083,627.00	$8,334,508.00	$1,500,000.00	$6,000,000.00	$3,980,000.00	$15,920,000.00
6	Reinforcing Steel	449,600	LB	$1.20	$589,047.94	$2.10	$944,160.00	$1.10	$494,560.00	$1.06	$476,100.00
7A	Concrete Class A (AE) (Substructure)	4,800	C.Y.	$499	$2,615,079.36	$842.00	$4,041,600.00	$1,100.00	$5,280,000.00	$1,100.00	$5,280,000.00
7B	Concrete Class A (AE) (Slabs)	56	C.Y.	$642	$39,252.39	$1,350.00	$75,600.00	$975.00	$54,600.00	$1,200.00	$67,200.00
7C	Concrete Class A (AE) (Misc)	5	C.Y.	$554	$3,024.29	$825.00	$4,125.00	$775.00	$3,875.00	$3,300.00	$16,500.00
7D	Concrete Class B (AE) (Tremi Seal)	2,600	C.Y.	$499	$1,416,501.32	$600.00	$1,560,000.00	$825.00	$2,145,000.00	$1,040.00	$2,704,000.00
8A	Structural Steel (Lift Span)	2,200,000	C.Y.	$2.70	$6,485,292.00	$5.63	$12,386,000.00	$6.30	$13,860,000.00	$4.70	$10,340,000.00
8B	Structural Steel (Lift Span Misc)	240,000	LB	$2.25	$589,572.00	$6.75	$1,620,000.00	$6.55	$1,572,000.00	$5.50	$1,320,000.00
8C	Structural Steel (Towers)	1,700,000	LB	$2.98	$5,531,058.80	$5.75	$9,775,000.00	$6.55	$11,135,000.00	$5.65	$9,605,000.00
8D	Structural Steel (Towers Misc)	180,000	LB	$2.25	$442,179.00	$8.00	$1,440,000.00	$4.60	$828,000.00	$8.65	$1,557,000.00
8E	Structural Steel (Counterweights)	640,000	LB	$1.40	$978,252.80	$2.40	$1,536,000.00	$4.75	$3,040,000.00	$5.40	$3,456,000.00
8F	Structural Steel (Existing Truss Mods)	25,400	LB	$11.68	$323,906.49	$12.00	$304,800.00	$17.75	$450,850.00	$34.00	$863,600.00
10	Off-Line Trackwork	460	L.F.	$572	$287,274.42	$1,223.00	$562,580.00	$1,860.00	$855,600.00	$800.00	$368,000.00
11	Demolition of Existing Structure	1	L.S.	$1,798,000	$1,963,056.40	$675,000.00	$675,000.00	$1,100,000.00	$1,100,000.00	$2,000,000.00	$2,000,000.00
13	Machinery/Tender's House	1	L.S.	$212,000	$231,461.60	$150,000.00	$150,000.00	$250,000.00	$250,000.00	$150,000.00	$150,000.00
15	Span Drive Machinery	1	L.S.	$1,527,000	$1,667,178.60	$2,600,000.00	$2,600,000.00	$5,000,000.00	$5,000,000.00	$3,000,000.00	$3,000,000.00
16	Span Lock Machinery	1	L.S.	$382,000	$417,067.60	$400,000.00	$400,000.00	$600,000.00	$600,000.00	$600,000.00	$600,000.00
17	Uphaul & Downhaul Ropes & Accessories	1	L.S.	$255,000	$278,409.00	$500,000.00	$500,000.00	$600,000.00	$600,000.00	$200,000.00	$200,000.00
18	Counterweight Sheaves, Shafts & Bearings	1	L.S.	$2,926,000	$3,194,606.80	$3,650,000.00	$3,650,000.00	$4,500,000.00	$4,500,000.00	$5,000,000.00	$5,000,000.00
19A	Structural Concrete in Counterweight	630	C.Y.	$554	$381,060.04	$750.00	$472,500.00	$700.00	$441,000.00	$640.00	$403,200.00
19B	Scrap Metal for Counterweight	50,000	LB	$0.60	$32,754.00	$1.00	$50,000.00	$3.00	$150,000.00	$2.00	$100,000.00
19C	Balance Blocks	135,000	LB	$0.35	$51,587.55	$1.25	$168,750.00	$0.30	$40,500.00	$0.90	$121,500.00
19D	Span Balance	1	L.S.	$53,000	$57,865.40	$100,000.00	$100,000.00	$600,000.00	$600,000.00	$200,000.00	$200,000.00
20	Counterweight Ropes and Accessories	1	L.S.	$647,000	$706,394.60	$700,000.00	$700,000.00	$1,000,000.00	$1,000,000.00	$1,700,000.00	$1,700,000.00
21A	Bridge Electrical System	1	L.S.	$1,728,000	$1,886,630.40	$2,000,000.00	$2,000,000.00	$2,100,000.00	$2,100,000.00	$2,300,000.00	$2,300,000.00
21B	Aerial Cables	1	L.S.	$196,000	$213,992.80	$200,000.00	$200,000.00	$300,000.00	$300,000.00	$350,000.00	$350,000.00
22	Generator Building	1	L.S.	$18,000	$19,652.40	$500,000.00	$500,000.00	$40,000.00	$40,000.00	$215,000.00	$215,000.00
23	Bridge Standby Generator	1	L.S.	$400,000	$436,720.00	$250,000.00	$250,000.00	$175,000.00	$175,000.00	$200,000.00	$200,000.00
26	Operation & Maintenance Manuals & Training	1	L.S.	$53,000	$57,865.40	$2,000.00	$2,000.00	$20,000.00	$20,000.00	$100,000.00	$100,000.00
27	Fender Work	1	L.S.	$486,400	$531,051.52	$500,000.00	$500,000.00	$750,000.00	$750,000.00	$700,000.00	$700,000.00
28	Site Work	1	L.S.	$265,000	$289,327.00	$1,000,000.00	$1,000,000.00	$425,000.00	$425,000.00	$2,433,000.00	$2,433,000.00
	*(includes 3% escalation + 6% contingency)										
	Bridge Total =				**$40,241,826.43**		**$69,945,437.00**		**$83,085,475.00**		**$89,685,900.00**
	Days to Complete										
BOND	Performance Bond (if required)	1	L.S.	0.00		0.5333	$373,000.00	0.4735	$393,400.00	0.5229	$469,000.00
	Grand Total For Project (w/ bond) =				$40,241,826.43		$70,318,437.00		$83,478,875.00		$90,154,900.00

Figure 3. Bid tabulations from advertisement of proposed replacement structure (CSX Bid, 2006)

Value Engineering and Proposal

HNTB's approach to the work began with assessment of the contract plans and examination of the bid tabulations to determine the most costly items. HNTB did this by breaking the project up into four major components. These were Substructure, Superstructure, Mechanical & Electrical, and Construction. For each of these components, costliest items were examined to determine how they might be reduced.

Superstructure and Substructure (See Figure 4))

The cost savings approach to the overall bridge focused on the interrelationship between the superstructure and tower substructure. The major cost of the substructure was two fold.

- The need to utilize cofferdams for all the pier construction.
- The quantities of drilled shafts, concrete and reinforcing steel being utilized for the construction of the piers.

HNTB's proposed solution was to utilize single steel box towers in lieu of the four legged towers thereby eliminating the need for the rear tower legs, tower piers, tower jump spans and the modifications required to the fixed approach steel truss spans. Although the quantity of steel for the box sections is comparable to the four column tower, its foot print is significantly smaller.

Figure 4. Rendering of Conceptual Arrangement of VE Structure (HNTB, 2007)

HNTB also proposed to utilize waterline footings on drilled shafts to avoid the costly cofferdam construction. A portion of the new footings was underwater and thus floating forms were required similar to what has been used on other of HNTB Designs. With the form partially submerged, the form acts as a tub withstanding the hydrostatic pressure of the water and, once the concrete is poured, to hold the concrete in position while curing.

The replacement of the large deep piers with pier caps allowed significant reduction in the quantities of concrete and reinforcing. This also resulted in less dead load for the drilled shafts to carry. This, in turn, reduced the quantity of the drilled shafts.

Lift Span Superstructure

HNTB developed a more economical span length for the superstructure by placing the new footing for Pier 2 outside of the existing Pier 2 and getting the new pier 4A as close to the existing Pier 4 as possible. This could be done because the new drilled shafts are away from the existing piers. By doing this, the span length was able to be reduced from 365 feet to 357 feet. To still allow the new lift span to be supported on the new portion of the footings, the span width had to be increased to approximately 38 feet wide from the original 22 feet wide. This required the floorbeams to be heavier to accommodate the wider span. By utilizing this reduced span length, the truss modification to the existing eastern fixed approach span was no longer required.

Mechanical and Electrical

Examination of the mechanical and electrical system revealed that the motors to lift the bridge were undersized in terms of the original design, and would be operating 60% over their full load capacity (AREMA, 2000). HNTB developed two alternates to accommodate the system as originally designed. The first alternate was to enlarge the motor to the proper size, but this would result in the need for a complete redesign of the mechanical and electrical systems. The second alternate was to develop a scheme to reduce the operating loads. This was done by changing the bronzed bushed counterweight sheave bearings to roller bearings. By doing so, the frictional load was dramatically reduced and overall operating loads were reduced.

Construction

During the bidding phase of the project, the contractors expressed concern with the requirements for minimizing the fouling of the tracks. Strict railroad guidelines exist that any crane or equipment has to be clear of the tracks a certain time before a train is passing. Since this was a main line track, the approximately 20 trains per day expected would result in the crane being stored more than utilized, resulting in a very inefficient and costly use of the cranes. The original tower design required the erection of numerous truss members within the track envelope resulting in costly erection. In contrast, HNTB's proposed single towers, which are located outside the new lift span truss panels, could be partially erected off site and installed in sections, resulting in a more efficient erection procedure and less time with the cranes deployed within or around the track fouling area.

Utilization of the water line footings resulted in multiple advantages from a construction standpoint. First it eliminated all need for cofferdams. These cofferdams were very expensive due the tight regulation on not interrupting rail traffic as well as the very restrictive clearance underneath the existing approach span where the cofferdam had to be installed. The placement of the cap beams outside of the existing piers allows their construction to occur with minimal interference to rail operations. This will expedite their construction assisting in lowering the unit cost of material installation. The unit price for the concrete would increase slightly to compensate for the necessity of utilizing the more costly form system.

Comparison of Costs

Once the structure type was developed and major details were worked out for the Value Engineering Alternate, quantities were determined to compare the existing and new designs and establish the cost savings. HNTB developed a spreadsheet that showed the original unit prices, original quantities and the new quantities for the proposed VE Alternate Structure. This provided a side by side comparison of both structures to clearly indicate where the cost savings could be achieved. (See Figure 5)

Comparison of Quantities between Bid and VE Recommendations

Items Affected by VE		Quantities					
Item No.		AS BID		HNTB		Unit Price	Savings
4A	Drilled Shaft (7' dia)	1,952	L.F.	1,808	L.F.	$1,374.00	$197,856.00
4B	Drilled Shaft (5' dia)	1,328	L.F.	0	L.F.	$701.00	$930,928.00
4C	Drilled Shaft 7' Casing	432	L.F.	400	L.F.	$1,200.00	$38,400.00
4D	Drilled Shaft 5' Casing	448	L.F.	0	L.F.	$1,076.00	$482,048.00
5A	Structural Excavation	6,700	C.Y.	0	C.Y.	$149.00	$998,300.00
5B	Cofferdams	4	EA.	0	EA.	$2,083,627.00	$8,334,508.00
6	Reinforcing Steel	449,600	LB	130,700	LB	$2.10	$669,690.00
7A	Concrete Class A	4,800	C.Y.	1,307	C.Y.	$842.00	$2,941,106.00
	Cost Differential for Floating Forms	0	C.Y.	1,307	C.Y.	$252.60	-$330,148.20
7D	Concrete Class B	2,600	C.Y.	0	C.Y.	$600.00	$1,560,000.00
8A	Structural Steel (Lift Span)	2,200,000	LB	2,320,000	LB	$5.63	-$675,600.00
8B	Structural Steel (Lift Span Misc)	240,000	LB	240,000	LB	$6.75	$0.00
8C	Structural Steel (Towers)	1,700,000	LB	1,320,000	LB	$5.75	$2,185,000.00
8D	Structural Steel (Towers Misc)	180,000	LB	180,000	LB	$8.00	$0.00
8E	Structural Steel (Counterweights)	640,000	LB	640,000	LB	$2.40	$0.00
8F	Structural Steel (Existing Truss Mods)	25,400	LB	10,160	LB	$12.00	$182,880.00
19A	Structural Concrete in Counterweight	630	C.Y.	660	C.Y.	$750.00	-$22,500.00
27	Fender Work	$500,000	L.S.	$500,000	L.S.		-$0
New Item	**Existing Pier Rehabilitation**	**$0**	**L.S.**	**$250,000**	**L.S.**		**-$250,000.00**
						Total Cost Savings	$17,242,467.80

Figure 5. Potential Cost Savings from VE review (HNTB, 2007)

Figure 6. Rendering of HNTB proposed final design alternate (HNTB, 2009)

Conclusion

This project emphasizes the need for bridge designers to carefully assess all project constraints when preparing designs. As in this case, such constraints can go beyond the physical characteristics of the site, the configuration and condition of existing structures, the function of the new or modified facility, the availability of labor, materials and equipment, and the usual codes and standards used for design. Other possible constraints can include local or owner-specific standards and rules (particularly with respect to safety on railroads) and the practicality of normally accepted construction techniques in specific applications. The challenge to identify such constraints by investigation early on, and to think creatively to meet them, can help to avoid unanticipated cost overruns and delays. A value engineering analysis can lead to significant cost savings.

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