APPENDIX G – WHITTIER BRIDGE TYPE STUDY – EVALUATION OF BRIDGE ALTERNATIVES

6. Evaluation of Bridge Alternatives

6.1 The Process

This report represents the outcome of a multi-discipline evaluation process designed to address all pertinent factors which may influence the selection of a bridge design alternative for the proposed Whittier Bridge main structure over the Merrimack River.

The intent of this process was to examine the various options available to span the Merrimack River at the location of the Whittier Bridge. The bridge design alternatives evaluated under this study include: steel plate and box girders, network arch with steel plate and box girder approach spans, segmental concrete box girder, extradosed with concrete superstructure, and cable-stayed with concrete and steel superstructures. The multi-discipline evaluation process, described herein, examined the merits and limitations for each type of structure proposed for this river crossing.

The bridge design alternatives were compared against one another with due consideration to the following aspects: structural/redundancy, highway/profile impact, inspection and maintenance, Accelerated Bridge Construction (ABC) /scheduling, constructability, aesthetics, environmental, construction costs, and life cycle cost.

6.2 Approximate Costs

The costs for this project break down into three (3) categories:

- Construction Costs
- Inspection/Preventive Maintenance Costs
- Life Cycle Costs – Based on 75 Years

Construction Costs

The intent of the construction cost effort was to obtain differences in costs for the eight (8) design alternatives. Thus, only quantities and costs for items that were different among the alternatives were obtained. Items that were similar, such as drainage and lighting, were not included. A basis for this approach is that the deck area is the same (189,800 SF) for all alternatives.

Quantities were measured from the plans in the Bridge Type Study for the eight (8) bridge alternatives. These quantities were reviewed by both estimators and engineers, and inserted into the cost estimates.

In-place Unit Prices were determined using MassDOT's latest Weighted Average Bid Prices, both for District 4 and Statewide. The quantities listed in the Weighted Average Bid Prices were taken into account to determine the unit prices used in the estimate. For example, a unit price in the Weighted Average Bid Prices might be based on a quantity that was considerably different from the quantity in the estimate, so adjustments to unit prices were made based on these quantity differences.

The MassDOT's on-line estimating program was also used as a check on unit prices. Several material suppliers were called to obtain additional information. Based on the above, Unit Prices were reviewed and adjusted to reflect the best estimate of cost in August 2010 dollars.

Separate estimates were prepared for each of the eight alternatives. The quantities and unit prices were extended to obtain a total for each item, and these totals were added to obtain the relative cost for the alternative. To reflect the conceptual level of design, a 20% contingency factor was added. That total was then escalated at a rate of 3.5% per year to August 2012, per direction from MassDOT.

The construction costs presented herein resulted from this procedure.

Inspection/Preventative Maintenance Costs

Inspection and preventative maintenance is cyclical over the long term of a bridge's life span. Maintenance included in the preventive maintenance estimate includes, but is not limited to, the following:

- Cleaning of abutments, drainage system, and expansion joints.
- Spot painting
- Minor repair of roadway decks and pavement.
- Inspection

This category of maintenance does not include major bridge repainting or the replacement of deteriorated components. These items are included in the Life Cycle costs instead.

The annual cost of preventive maintenance may vary slightly. The cost differences would be minor, so the same crew and crew days were used for each type. For the purposes of this estimate, a state crew of two inspectors, two laborers, a truck driver, and a medium size truck with a boom was used. It was estimated that this crew would dedicate an average of five (5) crew days per year to preventive maintenance for each of the eight alternatives, and that this would be done for the 75 year life span of the bridge.

The crew costs approximately $1400 per day in 2010 dollars. Assuming an average of five (5) days per year dedicated to maintenance on the Whittier Bridge, results in an annual preventive maintenance cost of $7,000 for the year 2010. Adding a contingency of 20% and an escalation factor of 3.5% to August 2012 results in an annual cost of approximately $9,000 for preventive maintenance. This cost was projected out 75 years, applying the formula at the top of page 75 of the NCHRP, adjusted for yearly maintenance.

It was assumed that bridge inspections will be conducted every two years. The inspection crew includes two bridge inspectors and an inspection vehicle such as a Snooper. The cost for this crew is assumed to be the same as for the maintenance crew, or $1400 per day. With a contingency of 20% and an escalation factor of 3.5% to August 2012 results in a daily cost of approximately $1,800 for bridge inspection. Assuming four (4) days per inspection results in a yearly cost of $7,200, divided by two to reflect bi-yearly inspections results in $3,600 per year for bridge inspections. The complexity, and therefore time expenditure, for the inspections are expected to vary for the alternatives, so increases have been made to the costs of the alternatives involving more complex inspections.

The formula at the top of page 75 of the NCHRP was applied to determine costs, assuming a two year inspection cycle starting in year six (6) after construction completion.

Life Cycle Costs

Per MassDOT, a 75 year Life Cycle has been used to determine Life Cycle Costs. These costs involve significant repairs or replacements, such as repainting steel bridges or replacing bridge bearings. The NCHRP 12-43 "Bridge Life-Cycle Cost Analysis Guidance Manual" was used as a guide to determine costs for maintenance and rehabilitation work.

A contingency factor of 20% and an escalation factor of 3.5% were applied to the initial construction costs to bring the costs to August 2012. Then the Present Value factor was applied over the 75 year life span of the bridge to determine the approximate costs for the 75 year life span in 2012 dollars.

As mentioned in the NCHRP in Chapter 1, page 3, "There is currently no commonly accepted methodology for LCCA, particularly as it might be applied to bridge management."

Based on previous experience, the following are the items typically used in the Life Cycle Cost analysis along with the intervals of the required work:

Required Work Item	Interval
Repair Roadway Finish Items	25 years
Repaint Steel (@$0.20/lb)	25 years
Replace Deck Joints	25 years
Repair/Replace 30% of Strands/Cables	37.5 years
Replace 50% of Bearings	37.5 years
Substructure Repairs (@5% of Initial Cost)	15 years
Replace Wearing Surface (Bit. Conc.)	25 years

The construction costs for these items were used as a basis for determining Life Cycle Costs for all eight (8) alternatives. The differences in Life Cycle costs result from different quantities and costs for construction.

Present Value and Discount Rate

"Present value is the worth of a cost incurred at some future time expressed as the amount that would be equivalent if that cost were incurred now, computed as a function of the discount rate and time period between now and the anticipated time when the cost will be incurred. " (from NCHRP Report 483, p. 67)

The discount rate results from the interest rate, the inflation rate and a risk assessment factor. These will vary significantly over future years, so a discount rate, based on previous projects, was applied as follows:

Assumed Discount Rate = 4.0%

The formula, per page 76 of the NCHRP, used to determine present value is:
PV = Initial Cost (Including contingency and escalation)/1.04 (Real Discount Rate) raised to the power of the intervals. For example, for substructure repairs every 15 years: PV = $3,500,000/$1.04^{15}$... $^{+}$$3,500,000/ 1.04^{60} = PV. Note that interval 75 is not used because that is the end of the life cycle, so no work would be done in that year.

The spreadsheet calculations reflect this pattern. User-related costs, such as traffic delays, resulting from maintenance activities have not been included because they are assumed to be similar for each of the alternatives.

The construction costs, inspection/maintenance costs, and life cycle costs are included together in one estimate for convenience. For a breakdown of the estimate for individual alternatives, please see Section 5.

CONSTRUCTION COSTS

ALTERNATIVE	CONST. COST	DECK AREA	COST/SF	RANK
1 - STEEL PLATE GIRDERS	**$91,824,576**	**189,800**	**$484**	**1**
2 - STEEL BOX GIRDERS	**$99,718,865**	**189,800**	**$525**	**5**
3 - NETWORK ARCH & PLATE GIRDER	**$100,119,560**	**189,800**	**$528**	**6**
4 - NETWORK ARCH & BOX GIRDER	**$103,759,300**	**189,800**	**$547**	**8**
5 - SEGMENTAL CONCRETE BOX	**$92,756,763**	**189,800**	**$489**	**3**
6 - EXTRADOSED CONCRETE	**$103,245,232**	**189,800**	**$544**	**7**
7 - CABLE STAYED CONCRETE	**$92,755,122**	**189,800**	**$489**	**2**
8 - CABLE STAYED STEEL	**$97,669,630**	**189,800**	**$515**	**4**

NOTES:
1. COSTS ARE IN AUGUST 2012 DOLLARS, USING 3.5% INFLATION FACTOR. ESCALTION TO CONSTR. MIDPOINT WAS THEN APPLIED.
2. ADJUSTMENTS WERE MADE TO SEVERAL MASSDOT UNIT PRICES TO REFLECT CURRENT PRICES, AND SUPPLIERS WERE CONSULTED FOR PRICING.
3. DESIGN FEE IS NOT INCLUDED.
4. ITEMS INCLUDED IN THIS ESTIMATE ARE THOSE THAT CONSTITUTE DIFFERENCES AMONG THE ALTERNATIVE DESIGNS IN ORDER TO DETERMINE RELATIVE COSTS.
5. COSTS FOR FEATURES THAT ARE SIMILAR FOR EACH ALTERNATIVE, SUCH AS DRAINAGE AND LIGHTING, ARE NOT INCLUDED IN THIS ESTIMATE.
6. ABOVE COSTS DO NOT REFLECT MAINTENANCE. MAINTENANCE AND ESTIMATED 75 YEAR LIFE CYCLE COSTS ARE INCLUDED BELOW.

MAINTENANCE, INSPECTION, AND LIFE CYCLE COSTS - 75 YEAR

ALTERNATIVE	MAINT. & L.C. COST	DECK AREA	COST/SF	RANK
1 - STEEL PLATE GIRDERS	**$3,925,575**	**189,800**	**$21**	**4**
2 - STEEL BOX GIRDERS	**$4,192,870**	**189,800**	**$22**	**5**
3 - NETWORK ARCH & PLATE GIRDER	**$4,351,448**	**189,800**	**$23**	**6**
4 - NETWORK ARCH & BOX GIRDER	**$4,476,341**	**189,800**	**$24**	**7**
5 - SEGMENTAL CONCRETE BOX	**$2,994,031**	**189,800**	**$16**	**1**
6 - EXTRADOSED CONCRETE	**$3,784,041**	**189,800**	**$20**	**3**
7 - CABLE STAYED CONCRETE	**$3,434,276**	**189,800**	**$18**	**2**
8 - CABLE STAYED STEEL	**$5,293,070**	**189,800**	**$28**	**8**

RANKINGS COMBINING TOTAL COSTS

ALTERNATIVE NAME	TOTAL COST	DECK AREA	TOTAL COST/SF	RANK
1. STEEL PLATE GIRDERS	**$95,750,150**	**189,800**	**$504**	**1**
2. STEEL BOX GIRDERS	**$103,911,736**	**189,800**	**$547**	**5**
3. NETWORK ARCH & PLATE GIRDER	**$104,471,007**	**189,800**	**$550**	**6**
4. NETWORK ARCH & BOX GIRDER	**$108,235,641**	**189,800**	**$570**	**8**
5. SEGMENTAL CONCRETE BOX	**$95,750,794**	**189,800**	**$504**	**2**
6. EXTRADOSED CONCRETE	**$107,029,273**	**189,800**	**$564**	**7**
7. CABLE STAYED CONCRETE	**$96,189,398**	**189,800**	**$507**	**3**
8. CABLE STAYED STEEL	**$102,962,700**	**189,800**	**$542**	**4**

Table 6.1 - Summary of Construction and Life Cycle Costs

6.3 Evaluation Rating

The bridge design alternatives proposed in this Type Study were further evaluated based on a rating system addressing the following aspects: structural/ redundancy, highway, inspection and maintenance, Accelerated Bridge Construction (ABC) /scheduling, constructability, aesthetics, environmental, and life cycle and construction costs. To the maximum extent possible, objective, quantifiable rankings were obtained for each aspect. Several aspects were identified as fully quantifiable, such as construction cost, life cycle and maintenance cost, and schedule. These aspects were rated using MassDOT's best value formula, where the ranking represents how close the alternative is to the best value. The formula used is (Best value / Alternative value) x 5 = Rating.

Highlights of these aspects, which are critical to the Whittier Bridge, are as follows:

Structural/ Redundancy
- Difficulty of design
- Redundancy of structure

Highway/ Profile Impact
- Profile impact of the structure

Inspection and Maintenance
- Accessibility
- Frequency

ABC / Schedule Impacts (Quantifiable)
- Suitability for Accelerated Bridge Construction (ABC)
- Overall time required for construction (number of months to complete)

Constructability
- Complexity of construction
- Shipping constraints

Environmental
- Shading (Wetlands)
- Loss of river bottom (sq. ft.)
- Noise
- Fisheries
- Wildlife
- Floodplains
- Historic
- Visual

Cost (Quantifiable)
- Preventative maintenance cost
- Life cycle cost
- Construction cost

Aesthetics
The evaluation of aesthetics involves a qualitative assessment of the character of the landscape and the potential impacts of proposed improvements, including the viewer response to proposed visual changes. Aesthetics is a consideration in Section 106 conformance and also in the NEPA / MEPA process. This aspect was divided into two considerations; aesthetics, which was determined through a qualitative voting procedure using the criteria below; and Section 106 conformance, which was rated on a quantitative basis according to the criteria below. Both Aesthetics and Section 106 were weighted as half of the total rating and combined into one overall "Aesthetics" rating for the evaluation matrix.

Aesthetic Criteria
- Visual impact of structure
- Articulation of channel location
- Driver's view

Section 106 Criteria (Quantifiable)
- Use of granite in piers (all alternatives)
- Graceful lines (all except Alt. 1)
- Iconic structure (all signature alternatives)
- Elegant arch (Arch alternatives)
- Reuse of artifacts (Arch alternatives)

Section 6.4 contains an outline of the overall characteristics for the different proposed bridge design alternatives and how they rate with respect to each of these aforementioned aspects.

6.4 Bridge Alternatives Design Parameters Matrix - Part 1

STRUCTURE TYPE	ALTERNATIVE 1 - STEEL PLATE GIRDERS	ALTERNATIVE 2 - STEEL BOX GIRDERS	ALTERNATIVES 3 & 4 - STEEL NETWORK ARCH (PLATE AND BOX GIRDER APPROACHES)
DESCRIPTION	– NB BRIDGE WIDTH 74'-0" CURB TO CURB – SB BRIDGE WIDTH 72'-0" CURB TO CURB – 6 - 11'-0" NB & SB LANES IN TEMPORARY CONDITION ON NB BRIDGE – 4 - 12'-0" NB & SB LANES IN FINAL CONDITION ON NB & SB BRIDGES – LENGTH OF NB & SB BRIDGES 1300'-0" C.L. TO C.L. OF END BEARINGS	– NB BRIDGE WIDTH 74'-0" CURB TO CURB – SB BRIDGE WIDTH 72'-0" CURB TO CURB – 6 - 11'-0" NB & SB LANES IN TEMPORARY CONDITION ON NB BRIDGE – 4 - 12'-0" NB & SB LANES IN FINAL CONDITION ON NB & SB BRIDGES – LENGTH OF NB & SB BRIDGES 1300'-0" C.L. TO C.L. OF END BEARINGS	– CABLE SUPPORTED STRUCTURE ON MAIN SPAN – NB BRIDGE WIDTH 74'-0" CURB TO CURB, SB 72'-0" CURB TO CURB – SUPERSTRUCTURE EXTENDS APPROXIMATELY 6' OUSIDE THE BARRIERS – 6 - 11'-0" NB & SB LANES IN TEMPORARY CONDITION ON NB BRIDGE – 4 - 12'-0" NB & SB LANES IN FINAL CONDITION ON NB & SB BRIDGES – WIDER DECKS FOR ARCH RIB AND CABLE HANGER CONNECTIONS – LENGTH OF NB & SB BRIDGES 1300'-0" C.L. TO C.L. OF END BEARINGS
STRUCTURAL / SUPERSTRUCTURE	– 4 SPAN CONTINUOUS (285'/365'/365'/285') – 7 PLATE GIRDER LINES - CONSTANT DEPTH 12'-0" WEBS – HYBRID DESIGN (GRADES 50 & 70 KSI STEELS) – 3 BFS PER GIRDER IN EACH OF THE 2 END SPANS AND 4 BFS IN EACH OF THE 2 INTERMEDIATE SPANS (14 TOTAL BFS FOR EACH GIRDER LINE) – CIP COMPOSITE DECK ROADWAY - 9" SLAB THICKNESS WITH 3 1/2" HMA OVERLAY AND MEMBRANE WATERPROOFING – 2 MODULAR JOINTS , 1 AT EACH BRIDGE END AT ABUTMENTS – FIXED BEARINGS AT PROPOSED PIER 2, EXPANSION BEARINGS AT PIERS 1 & 3 AND AT END ABUTMENTS	– 4 SPAN CONTINUOUS (285'/365'/365'/285') – 4 BOX GIRDER LINES - CONSTANT DEPTH 10'-0" WEBS – HYBRID DESIGN (GRADES 50 & 70 STEELS) – 3 BFS PER GIDER IN EACH OF THE 2 END SPANS AND 4 BFS IN EACH OF THE 2 INTERMEDIATE SPANS (14 TOTAL BFS FOR EACH GIRDER LINE) – CIP COMPOSITE DECK ROADWAY - 9" SLAB THICKNESS WITH 3 1/2" HMA OVERLAY AND MEMBRANE WATERPROOFING – 2 MODULAR JOINTS , 1 AT EACH BRIDGE END AT ABUTMENTS – FIXED BEARINGS AT PROPOSED PIER 2, EXPANSION BEARINGS AT PIERS 1 & 3 AND AT END ABUTMENTS	– 2 SPAN CONTINUOUS APPROACH (285'/285') ON SOUTH SIDE – 1 SIMPLE SPAN (250') APPROACH ON NORTH SIDE – 1 MAIN SPAN (480') OVER MAIN NAVIGATION CHANNEL – 4 EXPANSION JOINTS - 2 AT BRIDGE ENDS & 2 AT INTERFACE MAIN SPAN PIERS – APPROACH SPANS USE STEEL PLATE OR BOX GIRDER HYBRID DESIGN (GRADES 50 & 70 KSI STEEL) – NETWORK ARCH DESIGN USES 50 GRADE KSI STEEL – CIP COMPOSITE DECK ROADWAY - 9" SLAB THICKNESS WITH 3 1/2" HMA OVERLAY AND MEMBRANE WATERPROOFING – STAY CABLES ARE GRADE 270 LOW RELAXATION STRANDS
STRUCTURAL / REDUNDANCY	– MULTIPLE PLATE GIRDERS ARE REDUNDANT	– MULTIPLE BOX GIRDERS ARE REDUNDANT	– CAN BE MADE REDUNDANT AS DISCUSSED IN ARTICLE 5.3 AND 5.4 – STRUCTURE DESIGNED FOR INDIVIDUAL CABLE REPLACEMENT
STRUCTURAL / SUBSTRUCTURE & FOUNDATIONS	– T-SHAPED REINFORCED CONCRETE PIERS WITH A SINGLE RECTANGULAR WALL-TYPE VOIDED COLUMN ABOVE FOUNDATION PEDESTALS – SHALLOW FOUNDATIONS ON ROCK AT PIERS 1 & 2 – ABUTMENTS ON SPREAD FOOTINGS – DEEP FOUNDATIONS USING STEEL H-PILES AT PIER 3	– T-SHAPED REINFORCED CONCRETE PIERS WITH A SINGLE RECTANGULAR WALL-TYPE VOIDED COLUMN ABOVE FOUNDATION PEDESTALS – SHALLOW FOUNDATIONS ON ROCK AT PIERS 1 & 2 – ABUTMENTS ON SPREAD FOOTINGS – DEEP FOUNDATIONS USING STEEL H-PILES AT PIER 3	– STRADDLE BENT REINFORCED CONCRETE PIERS WITH TWO ELLIPTICAL SOLID COLUMNS – SHALLOW FOUNDATIONS ON ROCK AT PIERS 1 & 2 – ABUTMENTS ON SPREAD FOOTINGS – DEEP FOUNDATIONS USING STEEL H-PILES AT PIER 3
HIGHWAY	– PROFILE APPROXIMATELY 8' HIGHER THAN EXISTING BRIDGE TO MAINTAIN NAVIGATION CLEARANCE	– PROFILE APPROXIMATELY 8' HIGHER THAN EXISTING BRIDGE TO MAINTAIN NAVIGATION CLEARANCE	– PROFILE APPROXIMATELY 1' HIGHER THAN EXISTING BRIDGE TO MAINTAIN NAVIGATION CLEARANCE
CONSTRUCTABILITY & CONSTRUCTION SCHEDULE	– POSSIBLE OPPORTUNITIES FOR ABC SUCH AS GIRDER LAUNCHING, FULL DEPTH PRECAST DECK & SPAN BY SPAN ERECTION FROM BARGES – NEED TO ERECT LONG GIRDER SECTIONS IN PAIRS WITH DIAPRAGM BRACING – MORE PIECES TO HANDLE THAN BOX GIRDERS – CONSTRUCTION DURATION: 959 DAYS	– POSSIBLE OPPORTUNITIES FOR ABC SUCH AS GIRDER LAUNCHING & SPAN BY SPAN ERECTION FROM BARGES – MORE INHERENT STABILITY THAN A SINGLE LINE OF PLATE GIRDERS – LESS PIECES TO HANDLE THAN PLATE GIRDERS – CONSTRUCTION DURATION: 794 DAYS	– POSSIBLE OPPORTUNITIES FOR ABC SUCH AS FLOAT-IN FROM RIVER & LAUNCHING FROM LAND ON NORTH SIDE – CONSTRUCTION DURATION - PLATE GIRDERS: 816 DAYS BOX GIRDERS: 765 DAYS
AESTHETICS	– LEAST VISIBLE FROM DISTANCE, LITTLE INDICATION TO DRIVERS OF A RIVER – CLEAN PROFILE LINES DO NOT OBSTRUCT SCENERY	– LEAST VISIBLE FROM A DISTANCE, LITTLE INDICATION TO DRIVERS OF A WATERWAY – CLEAN PROFILE LINES DO NOT OBSTRUCT SCENERY – SIMPLE AND SLENDER FROM BELOW	– RESEMBLES EXISTING STRUCTURE – MODERN APPEARANCE & STATE-OF-THE-ART DESIGN
INSPECTION & MAINTENANCE	– PLATE GIRDER WEBS, FLANGES, BOLTED FIELD SPLICES AND CROSS FRAMES AS WELL AS BEARINGS AND EXPANSION JOINTS ARE VISIBLE AND READILY ACCESSIBLE FOR INSPECTION AND MAINTENANCE – 75 YR LIFETIME MAINTENANCE COST = $3,925,000	– LESS MAINTENANCE NEEDED THAN FOR STEEL PLATE GIRDER BRIDGES – ADDITIONAL EFFORT NEEDED TO INSPECT THE INTERIOR OF THE BOX GIRDERS. ACCESS OPENINGS WOULD BE PROVIDED. – BEARINGS AND EXPANSION JOINTS ARE ACCESSIBLE – 75 YR LIFETIME MAINTENANCE COST = $4,190,000	– STAY CABLES WILL REQUIRE INCREASED MAINTENANCE – TIE GIRDER INSPECTIONS WILL REQUIRE "CONFINED SPACE" PROCEDURES – 75 YR LIFETIME MAINTENANCE COST = $4,350,000 (ALT 3) $4,480,000 (ALT 4)
ENVIRONMENTAL	– TOTAL FOOTPRINT OF FOOTINGS EQUAL TO 10,152 SQ. FT. – SOME ADDITIONAL IMPACT FROM RAISED PROFILE	– TOTAL FOOTPRINT OF FOOTINGS EQUAL TO 10,152 SQ. FT. – SOME ADDITIONAL IMPACT FROM RAISED PROFILE	– TOTAL FOOTPRINT OF FOOTINGS EQUAL TO 14,527 SQ. FT. – NO ADDITIONAL IMPACT FROM RAISED PROFILE
CONSTRUCTION COST	– TOTAL ESTIMATED CONSTRUCTION COST = $91,820,000	– TOTAL ESTIMATED CONSTRUCTION COST = $99,720,000	– TOTAL ESTIMATED CONSTRUCTION COST = $100,120,000 (ALT 3) $103,760,000 (ALT 4)

6.4 Bridge Alternatives Design Parameters Matrix - Part 2

STRUCTURE TYPE	ALTERNATIVE 5 - SEGMENTAL CONCRETE BOX GIRDERS	ALTERNATIVE 6 - SINGLE TOWER EXTRADOSED	ALTERNATIVES 7 & 8 - SINGLE TOWER CABLE STAYED (CONCRETE & STEEL BOX GIRDERS)
DESCRIPTION	– NB BRIDGE WIDTH 74'-0" CURB TO CURB – SB BRIDGE WIDTH 72'-0" CURB TO CURB – 6 - 11'-0" NB & SB LANES IN TEMPORARY CONDITION ON NB BRIDGE – 4 - 12'-0" NB & SB LANES IN FINAL CONDITION ON NB & SB BRIDGES – LENGTH OF NB & SB BRIDGES 1300'-0" C.L. TO C.L. OF END BEARINGS	– CABLE SUPPORTED STRUCTURE – NB BRIDGE WIDTH 74'-0" CURB TO CURB, SB 72'-0" CURB TO CURB – DECK EXTENDS APPROXIMATELY 7' OUSIDE THE BARRIERS – 6 - 11'-0" NB & SB LANES IN TEMPORARY CONDITION ON NB BRIDGE – 4 - 12'-0" NB & SB LANES IN FINAL CONDITION ON NB & SB BRIDGES – LENGTH OF NB & SB BRIDGES 1300'-0" C.L. TO C.L. OF END BEARINGS	– CABLE SUPPORTED STRUCTURE – NB BRIDGE WIDTH 74'-0" CURB TO CURB, SB 72'-0" CURB TO CURB – DECK EXTENDS APPROX. 9' (CONCRETE) AND 6'-6" (STEEL) OUSIDE THE BARRIERS – 6 - 11'-0" NB & SB LANES IN TEMPORARY CONDITION ON NB BRIDGE – 4 - 12'-0" NB & SB LANES IN FINAL CONDITION ON NB & SB BRIDGES – LENGTH OF NB & SB BRIDGES 1300'-0" C.L. TO C.L. OF END BEARINGS
STRUCTURAL / SUPERSTRUCTURE	– 4 SPAN CONTINUOUS (265'/385'/385'/265') – 3 WEBS CONCRETE BOX GIRDER - GIRDER DEPTH VARIES FROM 20'-0" TO 10'-0", BOTTOM SLAB THICKNESS VARIES FROM 9" TO 3'-0" – USES LONGITUDINAL POST-TENSIONING – USES TRANSVERSE POST-TENSIONING IN TOP SLAB – 2 MODULAR JOINTS , 1 AT EACH BRIDGE AT ABUTMENTS – GIRDER TOP SLAB PROTECTED BY 3 1/2" HMA OVERLAY AND MEMBRANE WATERPROOFING – EXPANSION BEARINGS AT ABUTMENTS AND PIERS 1 AND 3. FIXED BEARING AT PIER 2	– 4 SPAN CONTINUOUS (250'/400'/400'/250') – 3 WEBS CONCRETE BOX GIRDER - GIRDER DEPTH VARIES FROM 18'-0" TO 10'-0", BOTTOM SLAB THICKNESS VARIES FROM 9" TO 2'-0" – SUPPORTED BY TWO CABLE PLANES WITH 11 CONTINUOUS STAY CABLES IN EACH CABLE PLANE – 2 MODULAR JOINTS , 1 AT EACH BRIDGE END AT ABUTMENTS – GIRDER TOP SLAB PROTECTED BY 3 1/2" HMA OVERLAY AND MEMBRANE WATERPROOFING – EXPANSION BEARINGS AT ABUTMENTS AND PIERS 1 AND 3. FIXED BEARING AT PIER 2	– 4 SPAN CONTINUOUS (250'/400'/400'/250') – TWO 320' LONG 6'-0" DEEP EDGE GIRDERS FOR BOTH CONCRETE AND STEEL ALTS. SPANNING ON EACH SIDE OF THE PYLON WITH A TRANSITION TO APPROACHES CONSISTING OF CONCRETE BOX GIRDERS OR STEEL BOX GIRDERS WHICH EXTEND TO THE ABUTMENTS – CONCRETE BOX GIRDER VARIES FROM 6'-0" TO 13'-0" IN DEPTH – STEEL BOX GIRDER VARIES FROM 6'-0" TO 10'-0" IN DEPTH – SUPPORTED BY TWO CABLE PLANES WITH 26 CABLES ON EACH CABLE PLANE – 2 MODULAR JOINTS , 1 AT EACH BRIDGE ABUTMENT – GIRDER TOP SLAB PROTECTED BY 3 1/2" HMA OVERLAY AND MEMBRANE WATERPROOFING – CIP COMPOSITE DECK ROADWAY - 8.5" SLAB THICKNESS (EXCEPT OVER CONCRETE BOX GIRDERS) WITH 3 1/2" HMA OVERLAY AND MEMBRANE WATERPROOFING
STRUCTURAL / REDUNDANCY	– CONCRETE STRUCTURE IS REDUNDANT	– CONCRETE STRUCTURE IS REDUNDANT – STRUCTURE DESIGNED FOR INDIVIDUAL CABLE REPLACEMENT	– CABLE-STAYED TYPE BRIDGES ARE CONSIDERED REDUNDANT – STRUCTURE DESIGNED FOR INDIVIDUAL CABLE REPLACEMENT – EDGE BEAMS FORM HINGES AT FAILURE AND BECOME COMPRESSION MEMBERS
STRUCTURAL / SUBSTRUCTURE & FOUNDATIONS	– REINFORCED CONCRETE PIERS WITH A SINGLE RECTANGULAR WALL-TYPE VOIDED COLUMN ABOVE FOUNDATION PEDESTALS – SHALLOW FOUNDATIONS ON ROCK AT PIERS 1 & 2 – DEEP FOUNDATIONS USING STEEL H-PILES AT PIER 3 – ABUTMENTS ON SPREAD FOOTINGS	– GOAL POST SHAPE PYLON AT PIER 2 - WITH: UPPER PYLON - TWO SOLID COLUMNS W/RECTANGULAR CROSS-SECTION LOWER PYLON - WALL-TYPE VOIDED COLUMN WITH DIAPHRAGMS – REINFORCED CONCRETE T-PIERS WITH: SINGLE RECTANGULAR WALL-TYPE VOIDED COLUMN AT PIERS 1 AND 3 – SHALLOW FOUNDATIONS ON ROCK AT PIERS 1 & 2 – DEEP FOUNDATIONS USING STEEL H-PILES AT PIER 3 – ABUTMENTS ON SPREAD FOOTINGS	– GOAL POST SHAPE PYLON AT PIER 2 -WITH: UPPER PYLON - TWO WALL-TYPE VOIDED COLUMNS W/RECT. CROSS-SECTION LOWER PYLON - SINGLE WALL-TYPE VOIDED COLUMN WITH DIAPHRAGMS – REINFORCED CONCRETE T-PIERS WITH: SINGLE RECTANGULAR WALL-TYPE VOIDED COLUMN AT PIERS 1 AND 3 – SHALLOW FOUNDATIONS ON ROCK AT PIERS 1 & 2 – DEEP FOUNDATIONS USING STEEL H-PILES AT PIER 3 – ABUTMENTS ON SPREAD FOOTINGS
HIGHWAY	– PROFILE APPROXIMATELY 8' HIGHER THAN EXISTING BRIDGE TO MAINTAIN NAVIGATION CLEARANCE	– PROFILE APPROXIMATELY 8' HIGHER THAN EXISTING BRIDGE TO MAINTAIN NAVIGATION CLEARANCE	– PROFILE APPROXIMATELY 1' HIGHER THAN EXISTING BRIDGE TO MAINTAIN NAVIGATION CLEARANCE
CONSTRUCTABILITY & CONSTRUCTION SCHEDULE	– POSSIBLE OPPORTUNITIES FOR ABC INCLUDE: PRECAST BOTH SUPERSTRUCTURE AND SUBSTRUCTURE; BALANCED CANTILEVER CONSTRUCTION ERECT FROM BARGES BY OVERHEAD GANTRY OR BY CRANES – FALSEWORK CONSTRUCTION IS REQUIRED NEAR ABUTMENTS – CONSTRUCTION DURATION: 1054 DAYS	– POSSIBLE OPPORTUNITIES FOR ABC INCLUDE: PRECAST BOTH SUPERSTRUCTURE AND SUBSTRUCTURE – STEEL TOWERS MAY BE USED TO ACCELERATE CONSTRUCTION – COULD USE TWIN VERTICAL LEG TOWERS FOR CONSTRUCTION – CONSTRUCTION DURATION: 1086 DAYS	– POSSIBLE OPPORTUNITIES FOR ABC INCLUDE: PRECAST BOTH SUPERSTRUCTURE AND SUBSTRUCTURE – STEEL TOWERS MAY BE USED TO ACCELERATE CONSTRUCTION – COULD USE TWIN VERTICAL LEG TOWERS FOR CONSTRUCTION – CONSTRUCTION DURATION - CONCRETE: 1478 DAYS STEEL: 1226 DAYS
AESTHETICS	– LEAST VISIBLE FROM A DISTANCE, LITTLE INDICATION TO DRIVERS OF A WATERWAY – CLEAN PROFILE LINES DO NOT OBSTRUCT SCENERY – SIMPLE AND SLENDER FROM BELOW	– SUPERSTRUCTURE CENTERED ON BRIDGE, CAN BE SEEN FROM A DISTANCE – LOWER PROFILE VERSION OF CABLE-STAYED, SIMILAR SCALE TO EXISTING – THOSE NAVIGATING THE RIVER WILL BE AWARE OF THEIR POSITION	– CONCRETE PYLONS ARE CENTERED ON THE BRIDGE AND CAN BE SEEN FROM THE GREATEST DISTANCE OF ALL ALTERNATIVES – THOSE NAVIGATING THE RIVER WILL BE AWARE OF THEIR POSITION
INSPECTION & MAINTENANCE	– CONCRETE BRIDGES REQUIRE MINIMAL MAINTENANCE – ADDITIONAL EFFORT NEEDED TO INSPECT THE INTERIOR OF THE BOX GIRDERS. ACCESS OPENINGS WOULD BE PROVIDED. – 75 YR LIFETIME MAINTENANCE COST = $2,990,000	– STAY CABLES WILL REQUIRE INCREASED MAINTENANCE AND INSPECTION – ADDITIONAL EFFORT NEEDED TO INSPECT THE INTERIOR OF THE BOX GIRDERS. ACCESS OPENINGS WOULD BE PROVIDED. – 75 YR LIFETIME MAINTENANCE COST = $3,780,000	– STAY CABLES WILL REQUIRE INCREASED MAINTENANCE AND INSPECTION – ADDITIONAL EFFORT NEEDED TO INSPECT THE INTERIOR OF THE BOX GIRDERS AT END SPANS. ACCESS OPENINGS WOULD BE PROVIDED. – 75 YR LIFETIME MAINTENANCE COST = $3,430,000 (ALT 7) AND $5,290,000 (ALT 8)
ENVIRONMENTAL	– TOTAL FOOTPRINT OF FOOTINGS EQUAL TO 9,347 SQ. FT. – SOME ADDITIONAL IMPACT FROM RAISED PROFILE	– TOTAL FOOTPRINT OF FOOTINGS EQUAL TO 10,901 SQ. FT. – SOME ADDITIONAL IMPACT FROM RAISED PROFILE	– TOTAL FOOTPRINT OF FOOTINGS EQUAL TO 11,442 SQ. FT. – NO ADDITIONAL IMPACT FROM RAISED PROFILE
COST	– TOTAL ESTIMATED CONSTRUCTION COST = $92,760,000	– TOTAL ESTIMATED CONSTRUCTION COST = $103,250,000	– TOTAL ESTIMATED CONSTRUCTION COST = $92,760,000 (ALT 7) $97,670,000 (ALT 8)

6.5 Evaluation Matrix

Considering aspects outlined in Section 6.3 of this report, the eight (8) different bridge design alternatives were ranked by a team of senior engineers. Each aspect was reviewed only by engineers specializing in each related field. The rating is identified as one of five (5) levels: Poor, Fair, Good, Very Good and Excellent, with corresponding numerical factors of 1, 2, 3, 4 and 5 respectively.

To the maximum extent possible, objective, quantifiable rankings were obtained for each aspect. Several aspects were identified as fully quantifiable, such as construction cost, life cycle and maintenance cost, and schedule. These aspects were rated using MassDOT's best value formula, where the ranking represents how close the alternative is to the best value. See Section 6.3 for the criteria used for each aspect.

Once rated by the individual professionals, the ratings were averaged for each aspect. The ratings for each aspect were then totaled for each alternative. The structure with the maximum cumulative rating is, theoretically, the most appropriate bridge type.

The evaluation process concluded that Alternative 4, Steel Network Arch with Steel Box Girder Approaches, ranked the first amongst all eight alternatives with the highest Rating Factor of 35.5.

Alternative 3, Steel Network Arch with Steel Plate Girder Approaches, ranked second with a Rating Factor of 34.4, a difference of 1.1 points below Alternative 4, the top choice. Alternative 6, Single Tower Extradosed, ranked last amongst all design alternatives with the lowest Rating Factor of 31.0.

The evaluation matrix shown in Table 6.2 on following page summarizes the ratings that resulted for each design alternative as an outcome of this multidiscipline evaluation process. The individual ratings can be found in Appendix 7.

Table 6.2: Main River Crossing - Evaluation Matrix

	ALTERNATIVE 1	ALTERNATIVE 2	ALTERNATIVE 3	ALTERNATIVE 4	ALTERNATIVE 5	ALTERNATIVE 6	ALTERNATIVE 7	ALTERNATIVE 8
ASPECT	STEEL PLATE GIRDERS	STEEL BOX GIRDERS	STEEL NETWORK ARCH & STEEL PLATE GIRDER APPROACHES	STEEL NETWORK ARCH & STEEL BOX GIRDER APPROACHES	SEGMENTAL CONCRETE BOX GIRDER	SINGLE TOWER EXTRADOSED	SINGLE TOWER CABLE STAYED & CONCRETE BOX GIRDER	SINGLE TOWER CABLE STAYED & STEEL BOX GIRDERS
STRUCTURAL / REDUNDANCY	4.4	4.2	3.4	3.4	4.0	3.4	3.4	3.4
HIGHWAY/PROFILE IMPACT	2.0	2.0	4.0	4.0	2.0	2.0	4.0	4.0
INSPECTION & MAINTENANCE	3.0	3.3	2.5	2.7	4.2	3.3	3.3	3.2
ABC / SCHEDULE IMPACTS	4.0	4.8	4.7	5.0	3.6	3.5	2.6	3.1
CONSTRUCTABILITY	4.5	4.7	3.2	3.2	3.8	3.0	3.0	3.0
AESTHETICS	1.4	2.4	4.6	5.0	2.5	3.6	3.7	3.7
ENVIRONMENTAL	3.0	3.3	4.0	4.5	3.3	3.8	3.5	3.5
CONSTRUCTION COST	5.0	4.6	4.6	4.4	4.9	4.4	4.9	4.7
LIFE CYCLE COST	3.8	3.6	3.4	3.3	5.0	4.0	4.4	2.8
TOTAL RATING	31.1	32.9	34.4	35.5	33.3	31.0	32.8	31.4

RANK	7	4	2	1	3	8	5	6

RATINGS:
1 = POOR
2 = FAIR
3 = GOOD
4 = VERY GOOD
5 = EXCELLENT