



Comparison of Bridge Rehabilitation versus Bridge Replacement Concepts

Introduction

The comparison of rehabilitation versus replacement of the Sellwood Bridge is being conducted in the early phases of this project as a necessary follow up to Metro's South Willamette River Crossing Study that was finalized in 1999. The study recommendations, adopted by JPACT, Metro, and the City of Portland, included preserving the bridge in its current condition or replacing it as a two-lane bridge. Since the time of the study, the bridge has further deteriorated. In 2000, the County determined that the bridge could not be safely preserved in its 1999 condition, and weight limits were reduced to preclude use of the bridge by buses, emergency vehicles, and heavy trucks. Structural deficiencies of the existing bridge are detailed in the "Sellwood Bridge Existing Structural Deficiencies Technical Memorandum" prepared in August 2006.

The current analysis re-examines the 1999 Metro study recommendation(s) and analyzes rehabilitation and replacement options in greater detail. The aim of this work is to provide information to support development of the Purpose and Need Statement for the project, assisting decision makers in determining if the statement of purpose and need should specify bridge rehabilitation or bridge replacement rather than require further consideration of both sets of options. This draft memorandum does not propose project alternatives or cross sections, that will be developed later in the project, but merely draws distinctions between likely rehabilitation and replacement concepts to assist in development of the Purpose and Need Statement.

This draft memorandum compares rehabilitation and replacement of the bridge using two rehabilitation concepts and six replacement concepts. It presents assumptions for comparing concepts, describes various concepts, and provides cost estimates and observations about each of the concepts. Based on these findings, a summary is offered.

Assumptions

This memorandum examines two potential concepts for bridge rehabilitation and six potential concepts for bridge replacement. Each concept has been optimized to achieve, as much as possible, an "apples to apples" comparison between rehabilitation and replacement costs. All options are capable of carrying legal loads (trucks, emergency vehicles, and buses). However, due to limitations imposed by the geometry and structural integrity of the existing bridge,

bridge width and length for rehabilitation options are not exactly the same as those for the replacement options.

What follows are the assumptions used to calculate cost information. Where warranted, the rationale behind each of these assumptions is included as Attachment A at the end of this memorandum.

General Assumptions

General assumptions for the comparison analysis between bridge rehabilitation concepts and bridge replacement concepts are described below.

Type of Cost Estimates

- Costs are presented in 2006 dollars. Because of inflation, costs will undoubtedly be higher when the bridge is constructed at a future date. Costs, such as repainting the steel members, that will be incurred after initial construction have been adjusted to reflect the anticipated rate of inflation at 4.5 percent and the cost of capital estimated at 5.25 percent per year.
- Costs estimates do not represent the project cost of rehabilitation or replacement of the bridge; only those costs that differentiate between rehabilitation and replacement are included. Costs that would be similar for either option – such as reconstruction of the west side interchange, east side tie-in, routine maintenance and mitigation – are not included.

Bridge Boundary Assumptions

- The two rehabilitation concepts and six replacement concepts include all of the structure from the east abutment to the west abutment of the existing bridge.
- The alignment of the replacement bridge is outside of the existing bridge alignment, within several hundred feet to the north or south of the existing bridge.
- Concepts 1 through 4 assume all the concrete approach spans will be replaced, and concrete deck and flooring system of the truss will be replaced. All approach concrete spans, steel girders, deck, railing, floor beams, and stringers are not worthy of rehabilitation or strengthening.

Service Life of the Structure

- The life-cycle cost analysis for the structure is based on a 75-year service life.¹
- The design life of the Sellwood Bridge is 75 years.²
- The metal fatigue of the existing 80-year old steel truss members was not thoroughly investigated. Metal fatigue may have some effect on the 75-year service life of a rehabilitated structure.

¹ Service life is defined as the length of time the structure is expected to be in operation.

² AASHTO Load-and-Resistance Factor Design (LRFD) Bridge Design Specifications define design life as the length of time within which the loads and load and resistance factors for design are not expected to be exceeded.

Contingency

- At the conceptual phase of a project, it is typical to include a large contingency, expressed as a percentage of construction cost, to represent the uncertainty of the cost estimates. The contingency takes into consideration unknown costs associated with the estimates. The use of contingency is expected to reduce the potential downside of underestimating the project. A 40-percent contingency was applied to the construction cost of the project for both rehabilitation and replacement concepts.
- An additional 10 percent contingency was added to cover the cost of construction engineering, including construction management, for both rehabilitation and replacement concepts.

Design

- The design cost includes bridge engineering, geotechnical investigation, hydraulic analysis, survey and mapping, roadway and traffic control, and environmental permitting. It is captured as a percentage of construction cost. Due to the inherent difficulty associated with designing bridge rehabilitation and strengthening, the design costs are expected to be significantly higher than the cost to design new bridges. For this reason, the cost of design is estimated at 18 percent of construction cost for the rehabilitation concepts, and 12 percent for replacement concepts.

Assumptions Regarding Specific Bridge Elements

Roadway/Structure Width

- For purposes of comparison, cross sections for the replacement concepts were developed on the basis of information about standards obtained from the City of Portland, Multnomah County, and the Oregon Department of Transportation. Replacement concepts were developed with 12-foot travel lanes and 14-foot width for shoulders, bicycle, and pedestrian facilities. These cross sections are placeholders that will be refined as part of the alternatives development process later in the project.
- Cross sections for the rehabilitation concepts used the maximum allowable cross section within the constraints of truss strength, which is two 12-foot travel lanes, two 2-foot shoulders, and shared bicycle/pedestrian multi-use paths. One concept is for two 10-foot multi-use paths at the roadway level, and the other concept uses a single 14-foot path at the level of the truss lower chords.
- Because the future travel demand for the bridge has not yet been determined, and it is not known if two travel lanes will accommodate future demand, four travel lane concepts have also been developed where they are structurally possible for comparison purposes.

Vertical and Horizontal Clearance

- Both rehabilitation and replacement concepts maintain the existing vertical clearance over the Willamette River.
- The approach spans on each side of the main river spans for the bridge rehabilitation/strengthening concepts will likely have span lengths ranging from 120 to 150 feet. The superstructure will most likely consist of precast concrete girder spans with overall lengths

for each approach on both sides of the steel truss spans of 590 feet (east approach) and 300 feet (west approach), respectively, that match the existing approach spans in length.

For more detail on the rationale for these assumptions, see Attachment A.

Deck Floor System

- The existing truss deck floor system does not have sufficient strength to carry current design vehicle loads.
- To maximize the utility of the existing truss, use of preformed fiber reinforced polymer (FRP), which is lighter than conventional concrete, is assumed for construction of the bicycle/pedestrian multi-use paths in the reconstruction concepts.

For more detail on the rationale for these assumptions, see Attachment A.

Truss System

- To accommodate existing loads and to add heavy traffic, the truss must be strengthened. There is a limit to how much it can be strengthened, and the proposed concepts push the existing truss as far as it can go. The proposed concepts maximize the utility of the existing truss by incorporating light weight materials (other than lightweight concrete) for reconstruction of the deck and FRP deck panels for sidewalks and bike paths.

For more detail on the rationale for these assumptions, see Attachment A.

Seismic Retrofit

- Cost estimates for Phase I and Phase II seismic retrofits have been included as part of the rehabilitation concepts. The Phase II seismic retrofit incorporates seismic retrofit of the truss span bridge pier foundations in the river and strengthening of truss crossframes and lateral bracing.
- Considering the poor condition of the concrete approach spans, the insufficient capacity to support desired vehicle loads, and the significant improvements needed to accommodate the 1,000-year return period earthquake, the County has already decided to replace the approach spans with structures designed for current seismic design standards.

For more detail on the rationale for these assumptions, see Attachment A.

Detour Bridge

- Construction of the rehabilitation concepts requires closure of the bridge to traffic. The cost of a temporary detour bridge constructed near the existing bridge has been included to allow maintenance of traffic during construction. The detour bridge cross-section is narrow to minimize construction cost.
- Closure of the bridge to traffic for the bridge replacement concepts is expected to be minimal and limited to the time required to construct tie-ins at bridge approaches; thus, no detour bridge cost is included for the replacement concepts.

Right of Way

It is difficult to estimate right-of-way costs at this time. Specific alignments have not been identified, development of some parcels is expected to occur in the immediate future, and costs

for relocation and damages will vary dramatically from parcel to parcel. Yet, it is important for this analysis to reflect the differences between right-of-way costs for rehabilitation and replacement options. Toward that end, costs have been developed on the basis of these assumptions:

- The values presented for each concept represent current market value estimates identified by the Multnomah County assessors' office.
- Any parcel touched by the design envelope will be acquired in its entirety.
- No allowance was made for severance damages and or cost to cure damages associated with partial property acquisitions.
- No costs were estimated for property acquisition expenses or for relocation expense.
- Properties will be acquired by fee as opposed to easements.

Maintenance

- Life-cycle costs for repainting the steel members are based on two repainting cycles for the steel truss and one repainting cycle for the new structural members. The current paint system on the existing truss is expected to last 25 years and the paint system on the new structure is expected to last 40 years. The cost estimates are based on the escalated per-square-foot cost of recently painted steel surface areas on the Hawthorne Bridge and Broadway Bridge. Costs assume removal of existing painted surfaces to bare steel for painting.

Rehabilitation/Strengthening Concepts

Concept 1: Deck Widening/Strengthening

Concept 1 is illustrated in Figure 1. This concept is configured into two 12-foot lanes with two 2-foot shoulders. To help reduce bridge width, the bike paths and sidewalks are combined into two 10-foot multi-use paths constructed with FRP decks and separated from the roadway by traffic barriers. Doing so will lower the structure weight and limit the distance the wheel loads can overhang the existing truss. However, the multi-use paths both overhang the truss significantly, and pedestrian loading is similar in magnitude to a vehicular lane load.

Concept 1 has significant overload of the existing truss chords and diagonals. In determining overload, a comparison of the required loads, or demands, to the member capacity is made. Demand capacity ratios greater than 1.0 mean that the member must be strengthened. See Attachment B for detailed information on the demand-to-capacity ratios of the truss for this concept.

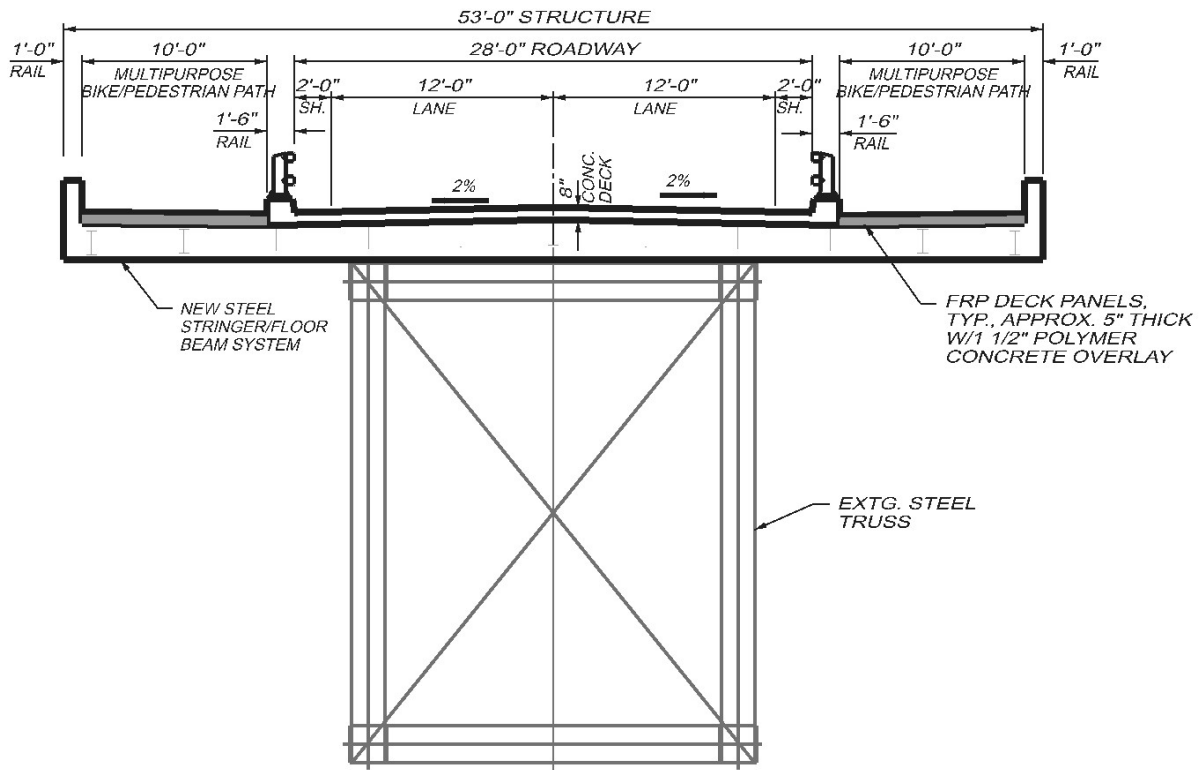
Pros of Concept 1

- Maintains existing alignment and tie-in to approaches
- Re-uses existing truss

Cons of Concept 1

- Requires right of way on both sides of existing roadway
- Substandard 2-foot shoulder width/no breakdown lane/no lane for emergency vehicles to pull over
- Requires a detour bridge and associated temporary right of way
- 75 percent of the main chord and 100 percent of diagonal members need strengthening
- Strengthening/rehabilitation of existing truss requires either:
 - Permitting for barge/crane access from river (strengthening easier under less load)
 - Performing incremental repairs by access from existing deck (strengthening more difficult under high dead and equipment loads)
- Construction duration for truss strengthening/rehabilitation is longer than for replacement
- Rehabilitation often exposes problems and cost items not seen or anticipated at the start
- Existing truss will be reused, but modifications to the structure may compromise historic character
- Requires complete containment for removal of lead based paint and repainting

FIGURE 1 — Concept 1: Deck Widening With Strengthening



CONCEPT 1: DECK WIDENING W/STRENGTHENING

Concept 2: Double Deck Widening/Strengthening

Concept 2, as illustrated in Figure 2, uses the same vehicular roadway configuration as Concept 1, but places a multi-purpose bicycle and pedestrian path on a new floor system at the truss bottom chords.

See Attachment B for details on the demand-to-capacity ratios of the truss under this concept.

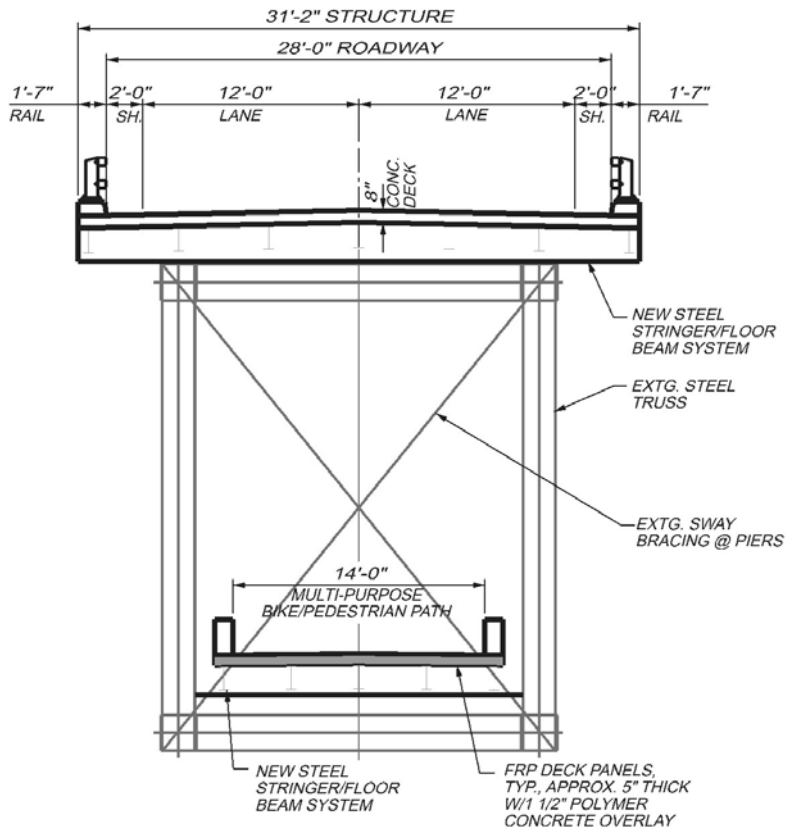
Pros of Concept 2

- Maintains existing alignment and tie in to approaches
- Re-uses existing truss

Cons of Concept 2

- Sub-standard 2-foot shoulder width/no breakdown lane/no land for emergency vehicles to pull over
- Pedestrian/bike path interferes with truss seismic sway bracing at piers and requires new stringer/floor beam system at truss bottom chord level
- Pedestrian/bicycle safety is compromised in isolated “tunnel” environment
- Requires a detour bridge and associated temporary right of way/easement
- 37.5 percent of the main chord and 90 percent of the diagonal members need strengthening
- Strengthening/rehabilitation of existing truss requires either:
 - Permitting for barge/crane access from river (strengthening easier under less load)
 - Performing incremental repairs by access from existing deck (strengthening more difficult under high dead and equipment loads)
- Construction duration for truss strengthening/rehabilitation longer than for replacement
- Rehabilitation often exposes problems and cost items not seen or anticipated at the start
- Existing truss is reused, but modifications to the structure may compromise historic character
- Requires complete containment for removal of lead-based paint and repainting

FIGURE 2 — Concept 2: Double Deck Widening With Strengthening



CONCEPT 2: DOUBLE DECK WIDENING W/STRENGTHENING

Bridge-Only Cost Estimates for Rehabilitation/Strengthening

The cost estimates for the two bridge rehabilitation/strengthening concepts are presented in Table 1 below.

TABLE 1
Bridge-Only Cost Estimate for Rehabilitation/Strengthening Concepts (2006 Dollars)

Cost Element	Bridge Rehabilitation/Strengthening Concept Costs*			
	Deck Widening/Strengthening		Double Deck Widening/ Strengthening	
	1		2	
	2-Lane		2-Lane	
	Low	High	Low	High
Approach Spans	\$10	\$11	\$11	\$12
Main Span	\$18	\$21	\$18	\$20
Seismic Retrofit	\$23	\$25	\$23	\$25
Detour Bridge	\$12	\$23	\$12	\$23
Contingency	\$32	\$40	\$31	\$40
Design	\$10	\$11	\$10	\$11
Right of Way**	\$2.0		\$2.0	
Repainting	\$10		\$10	
Routine Maintenance	Not Included		Not Included	
Westside Interchange	Not Included		Not Included	
Eastside Tie-in	Not Included		Not Included	
Mitigation	Not Included		Not Included	
TOTAL COST***	\$117M	\$143M	\$117M	\$143M

* All costs are reported in millions (M) and 2006 dollars.

** All right-of-way costs are based on tax assessor property values.

*** This does not reflect the total cost of the project, only the costs that differentiate between rehabilitation and replacement concepts

Approach Spans

Both sets of existing approach spans must be demolished. The new approach spans will match deck widths to each bridge rehabilitation/strengthening concept. An average unit cost of \$200/square foot of deck surface was used for the cost estimate. The approach spans for Concept 2 (double deck widening option) are expected to cost more than Concept 1 (deck widening concept), with an addition of a second level structure for the bike and pedestrian path below the main roadway.

Main Span

Superstructure rehabilitation and strengthening work to correct load carrying deficiencies are as follows:

- Remove the existing bridge rails, concrete deck, sidewalk, and wearing surface.
- Remove the existing steel stringers and floor beams.
- Construct an enclosure around the remaining truss structure to allow removal, collection, and disposal of the existing lead-based paint system.
- Strengthen truss members and gusset plate connections by adding steel side plates. This will require removing existing rivets in stages and replacing them with high strength bolts.
- Fabricate and erect new steel floor beams and stringers.
- Paint the rehabilitated truss and floor system.
- Construct a new concrete roadway deck and bridge rails.
- Construct new FRP multi-use bicycle and pedestrian facilities.

Both Concepts 1 and 2 require strengthening of the existing truss to accommodate the increase in design loading. Strengthening an 80-year-old riveted steel truss will raise some difficult construction staging issues with removing rivets in members and gusset connection plates. Although repair and strengthening concepts can be engineered, opening up old structures often identifies additional repairs that must be made. This triggers new costs that cannot be anticipated.

Seismic Retrofit

Seismic retrofits to address truss span deficiencies are assumed to be the following:

- Remove and replace existing lateral sway bracing between trusses at each pier with new steel wide flange beams and associated connection plates and high strength bolts. Due to the magnitude of the forces associated with current seismic design standards, the new bracing requires much larger members than the existing one. For Concept 2, an X-type configuration of the new seismic sway bracing limits the width of a bicycle and pedestrian multi-use path between the lower chords of the two trusses to 3 feet maximum for an 8-foot vertical clearance. Replacement of the truss verticals at each pier to create a Vierendeel-type brace is required to accommodate a 14-foot-wide multi-use path with an 8 foot vertical clearance. Even with replacement of the truss verticals, the width of the path is 6 feet narrower than the dual paths provided in Concept 1.
- Replace bearings supporting the trusses at each pier with new lower height bearings to reduce the tension forces on the anchor bolts and instability of the bearings. Add concrete pedestals to support the lower height bearings and help resist earthquake lateral loads.
- Add vertical and horizontal reinforcing steel and concrete encasement of existing Piers 17, 18, 19, and 20 to provide needed additional structural capacity to resist lateral displacements and forces due to earthquake. This will also provide sufficient confinement of the concrete

to ensure acceptable performance of the concrete piers during a 1,000-year return period earthquake.

- Enlarge footings at Piers 17, 18, 19, and 20 to provide sufficient size and bearing capacity to meet current AASHTO design code requirements. This will result in lateral displacement and rocking and bring the structure within code acceptable limits and likely prevent permanent displacement or leaning of the structure.

Seismic retrofit costs are based upon conceptual quantities and in-place material costs of similar types of construction.

Right of Way

Right-of-way costs for both rehabilitation/strengthening concepts are similar. Both concepts will require expansion of the bridge deck to the north and the south, which will have impacts on the same properties.

Detour Bridge

Concept 1 (deck widening with strengthening) and Concept 2 (double deck widening with strengthening) assumes construction of a detour structure to maintain traffic across the Willamette River on Tacoma Street. Under both of these scenarios, it is not feasible to stage construction of the approach spans and river spans to maintain traffic on the existing bridge due to the narrow roadway cross section of 24 feet. Construction of the new approach spans and replacement of the concrete roadway deck on the truss spans will require closure of the existing bridge to traffic.

An alignment to the north of the existing bridge using Spokane Street to the east and connecting to the west at Highway 43 near the current boat launch next to Staff Jennings will be considered. Another alignment to the south, beginning near the east approach and running approximately parallel to the existing bridge and connecting to the west at Highway 43 near the city park, will also be considered.

The detour bridge is expected to be slightly longer than the existing bridge in order to reach the approach roadway at each end of the bridge. Depending on which alignment is selected, there will be some variability in the length of the detour bridge. The cost estimate for the detour structure will be based on the longer of the two alignments. The detour bridge is expected to be at least 2,200 feet long.

The cross section of the detour structure is expected to maintain two 12-foot travel lanes and 2-foot shoulders on each side. Bike and pedestrian access will not be provided. This assumption is based on limited access for bike and pedestrian access at the existing bridge. If bike and pedestrian access is required, an additional 8 feet of roadway cross section plus deck width for a median barrier to separate the traffic from the bike and pedestrian path will be required.

The detour bridge is expected to have a vertical clearance of at least 75 feet through the main navigation channel of the river. The opening between the bridge piers of the detour structure will be narrower than the existing bridge. It is expected that the river spans of the detour bridge will be shorter than the existing bridge taking advantage of the application of precast girders. The use of precast girders is expected to be extremely price competitive. The proposed precast concrete girder superstructure is expected to be supported on piles or drilled shafts foundation.

A similar detour structure was proposed and constructed near the I-5 Willamette River crossing north of the City of Eugene. This structure, which was bid in 2003, cost an average of \$100/square foot. The structure is approximately 2,000 feet long and has tall bridge piers with a superstructure that is approximately 60 feet above the river. The detour bridge has four travel lanes, a median, and full travel shoulders. Because of costs escalation over the last 2 years and the proposed detour structure being significantly narrower than the proposed structure, it is expected that the proposed cost per square foot of the detour structure will be higher; we anticipate the cost will be closer to the \$150/square foot cost.

In addition to the structure cost, the cost of an intersection and right of way at each end of the detour bridge has been included in the estimate. The approach roadway sections will be reconstructed to transition traffic from Tacoma Street to the detour bridge, reconnecting the detour bridge to the west side interchange at Highway 43.

Maintenance

Long-term maintenance of the truss spans will consist of repainting the entire truss every 25 years. Cost for routine maintenance is not included in the cost table because it is expected to be similar for both rehabilitation and replacement options.

Replacement Concepts

Concept 3: Twin Truss (2 Lane)

By constructing an additional two-plane truss parallel to the existing structure, strengthening of the existing truss can be avoided, and additional roadway width achieved. Concept 3, shown in Figure 3, provides a 52-foot-wide cross section of two 12-foot lanes and two 14-foot widths for shoulder, bicycle, and pedestrian facilities. This cross section is a “place holder” concept for purposes of comparison. Design of the cross section for shoulder, bicycle and pedestrian facilities will be completed as part of alternatives development later in the project.

Because extra roadway width is support by an additional truss, the analysis of this concept shows no need to modify the existing truss to obtain extra strength, although some minor repairs are anticipated. Instead, the additional truss acts as the strengthening mechanism. The two trusses are separated by 8-foot center to center of truss planes. Despite reuse of the existing truss, this concept is categorized as a replacement concept because approximately 75 percent of the structure is new.

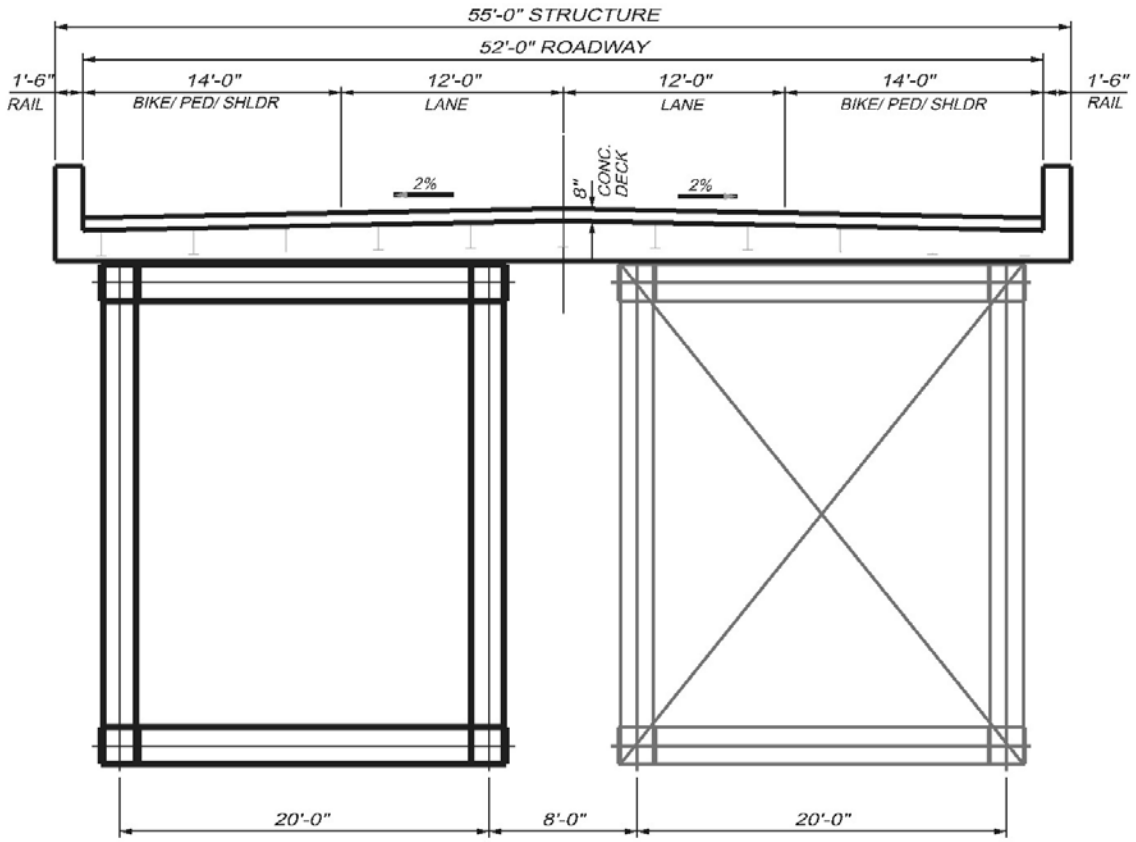
Pros of Concept 3

- Roadway width allows for desirable lane, shoulder, bicycle, and pedestrian facilities
- Meets/maintains current two-lane traffic capacity with safety improvements
- Re-use of existing truss
- Existing truss does not need strengthening
- Staged construction eliminates need for a detour bridge

Cons of Concept 3

- Requires additional right of way
- Proximity of two trusses causes overlap of existing and new pier shafts
- Requires complete containment for removal of lead based paint and repainting
- Additional truss will not have same details as existing truss

FIGURE 3 — Concept 3: Twin Truss With 2-Lane



CONCEPT 3: TWIN TRUSS W/2-LANE

Concept 4: Twin Truss (4 Lane)

Concept 4, shown in Figure 4, also uses an additional two-plane truss. In this concept, the two trusses are separated by 20-foot center to center of truss planes. This spread, along with an increased overhang, is used to accommodate two additional 12-foot travel lanes for a roadway width of 76 feet. This cross section is a “place holder” concept for purposes of comparison. Design of the cross section for shoulder, bicycle and pedestrian facilities will be completed as part of alternatives development later in the project.

The larger spacing between trusses creates an overload situation on both planes of the existing truss, with the interior truss overloaded.

The existing exterior truss is also overloaded, so any double truss spacing arrangement will require strengthening of the existing truss.

See Attachment B for details on the demand-to-capacity ratios of the truss under this concept.

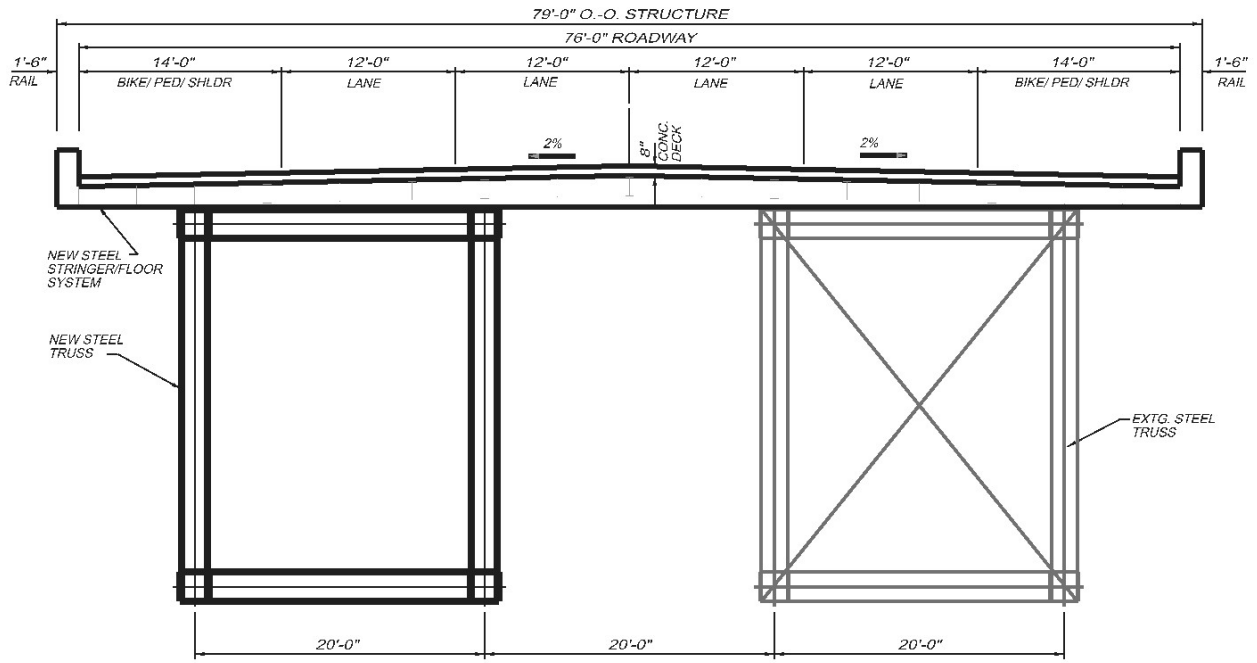
Pros of Concept 4

- Roadway width allows for desirable lane, shoulder, bicycle, and pedestrian facilities
- Re-uses existing truss
- Staged construction eliminates the need for a detour bridge

Cons of Concept 4

- 70 percent of the main chord and 100 percent of the diagonal members need strengthening
- Strengthening/rehabilitation of existing truss requires either:
 - Permitting for barge/crane access from river (strengthening easier under less load)
 - Performing incremental repairs by access from existing deck (strengthening more difficult under high dead and equipment loads)
- Construction duration for truss strengthening longer than for replacement
- There is more uncertainty involved in strengthening/rehabilitation
- Re-uses existing truss – modifications to the structure may compromise historic character
- Additional truss will not have same details as existing and may also compromise historic character
- Requires complete containment for removal of lead based paint and repainting

FIGURE 4 — Concept 4: Twin Truss with Strengthening & 4-Lane



CONCEPT 4: TWIN TRUSS W/STRENGTHENING & 4-LANE

Concept 5: Conventional Bridges

A concrete segmental box girder concept for conventional bridge replacement is shown in Figures 5 and 6. Another concept for conventional replacement is a steel plate girder structure.

FIGURE 5 — Conventional Segmental Box Girder Cross Sections

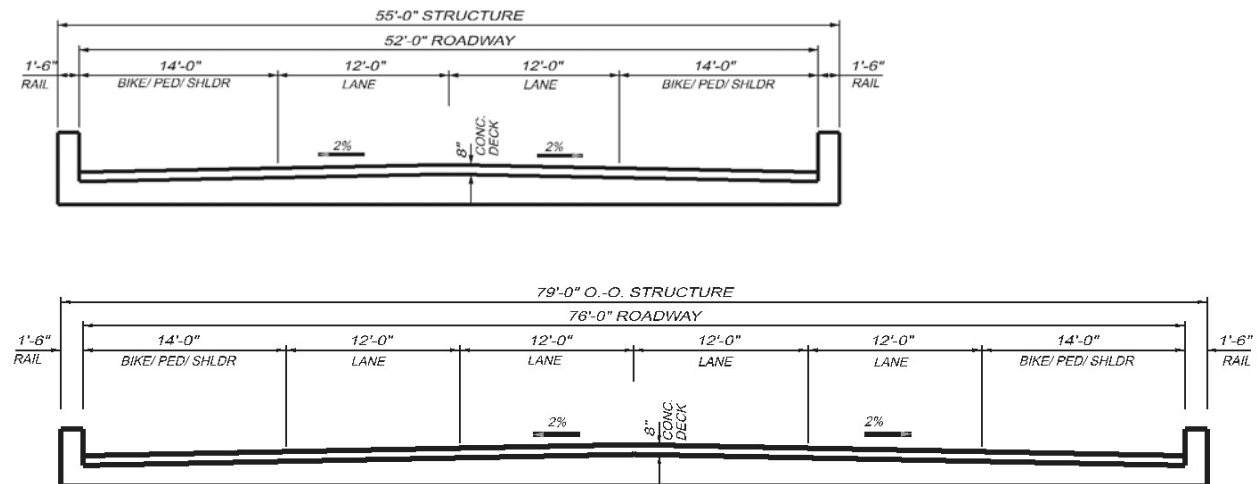
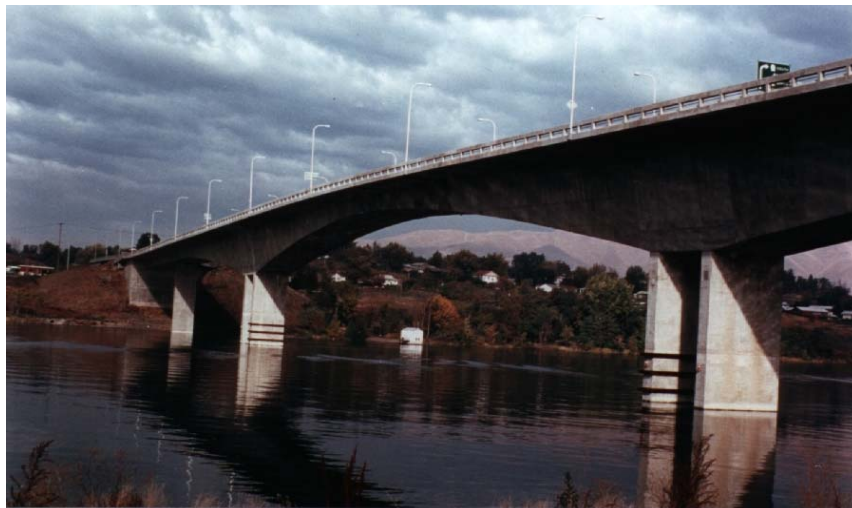


FIGURE 6 — Conventional Segmental Box Girder Example



A concrete box girder will eliminate one of the piers within the river channel, while the steel plate girder will likely retain the current pier layout. These span layouts are based on the most cost competitive layout for each of these structure types.

Both two- and four-lane templates are feasible with any of the conventional replacement concepts. Full bicycle and pedestrian facilities, full shoulders, and modern bridge railings

would also be part of conventional replacement design. This cross section is a “place holder” concept for purposes of comparison. Design of the cross section for shoulder, bicycle and pedestrian facilities will be completed as part of alternatives development later in the project.

A concrete segmental box girder alternative has a deep arch-like soffit across the main river channel. A steel plate girder alternative has either haunched or parallel flange girders for the shorter span. The deck is modern high-performance concrete, requiring very little maintenance. Either type can be constructed adjacent to the existing bridge, so construction of a detour bridge is not necessary. In the case of the concrete segmental box girder, the construction method involves only minimal river equipment because the bridge is constructed in cantilever fashion from each pier. In the case of a steel plate girder bridge, the superstructure is erected with large barge-mounted cranes working in the river throughout the erection process.

Either type of conventional bridge is designed to minimize maintenance costs. The concrete segmental box girder will be all concrete, and have minimal maintenance other than normal roadway upkeep. The steel plate girder requires slightly more maintenance, but it is assumed weathering steel will be used, which requires no painting.

Pros of Concept 5

- Meets traffic safety and seismic safety standards
- May remove a pier from the river to open up the navigational channel
- Provides modern structure with minimal long term maintenance
- Least cost replacement alternative

Cons of Concept 5

- Requires additional right of way
- Results in removal of existing bridge, changing the visual horizon along the river

Concept 6: Signature Bridges

A signature bridge replacement design is based on both function and aesthetics. All of the functional characteristics of the conventional replacement apply to the signature bridge replacement. This cross section is a “place holder” concept for purposes of comparison. Design of the cross section for shoulder, bicycle and pedestrian facilities will be completed as part of alternatives development later in the project.

The iconic stature of the bridge is developed in the design process, and typically includes a more visually striking structure and a more prominent profile on the river. Based on the span arrangement and width of channel, signature spans are longer than those for the conventional bridge, and are likely to result in two piers within the main river channel. Figures 7 and 8 illustrate two possible concepts.

FIGURE 7 — Cable-Stayed and Arch—Signature Replacement Cross Sections

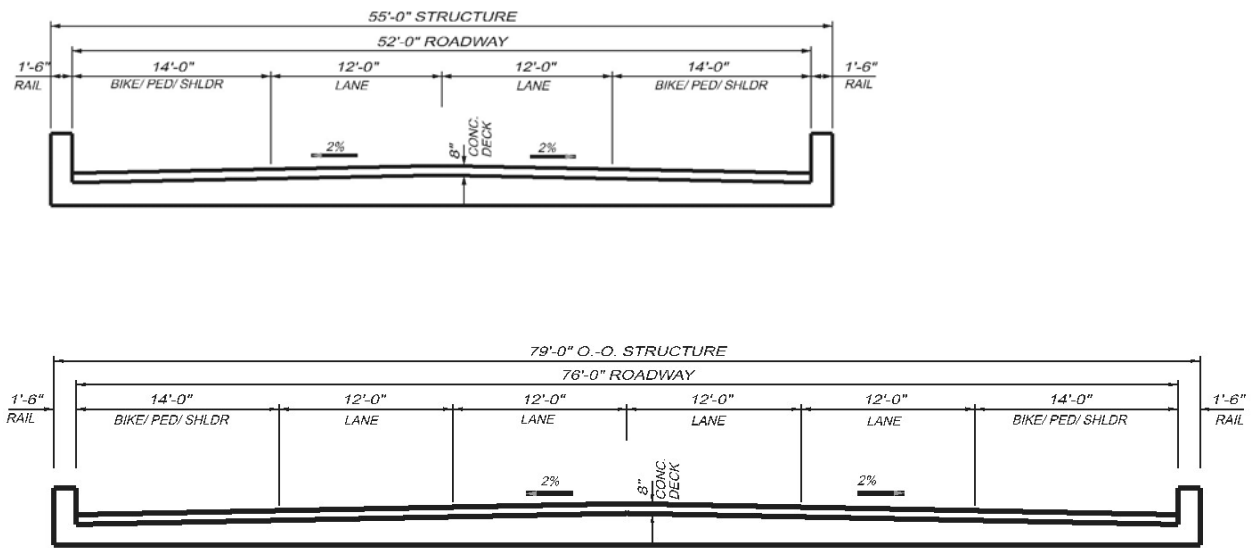


FIGURE 8 — Cable-Stayed and Arch photo



The signature spans offer a pleasing symmetry to the bridge profile, and reduce the amount of work in the river. The longer main span opens up the river to navigation and also improves the hydraulic channel in this reach of the river.

In the pictured example of a cable-stayed concept, the bridge would have a tall pylon that would be unique in the region of the bridge, and a web of cables that would be visible from a considerable distance. The bridge deck would have additional width to accommodate the tower and stay cables that support the deck from above. The main bridge elements would most likely be concrete, which would require only minimal maintenance. The stay cables themselves would require additional inspection and some additional maintenance on a routine basis. In the case of a through arch, the steel arch would require painting as a maintenance item, and would have similar demands for cable inspection (for hangers) as the cable-stayed concept.

In the example of an arch concept, the bridge would have a single span arch across the main portion of the channel. While not as dominant or unique in form as the cable-stayed concept, the grace of a classical arch would blend well with the Freemont and historic bridge structures in the region. The arch concept offers more variations in layout and form than the cable-stayed, so visual effects and costs can vary widely. Both the arch and cable-stayed forms lend themselves to an artistic development for this site.

Pros of Concept 6

- Meets traffic safety and seismic safety standards
- Removes two piers from the river to open up the navigational channel
- Provides modern structure with minimal long term maintenance
- Provides new icon for the community, City and County

Cons of Concept 6

- Requires additional right of way
- Results in removal of existing bridge, changing the visual horizon along the river
- More expensive than a conventional replacement
- Requires more inspection than a conventional replacement

Bridge-Only Cost Estimates for Replacement

Cost estimates for bridge replacement concepts are provided in Table 2.

TABLE 2
Bridge-Only Cost Estimate for Replacement Concepts (2006 Dollars)*

Cost Element	Bridge Replacement Concept Costs*																			
	Twin Truss				Concrete Box Girder				Steel Plate Girder				Cable-Stayed				Arch			
	3		4		5				6a				6b							
	2-Lane		4-Lane		2-Lane		4-Lane		2-Lane		4-Lane		2-Lane		4-Lane		2-Lane		4-Lane	
Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	
Approach Spans	\$11	\$12	\$14	\$16	\$13		\$19		\$13		\$19		\$13		\$19		\$13		\$19	
Main Span	\$25	\$28	\$32	\$36	\$20	\$32	\$26	\$41	\$26	\$41	\$35	\$52	\$36	\$56	\$50	\$75	\$53	\$112	\$69	\$117
Seismic Retrofit	\$21	\$23	\$21	\$23	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A	
Detour Bridge	N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A		N/A	
Contingency	\$28	\$31	\$34	\$37	\$17	\$23	\$23	\$30	\$20	\$27	\$27	\$35	\$25	\$35	\$34	\$47	\$33	\$63	\$44	\$68
Design	\$9	\$10	\$11	\$12	\$4	\$5	\$5	\$7	\$5	\$7	\$7	\$9	\$6	\$8	\$8	\$11	\$8	\$15	\$11	\$16
Right of Way**	\$9		9		9		\$9		\$9		\$9		\$9		\$9		\$9		\$9	
Repainting	\$15		\$15		\$0		\$0		\$0		\$0		\$0		\$0		\$18		\$23	
Routine Maintenance	Not Included		Not Included		Not Included		Not Included		Not Included		Not Included		Not Included		Not Included		Not Included		Not Included	
Westside Interchange	Not Included		Not Included		Not Included		Not Included		Not Included		Not Included		Not Included		Not Included		Not Included		Not Included	
Eastside Tie-in	Not Included		Not Included		Not Included		Not Included		Not Included		Not Included		Not Included		Not Included		Not Included		Not Included	
Mitigation	Not Included		Not Included		Not Included		Not Included		Not Included		Not Included		Not Included		Not Included		Not Included		Not Included	
TOTAL COST***	\$118M	\$128M	\$136M	\$148M	\$63M	\$82M	\$82M	\$106M	\$73M	\$97M	\$97M	\$124M	\$89M	\$121M	\$120M	\$161M	\$134M	\$230M	\$175M	\$252M

* All costs are reported in millions (M) and 2006 dollars.

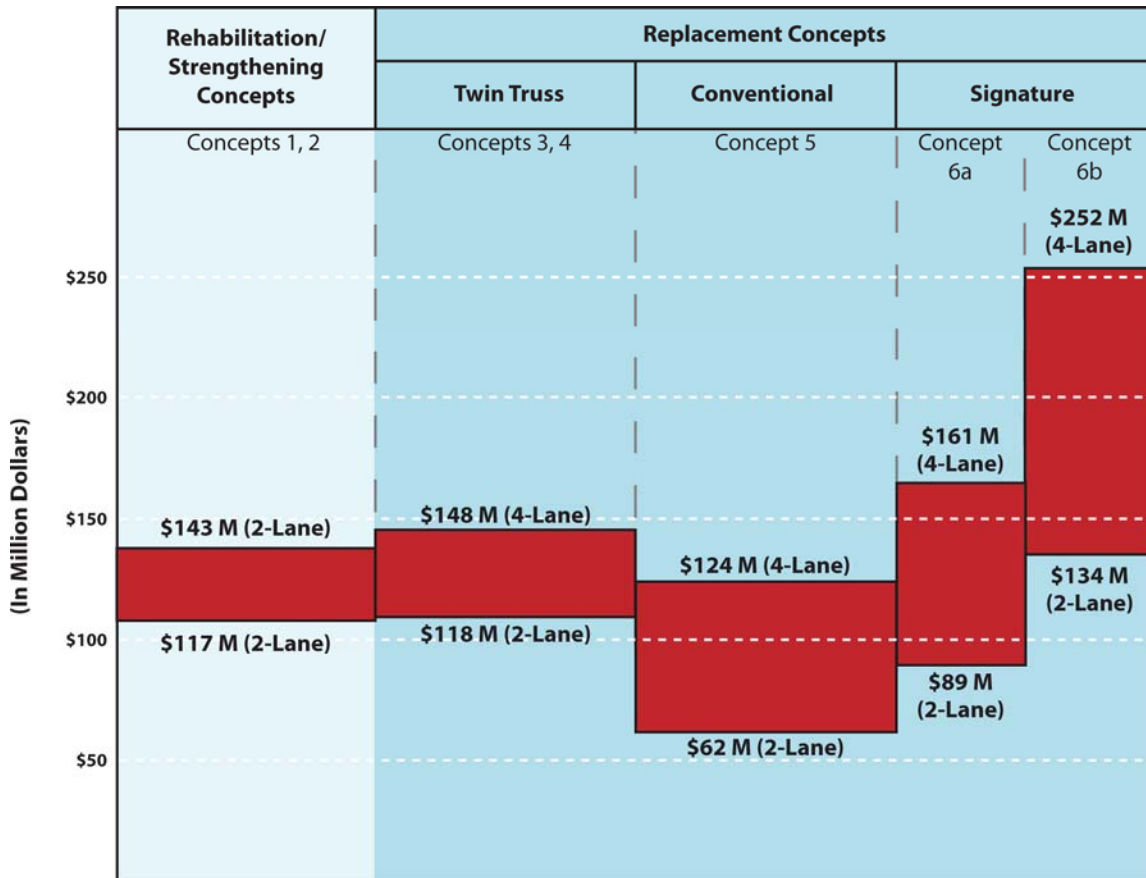
**All bridge replacement concepts are shown with minimum right-of-way cost based on tax assessor property values. Right-of-way cost may increase to \$15 M.

***This does not reflect the total cost of the project, only the costs that differentiate between rehabilitation and replacement concepts.

Summary of Findings

Figure 9 is a summary of the cost ranges for all of rehabilitation/strengthening and replacement concepts. Concept 6a represents Cable-Stayed type structures and Concept 6b represents the Steel Arch type structures. Costs are based on 2006 dollars and include only those elements that differentiate concepts. Cost ranges do not reflect the complete cost of the project.

FIGURE 9 — Comparison of Overall Bridge Rehabilitation/Strengthening Costs vs. Bridge Replacement Costs



Costs are based on 2006 dollars.
 Costs include only those elements that differentiate concepts and do not reflect the complete cost of the project.

Structural Characteristics

All rehabilitation and replacement concepts are capable of allowing legal loads (trucks, emergency vehicles, and buses), and all meet current seismic safety standards.

Construction

Rehabilitation concepts maintain the existing alignment, thus require less permanent right-of-way acquisition than replacement concepts.

Rehabilitation concepts require replacement of the east and west approaches, bridge deck and sidewalk, floor support system, and railings. The historic truss is retained, but only by strengthening most of its members, which could detract from its historic character. The main river piers are also retained, but they will also require significant strengthening and rehabilitation.

If traffic is to be maintained during construction, the rehabilitation concepts require building a temporary detour bridge. Depending on its location, a temporary detour bridge might require acquisition of temporary right of way for several years. Replacement concepts can be constructed while the existing bridge is still in service. Under both rehabilitation and replacement concepts, the bridge will be closed to traffic for a brief period when final tie-ins to the existing roadway network are accomplished.

Cross Sections

Rehabilitation concepts use the maximum allowable cross section within the constraints of truss strength, which is two 12-foot travel lanes, two 2-foot shoulders, and two 10-foot shared bicycle and pedestrian multi-use paths or a single 14-foot-wide multi-use path on the lower chord. These shoulders are too narrow to allow for passage of emergency vehicles when the bridge is congested, or to facilitate clearing of vehicular breakdowns that can add to congestion on the bridge. The 2-foot width does not meet existing design standards. While the width of the multi-use path meets minimum design standards, it is not an optimum facility to accommodate bicycle and pedestrian use.

Replacement concepts allow for a full cross section that can meet design standards and provide optimum bicycle and pedestrian facilities.

Costs

Costs are presented in 2006 dollars. Because of inflation, costs will undoubtedly be higher when the bridge is constructed at a future date. Costs estimates do not represent the full cost of rehabilitation or replacement of the bridge; only those costs that differentiate between rehabilitation and replacement are included. Costs that would be similar for all options--such as reconstruction of the west side interchange, east side tie-in, routine maintenance and mitigation--are not included.

Rehabilitation concepts are: more expensive than 2-lane and 4-lane conventional replacement concepts, about the same cost as 2-lane and 4-lane twin truss replacement concepts, about the same as the least expensive signature bridge concept (2-lane cable stayed), but less expensive than the elaborate signature bridge concepts.

These findings regarding cost are consistent with those of the 1999 Metro South Willamette Crossing Study.

Attachment A: Rationale for Assumptions

Deck Floor System

The assumption that the existing truss deck floor system does not have sufficient strength to carry current design vehicle loads is based on a load rating performed in 2005. The steel floor beams and stringers are only capable of carrying between 75 and 82 percent of a vehicle similar to current design standards. The concrete deck, which is only 6½ inches thick, has a 2½-inch asphalt wearing surface and both are in poor condition. The sidewalk is only 4 inches thick. Therefore, each of the rehabilitation concepts will require removal and replacement of the concrete bridge deck, steel stringers, and steel floor beams with a new deck and floor system.

Truss System

To create a base point for the rehabilitation concepts, the project team evaluated the existing truss structural conditions using the current AASHTO LRFD specifications. The evaluation results show that 30 percent of the truss members are overloaded with the dead load and AASHTO design live loads by 1 to 19 percent. This analysis shows that even with the existing narrow roadway configuration, the truss spans do not have adequate capacity to meet current loading demands. Any increases in structure weight or roadway width will only exacerbate the situation.

The existing truss structure consists of two separate vertical planes of truss chords and diagonals positioned at 20-foot center to center laterally. The existing bridge deck width is 30 feet, 9 inches. With these dimensions, truck wheel loads are able to cantilever past one of the truss planes by 1 foot, 6 inches, creating a lever effect that amplifies the proportion of the truck load resisted by that truss. With the current two lanes of loading, one truss is required to resist 1.25 lanes of loading. Creating a wider roadway would allow the wheel loads to cantilever further past the truss, accentuating this effect even further.

Also, a new concrete deck to support 52 feet of roadway would weigh more than the existing deck. Thus, alternatives with less weight and narrower roadways were considered. ODOT standards require a conventional reinforced concrete deck to have a minimum thickness of 8 inches with an allowance of 25 pounds per square foot for a future wearing surface. The weight of this deck system is 11 percent higher than what the current bridge is resisting. If a conventional reinforced concrete deck is used, it is clear that additional width will only increase the self weight of the structure. Three lighter weight systems were identified for potential use:

- Lightweight concrete deck – 80 to 85 percent of the weight of conventional concrete
- Fiber reinforced polymer (FRP) deck with polymer concrete overlay – 32 to 38 percent of the weight of conventional concrete
- Orthotropic steel deck with polymer concrete overlay – 50 to 60 percent of the weight of conventional concrete

The lightweight concrete solution does not provide a significant weight reduction. As previously stated, a new conventional concrete deck is 11 percent heavier than the current deck weight. At 80 to 85 percent of conventional concrete, the weight of a new lightweight concrete deck would be 88 to 94 percent of the existing deck weight. Sources of lightweight aggregate are

not abundant; this drives the cost up. Lightweight aggregate is softer than conventional aggregate, and this leads to a less durable deck. For these reasons, the Bridge Working Group eliminated lightweight concrete for consideration.

FRP decks are still a relatively new technology. Because there is limited historical information on FRP, there are concerns that it is not sufficiently durable. The movable span of the Broadway Bridge has recently been retrofitted with an FRP deck rather than the open grid deck that is typically used to reduce weight on movable bridges. The Bridge Working Group decided that FRP would not be considered for the vehicular roadway, but would be used for sidewalks and bike paths. This decision was based primarily on the limited amount of historical data available regarding FRP long term performance.

No evaluation was done for an orthotropic steel deck. An orthotropic steel deck with polymer concrete overlay costs approximately 5 times a conventional 8-inch reinforced concrete deck. While the lighter weight orthotropic deck would eliminate the need to strengthen the existing truss, the cost of the deck would be more than the savings derived from no strengthening. Therefore, orthotropic solutions were not investigated.

Rehabilitation of Truss

Each of the rehabilitation concepts is based on the load rating performed in 2005 regarding the integrity of the truss. The following computations were made:

- The existing truss self weight reactions were divided by the truss length to determine the equivalent uniform load of each truss panel. An eccentricity of the dead load causes the equivalent weight of the left and right truss panels to be 3,450 and 3,050 pounds per foot (lbs/ft) respectively. The self weight of the proposed configuration was computed and compared to the existing left truss weight. The ratio of these two weights was used to factor the existing self weight values.
- No separate lane load analysis was done as part of the existing load rating. The original design plans show the truss member forces for a uniform live load of 1,160 lbs/ft. The proposed uniform live loads for pedestrian and vehicular lane loads were computed and compared to the original design load. The ratio of these two loads was used to factor the original uniform live load design values.
- No separate HL-93 truck load was evaluated as part of the existing load rating. A separate analysis of a four-span prismatic girder structure was performed to compare the magnitude of bending moments from a 3S2 permit vehicle to those of an HL-93 (or HS20) truck. The chord forces in a truss closely approximate those of a girder bending moment divided by the lever arm between truss chords. The HL-93 and 3S2 truck bending moments are very nearly identical. The one exception is the result near the pier for a double HL-93 truck. The results of the 3S2 vehicle were used to closely approximate the effects of HL-93 trucks.

Seismic Retrofit

A seismic evaluation of the Sellwood Bridge was completed in 1995. This seismic evaluation identified several bridge elements as vulnerable during a moderate to major earthquake with a 500-year return period or an earthquake with 10 percent probability of exceedance in 50 years.

Such an earthquake has a peak ground acceleration of 0.19g at the location of the Sellwood Bridge.

Current ODOT design standards specify that all bridges be designed for a 1,000-year return period earthquake or an earthquake with a 5 percent probability of exceedance in 50 years. Such an earthquake has a peak ground acceleration of 0.26g at the location of the Sellwood Bridge. In addition, ODOT recommends that all bridges with 1,000-year return period earthquake peak ground acceleration equal to or greater than 0.19g be seismically retrofitted.

Considering the major investment in the rehabilitation of the Sellwood Bridge and the expected service life of at least 75 years, the 1,000-year period earthquake with a peak ground acceleration of 0.26g is considered the appropriate earthquake for the seismic retrofit of the bridge. The existing concrete approach spans and the existing steel truss spans are vulnerable to possible damage or failure during such an earthquake. The existing concrete approach spans at the east and west ends of the bridge have the following deficiencies for a 1,000-year return period earthquake:

- Piers supporting the bridge superstructure at expansion joint locations have concrete beams supporting the superstructure that have insufficient width to accommodate the anticipated lateral movements of the bridge superstructure during such an earthquake. The bridge superstructure could possibly fall off of the supporting beams.
- Columns supporting the bridge and horizontal members between columns have insufficient reinforcing steel to withstand the lateral displacements and forces associated with such an earthquake. This could possibly result in cracking and crumbling of the concrete columns, which would lead to a collapse of the columns.
- Footings supporting the columns are not large enough to resist lateral earthquake forces associated with such an earthquake. As a result, the bridge will likely move laterally and rock back and forth during such an earthquake. As a result, it is possible that the bridge could be left permanently leaning to one side following such an earthquake.
- Unstable soils at the west end of the bridge may slide during such a seismic event, causing major damage or collapse of the west approach bridge structure.

The four steel truss spans and supporting concrete piers have the following deficiencies for a 1,000-year return period earthquake:

- Steel cross bracing located between truss chords at each pier location have insufficient structural capacity to transfer lateral loads from the bridge superstructure to the piers. This could possibly result in significant lateral deformation of the steel trusses resulting in loss of vertical load capacity.
- Anchor bolts for bearings supporting the steel trusses at each pier have insufficient capacity in tension and shear. This could possibly result in the anchor bolts failing and the trusses moving laterally and falling from the piers.
- Four of the five piers supporting the truss spans (Piers 17, 18, 19, and 20) have insufficient reinforcing steel to withstand the lateral displacements and forces associated with such an earthquake. Pier 19 resists all of the longitudinal lateral forces from the bridge superstructure (four truss spans) as a result of an earthquake. All of the piers resist

transverse lateral forces from the bridge superstructure as a result of an earthquake. None of these four piers have sufficient structural capacity to accommodate lateral forces from the bridge superstructure nor the lateral forces resulting from their own weight. This could possibly result in the concrete in the piers cracking and crumbling and the reinforcing steel elongating excessively or buckling, which would lead to a collapse of the piers.

- Footings supporting these piers are insufficient in size to resist lateral earthquake forces associated with such an earthquake. As a result, these piers will likely move laterally and rock back and forth during such an earthquake resulting in possible permanent leaning of the bridge to one side following such an earthquake.

Attachment B: Demand-to-Capacity Ratios of Rehabilitation Concepts

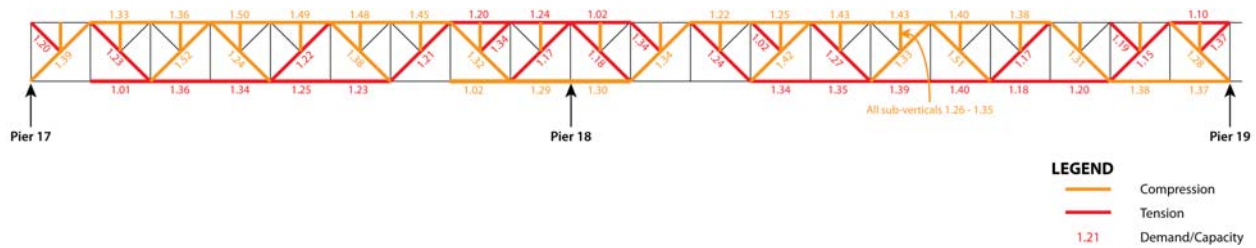
Demand-to-Capacity Ratios of Rehabilitation Concepts

Concept 1: Deck Widening/Strengthening

TABLE B-1
Demand/Capacity of Existing Structure for Concept 1

Member Type	Percentage of Members with Demand/Capacity Ratios Greater Than 1.03	Range of Demand/Capacity Ratio
Chords	75%	1.18—1.50
Diagonals	100%	1.15—1.52
Verticals	0%	N/A
Sub-diagonals	25%	1.19—1.37
Sub-verticals	100%	1.26—1.35

FIGURE B-1 — Concept 1: Demand/Capacity of Existing Structure



Concept 2: Double Deck Widening/Strengthening

TABLE B-2
Demand/Capacity of Existing Structure for Concept 2

Member Type	Percentage of Members with Demand/Capacity Ratio Greater Than 1.03	Range of Demand/Capacity Ratio
Chords	37.5%	1.04—1.31
Diagonals	90%	1.04—1.34
Verticals	0%	N/A
Sub-diagonals	20%	1.04—1.21
Sub-verticals	100%	1.10—1.18

Attachment C: Bridge Terms: Quick Reference Guide

Bridge Terms: Quick Reference Guide

Term	Definition
Abutment	End vertical support of a bridge span; separates the roadway on the ground from the bridge
Bent	Foundation structure to support bridge girders and deck; term can be used interchangeably with "pier"
Cross-Bracing Members	Structural members providing lateral stability for main truss members
Dead Load	Weight of structural members comprising the bridge
Delaminations	Separation of concrete from steel reinforcement
Diagonals	Angled structural members connecting the upper chord members and lower chord members of a truss
Fascia	Flat vertical surface immediately below the deck; exterior girder
Girder	Main longitudinal load-carrying members of a bridge span
Floorbeam	Load-carrying member of bridge deck perpendicular to the roadway alignment; transfers the load of deck onto the girders and truss
Live Load	Weight of trucks and pedestrians as applied to design of bridge members
Longitudinal	Parallel to the direction of traffic on a bridge
Lower Chords	Lower horizontal members of steel truss
Pier	Foundation structure to support spans; intermediate vertical support for a bridge span"
Popout	Concrete separation from member due to corrosion or impact force
Seismic Loads	Horizontal forces generated by earthquake
Spall	Separation of small pieces of concrete from a larger mass of concrete due to corrosion
Span	Horizontal portion of a bridge that crosses over a roadway or river
Stringers	Structural members that support the bridge deck
Sub-Diagonals	Secondary angled steel members that connect the diagonals to the upper chord members of a steel truss
Sub-Verticals	Secondary vertical members that connect the diagonals to the upper chords of a steel truss
Supports	Bridge footings and columns comprising the bridge foundation
Transverse	Perpendicular to the direction traffic runs on a bridge
Truss	A structure comprised of straight members connected at each end, or joints by pins and loaded by forces applied only at the joints (straight members are typically arranged in a system of triangles)
Upper Chords	Upper horizontal members of steel truss
Verticals	Vertical members connecting the upper and lower chords of steel truss