5. Structure Evaluation

5.1 Evaluation Criteria

Previous sections defined the project goals and constraints and identified all plausible layouts and structure types that fit these constraints. Selection of the structure type and layouts to be studied further in the next phase is based on which options provide the best overall value to the project in terms of a diverse set of evaluation criteria. The evaluation criteria are based on the structural and functional requirements of the bridge and include the following:

- Impact to the Arkansas River Floodwall
- Impact to the UP and BNSF Railroad Yard
- Arkansas River Impacts
- Bridge Aesthetics
- Bridge Cost
- Constructibility
- Durability / Maintainability

This section provides an evaluation of the layout and structure type alternatives discussed in Section 4. This evaluation is then summarized in a matrix that gives each alternate a rating (satisfactory, good, excellent, unacceptable) for each of the criteria. An overall rating is then assigned to each alternate. If any of the criteria receives an unacceptable rating, that alternate is not recommended for further consideration. From the overall ratings, structure alternates are recommended for further study in the next phase of the project.

5.2 Description of Criteria

This section describes each of the evaluation criteria as they apply to new bridge construction and the specific constraints of the 4th St. Bridge Site.

5.2.1 Impact to the Arkansas River Floodwall

This reach of the Arkansas River was changed by the construction of a floodwall following a devastating flood in 1921. The floodwall is paved on the western slope adjacent to the Arkansas River and is earthen embankment on the eastern slope adjacent to Pueblo railroad yard. The floodwall is controlled by the Pueblo Conservancy District and is not suitable for vehicular or pedestrian traffic. The Pueblo Conservancy District does not require a minimum vertical clearance over the wall.

Impacts to the floodwall are considered based on pier placement in or near the wall. Access to this area is somewhat limited, but a narrow road exists in the railroad yard between the wall and the nearest track. Concerns about piers in or near the floodwall

include and the risk of compromising the integrity of the wall during construction and possible load sharing between the piers and the wall in the final configuration. Those options without piers in this location and that minimize impacts to the floodwall are given the best ratings in the summary matrix. If pier placement for a given option avoids the wall altogether, the option is rated as excellent. If a pier is located slightly in or near the wall, a good rating is given. An unacceptable rating is given if the option has a pier completely in the wall.

5.2.2 Impact to the UPRR and BNSF Railroad Yards

There are 28 tracks in the Pueblo Yard including two UPRR mainline tracks and one BNSF mainline track. The yard is very active and commonly utilizes the available track space. Tracks are typically located 13 to 14 feet on center, less than current railroad criteria. Inadequate horizontal clearance between the bridge piers and adjacent tracks is a major factor in the low bridge rating of the existing bridge. A new bridge with similar clearances can be expected to also rate poorly. The railroads have no plans to remove, relocate, or add any tracks. Coordination with railroad personnel and activities will be critical to the success of the project. Railroad flagmen will be needed on site at all times during construction in the yard and special railroad operations may be required depending on the span layout, structure type, and construction methods chosen.

Impacts to the railroad yard may be in the form of track delay costs, track relocation or removal costs, personnel costs, additional construction requirements, and yard congestion during construction and in the final configuration. Ground-based construction activities, such as cranes operating in the yard and the delivery of materials, can be expected to require track space and cause delays of railroad operations. Access to the railroad yard is limited and yard roads far apart. If crossing tracks is necessary, the construction of temporary crossings will be required.

Pier congestion in the railroad yard is also a concern. Not matching current pier locations or adding piers creates congestion. On the other hand, yard congestion is reduced with solutions that lessen the number of piers in the yard.

In the summary matrix, ratings are assigned based on the number of tracks with less than the required 18’-0” minimum horizontal clearance to a pier. The specific tracks affected are identified graphically in the figures in Section 4. Table 5.1 below is a summary of the number of affected tracks for each layout option.

Clearances less than the current minimum standard will require negotiation with the railroads. Removal and/or relocation of tracks is expensive and may not be acceptable to the railroads or practical given the yard constraints and site congestion. Any track layout changes are subject to railroad approval.

Table 5.1 Summary of Affected Tracks for Each Layout Option

Layout Alternate	Tracks With Less Than 18'-0" Minimum Horizontal Clearance
Match Existing	7
Match Existing w/ Modified River Spans	7
Moderate Span Layout 1	9
Moderate Span Layout 2	2
Moderate Span Layout 3	2
Long Span Layout 1	4
Long Span Layout 2	2
Long Span Layout 3	0

5.2.3 Arkansas River Impacts

The U.S. Army Corps of Engineers recently approved the Arkansas River Corridor Legacy Project sponsored by the City of Pueblo. This project covers the Arkansas River from below Pueblo Dam to the confluence with Fountain Creek and includes the 4th Street Bridge site. The goals of the Legacy Project are to improve fish and wildlife habitat and encourage recreational use of the area. Possible improvements include redefining the river channel, re-vegetating riverbanks, creating a fish ladder at the West Plains Energy Diversion Structure, creating a kayak run, and providing boating facilities.

Careful selection of bridge pier locations west of the floodwall will minimize environmental and recreational impacts of the project associated with the Arkansas River and surrounding area. Ratings in the summary table are based the location of piers in or near the river since construction in the river will have the most pronounced effects. Scour issues in the river channel and beneath the floodwall are a concern if piers are located in the river and near the floodwall. If no piers are placed in or near the river, the option is rated as excellent. Options with one pier on the banks of the river are rated as good. Options with piers located in the river are rated as satisfactory.

5.2.4 Bridge Aesthetics

Aesthetics are an important consideration for this project. The new bridge can be considered a "gateway" into the downtown area from the western neighborhoods and I-25. Redevelopment near the project is occurring in Pueblo. The Historic Arkansas

River Project (HARP) and the newly announced Arkansas River Legacy Project are examples. Redevelopment of the industrial and commercial area at the east end of the bridge has also been discussed.

Structure type affects bridge aesthetics. Box girder bridges allow for clean lines and an uncluttered appearance. Longer deck overhangs create shading and give the bridge a thin ribbon-like appearance. Substructure elements can often be minimized with box girder bridges due to deck overhangs, sloping girder webs, and internal pier diaphragms. Precast U girder and steel box girder bridges require more girder lines than a segmental or cast-in-place box girder bridge. Precast bulb-T and steel plate girder bridges can present a more cluttered and massive appearance due to numerous girder lines and cross bracing.

Ratings in the summary matrix are assigned as excellent for those options utilizing segmental or cast-in-place concrete box girders, good for those options utilizing precast U girders or steel box girders, and satisfactory for those options using steel plate girders or precast bulb-T girders.

5.2.5 Bridge Cost

Conceptual level bridge construction costs for each of the structure types studied are summarized in tables 5.2 and 5.3 below. The costs presented are not intended to represent a final construction cost estimate, but are for comparison of alternates only. The square footage costs are based on historical CDOT data, experience with other projects, and consideration of site constraints. The approximate deck area of the new bridge is 114,400 square feet (104’ x 1100’).

Table 5.2 New Structure Comparison Costs

Structure Type	Comparison Cost/SF
Precast Concrete Bulb-T	$70
Precast Concrete U Girder	$80
Spliced Precast Bulb-T	$80
Spliced Precast U Girder	$90
Steel Plate Girder	$105
Steel Box Girder	$125
Concrete Box Girder CIP w/ Form Travelers	$120

It is important to note that the above square footage costs do not include costs associated with the railroad impacts anticipated with this project. Table 5.3 shows overall costs that have been modified to account for these impacts. A unit cost of $200 per track foot and an average affected track length of 3,000 feet have been used in conjunction with the number of affected tracks to calculate a cost of railroad impact for each alternate. An affected track is one that does not meet the minimum horizontal clearance requirement specified by the railroads.

Table 5.3 Modified Comparison Costs

Alternate	Layout	Structure Type	Base Cost	No. Tracks Impacted	Railroad Cost	Total Cost
1	Match Existing	Steel Plate Girder	$ 12.0 M	7	$ 4.2 M	$ 16.2 M
2		Steel Box Girder	$ 14.3 M			$ 18.5 M
3	Match Existing w/ Modified River Spans	Precast PT Spliced Bulb-T	$ 9.2 M	7	$ 4.2 M	$13.4 M
4		Precast PT Spliced U Girders	$ 10.3 M			$ 14.5 M
5	Moderate Span 1	Precast Bulb-T	$ 8.0 M	9	$ 5.4 M	$ 13.4 M
6		Precast U Girder	$ 9.2 M			$ 14.6 M
7	Moderate Span 2	Steel Plate Girder	$ 12.0 M	2	$ 1.2 M	$ 13.2 M
8		Steel Box Girder	$ 14.3 M			$ 15.5 M
9	Moderate Span 3	CIP Box w/ Form Travelers	$ 13.7 M	2	$ 1.2 M	$ 14.9 M
10		Steel Plate Girder	$ 12.0 M			$ 13.2 M
11		Steel Box Girder	$ 14.3 M			$ 15.5 M
12	Long Span 1	CIP Box w/ Form Travelers	$ 13.7 M	4	$ 2.4 M	$ 16.1 M
13	Long Span 2	CIP Box w/ Form Travelers	$ 13.7 M	2	$ 1.2 M	$ 14.9 M
14	Long Span 3	CIP Box w/ Form Travelers	$ 13.7 M	0	$ 0	$ 13.7 M

Total comparison costs shown in Table 5.3 range from $ 13.2 M to $ 18.5 M. Ratings of excellent are given for options in the lower third of this cost scale, good for those in the middle third, and satisfactory for those in the highest third. The cost rankings are shown in the summary matrix.

5.2.6 Constructibility

Constructibility is especially important given the complexity of the site. Construction utilizing precast concrete or steel girders is best suited where space below the structure is available and easily accessible. In this case, access in the railroad yards is limited and delivery and lifting of girders will be more difficult. Therefore, the precast bulb-T, precast U girder, steel plate, and steel box girder options are given lower constructibility rankings in the summary matrix.

Construction of cast-in-place concrete box girders from above using form travelers is much less intrusive to the railroad yard and Arkansas River. Materials are more manageable and concrete is cast in-place eliminating delivery and placement of large elements. Delivery of concrete could be from the existing bridge with pump trucks during night hours. Another benefit of this construction technique is an integral post-tensioned deck, which eliminates the second stage of pouring a deck after girders have been placed. By progressing in balanced cantilever, the completed portions of the cantilevers provide the work platform for the next operations. When the spans are closed, the full cross section is complete. For these reasons, the cast-in-place concrete box girder options are generally given higher constructibility rankings in the summary matrix. Consideration is also given to those options with the fewest cantilevers to build.

Long Span Layout 3 received an excellent constructibility ranking. This option has the fewest number of cantilevers compared to the other options considering cast in place concrete box girders constructed from above using form travelers. It is anticipated that the east and west end spans would be cast on falsework since this method of construction is available at these locations and can progress simultaneously with the form traveler operations. The concrete box alternate for Moderate Span 3 was rated as satisfactory because of the large number of cantilever operations that are required.

5.2.7 Durability / Maintainability

In general prestressed concrete bridges are more durable and require less maintenance than steel bridges although weathering steel offers some mitigation. Options that utilize a mildly reinforced concrete deck are less durable than those with an integral prestressed deck. This is because mildly reinforced decks are prone to the development of cracks, allowing penetration of chlorides, which lead to reinforcing corrosion and subsequent concrete deterioration. Eventually, deck replacement is required. Also, features such as continuity improve durability by reducing the number of expansion joints, which tend to require maintenance.

The prestressed cast-in-place concrete box girder structure options are given the highest ratings for durability and maintainability. These are prestressed in both the longitudinal and transverse directions and utilize an integral deck with higher strength and lower permeability than the mildly reinforced concrete decks used with the other options. Precast, pre-tensioned concrete girders also have a good record of durability, but they include a mildly reinforced concrete deck vulnerable to deterioration. These types are given good ratings. Steel structure options were given a lower rating for durability and maintainability since both the deck and girders are more susceptible to corrosion and deterioration resulting in a higher level of maintenance.

5.3 Maintenance of Traffic

As discussed in Section 3.3, maintaining the existing four lanes of traffic at all times is critical to traffic flow in Pueblo and the success of the project. All of the structure options studied for the proposed north alignment require similar effort for maintenance of traffic (MOT). Therefore, MOT is not included as evaluation criteria.

5.4 Summary Evaluation Matrix

The category ratings for each of the span layouts and structure options are summarized in Table 5.4 below. An overall rating is also shown for each span layout and structure option considering all of the criteria. This evaluation will be used in Section 6 to recommend options for further study in the preliminary design phase of the project.

Table 5.4 Summary Evaluation Matrix

Evaluation of Structure Options

◯ Excellent ⊖ Good ○ Satisfactory ⊗ Unacceptable

Layout Option		Structure Type	Evaluation Criteria: Impact to Floodwall	Impact to UP & BNSF Railroads	Impact to Arkansas River	Bridge Aesthetics	Bridge Cost	Constructibility	Durability/ Maintainability	Overall
1	Match Existing	Steel Plate Girder	⊖	○	⊖	○	⊖	○	○	○
2		Steel Box Girder	⊖	○	⊖	⊖	○	○	○	○
3	Match Existing w/ Mod. River Spans	Precast Spliced Bulb-T	⊖	○	○	○	◯	○	⊖	⊖
4		Precast Spliced U Girder	⊖	○	○	⊖	◯	○	⊖	⊖
5	Moderate Span 1	Precast Bulb-T	⊖	⊗	○	○	◯	○	⊖	⊗
6		Precast U Girder	⊖	⊗	○	⊖	◯	○	⊖	⊗
7	Moderate Span 2	Steel Plate Girder	⊖	⊖	◯	○	◯	⊖	○	⊖
8		Steel Box Girder	⊖	⊖	◯	⊖	⊖	⊖	○	⊖
9	Moderate Span 3	C.I.P. Box w/Travelers	⊗	⊖	◯	◯	◯	○	◯	⊗
10		Steel Plate Girder	⊗	⊖	◯	○	◯	⊖	○	⊗
11		Steel Box Girder	⊗	⊖	◯	⊖	⊖	⊖	○	⊗
12	Long Span 1	C.I.P. Box w/Travelers	◯	⊖	⊖	◯	⊖	⊖	◯	◯
13	Long Span 2	C.I.P. Box w/Travelers	◯	⊖	⊖	◯	◯	⊖	◯	◯
14	Long Span 3	C.I.P. Box w/Travelers	⊖	○	○	○	◯	○	◯	○