# **HEAVY MOVABLE STRUCTURES, INC.**

# **EIGHTH BIENNIAL SYMPOSIUM**

**NOVEMBER 8 – 10, 2000** 

Grosvenor Resort Walt Disney World Village Lake Buena Visa, Florida

# "Design Considerations for Replacement of Two Historic AMTRAK Movable Bridges"

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# Structure Type Selection and Design Considerations for the Replacement of Two Historic AMTRAK Movable Bridges

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# Abstract

AMTRAK Bridge 124.09 across the Thames river between Groton and New London, Connecticut and Bridge 116.74 over the Niantic at East Lyme, Connecticut are vital transportation structures serving a major commuter rail line between Boston and New York. These historic spans were constructed very early in the twentieth century, and each has great historical significance to the state of Connecticut. Bridge 124.09 is one of only two Strauss heel trunnion movable bridges remaining in the state. Both bridges have been added to the National Register of Historic Places.

AMTRAK contracted with HNTB to provide recommendations on whether to rehabilitate or replace the two structures. At the conclusion of the preliminary study, final plans were prepared for one of the structures; the preliminary design for the second structure is currently under review. This paper presents the methods used to compare and rate up to twenty four options to select the optimal recommendation for each span. Evaluation criteria related to historic significance, reliability, rail operations, navigation operations, construction, and environmental impact were developed to assess each option. The structural capacity of the existing bascule and approach spans was determined, and the effect that each of the span replacement options would have on the approach spans was studied. AMTRAK was provided with a matrix summary of all the options as they relate to the evaluation criteria, a probable cost of construction for each, and two very different recommended best options.

## Introduction

AMTRAK Bridge No. 116.74 crosses the Niantic River at East Lyme, Connecticut, and AMTRAK Bridge 124.09 crosses the Thames River between Groton and New London, Connecticut. Separated by approximately eight track miles along AMTRAK's Northeast Corridor in Coastal Connecticut, AMTRAK's movable bridges over the Niantic River and Thames River share many of the same traits. However, separate criteria were applied to each bridge in assessing probable rehabilitation and replacement options. Both movable spans are bascule-type spans that were constructed in the early 1900's and serve as a vital transportation link along the heavily traveled corridor shown in Figure 1.



#### Figure 1 - AMTRAK Northeast Route Map

Likewise, both bridges are quickly approaching their respective design lives and are on AMTRAK's priority list for evaluation to rehabilitate or replace. Although the existing bascule spans have experienced mechanical, electrical and structural rehabilitative efforts and have routine maintenance programs, the performance of the movable spans is not considered reliable. Special maintenance efforts are required to open and close the span. This maintenance effort will continue as long as the draw spans remain in their current condition. This issue becomes more critical with AMTRAK's ACELA high speed rail service on the horizon. Because of these issues, AMTRAK retained HNTB Corporation to evaluate rehabilitation and replacement alternatives for the existing modified Scherzer rolling lift bascule span on the Niantic River bridge and the rolling lift Strauss heel trunnion bascule span on the Thames River bridge. In order to properly evaluate the options to replace or rehabilitate the existing draw spans, HNTB began with careful review of the plans and inspection reports of the existing structures. Visual inspection of the structural, mechanical, and electrical components was performed to determine the current condition of each draw span. The spans were then rated in accordance with the American Railway Engineering and Maintenance of Way Association (AREMA) standards prior to evaluating the options for replacement and rehabilitation.

The process and criteria used to evaluate and select the most appropriate rehabilitation or replacement option for each location is vastly different; a comparison of the criteria used for evaluating rehabilitation and replacement alternatives for the Niantic River and Thames River Bridges is presented. A discussion of the structure type selection associated with each bridge as well as unique design features for the Thames River Bridge is also presented.

# AMTRAK Bridge 116.74 Over the Niantic River

The King Bridge Company of Cleveland, Ohio, constructed the Niantic River Bridge in 1907, however, Mr. William Scherzer originally patented the design in 1893. Due to the historical nature of the draw span, the Niantic River Bridge has been documented to Historic American Engineering Record standards and is archived at the Library of Congress. A photograph of the bridge is shown in Figure 2.



Figure 2 - AMTRAK Bridge 116.74 over the Niantic River

The existing bridge consists of five spans as follows:

Span 1 50'-0" Deck plate girder span

Span 2 26'-0" Deck plate girder span

Span 3 69'-3" Through girder draw span (movable span)

Span 4 70'-3" Deck plate girder span

Span 5 76'-2" Deck plate girder span

The spans total 291'-8" of bridge length from centerline of bearing to centerline of bearing at abutments. The double track bridge is supported on masonry piers and abutments. The historic bascule span is a through girder structure that is 68 feet long from center of roll to centerline of bearing at the rest end. The structure provides 11 feet of vertical clearance above mean high water elevation. The existing horizontal navigational clearance is approximately 40 feet.

The principal features of the bridge are its historical nature, and the chain drive mechanism, shown in Figure 3, that operates the movable span. The chain drive mechanical system has caused some operational difficulties in the past 15 years. Efforts to adjust or tighten the chains have caused uneven roll and some misalignment during seating of the bridge. In addition, the segmental rolling girders have had some performance problems, and misalignment of the girder on the track pintles has been observed. This continued misalignment has further caused accelerated wear in the operating gear train which compromises the ability to reliably open and close the span. In its current condition, the draw span runs a risk of failure to operate as required by the United States Coast Guard.



Figure 3 - AMTRAK Bridge 116.74 Chain Drive

## **Project History**

Of the bascule bridges on the Northeast Corridor, the Niantic River Bridge is the only chain driven version. The chain driven bascule was an innovation at the time, and was developed to allow the drive mechanism to be located below the track. The drive mechanism is typically located with the counterweight on a rolling bascule bridge. By placing the mechanism below the track, accessibility for maintenance and repairs is easier. The belowtrack location also affords more protection from weather and vibration. These special variations of the Niantic River Bridge were designed in January 1907. In March of that year, a local contractor, John Y. Higginson of Niantic, constructed the masonry piers. The structure was erected in August of 1907 by the American Contracting Company and the King Bridge Company of Cleveland.

Having been in service for over 90 years, the historic Scherzer double track bascule span has experienced its share of structural, mechanical and electrical setbacks. To alleviate this, there have been several major repairs in recent history. In 1978, the Northeast Corridor Improvement Project (NECIP) strengthened many of the deteriorated bracing members and the deck plate girder spans. On a separate occasion, the babbit material was refurbished to repair wear in the machinery bearings and bushings.

The bridge is physically close to the public; access to the beach is gained by walking directly beneath the deck girder approach spans only 9 feet overhead. Because of this, the design of rehabilitation or new bridge must take into consideration the aesthetics of the resulting structure. Of particular concern to the local citizens is improving the appearance of the bridge, especially limiting the prominence of any overhead counterweights. The river traffic at this location is primarily recreation-type vessels, with several larger, commercial boats also operating in the area. Based on the results of prior river traffic studies. it has been estimated that nearly 80 percent of the river traffic could pass beneath the bridge if the vertical clearance of the movable span were increased approximately 4 feet.

## Structure Type Selection

Initially, 24 options were developed to replace or rehabilitate AMTRAK's Bridge No. 116.74 over the Niantic River. The twenty-four options were evaluated against ten project criteria using a numerical matrix and weighting factors. This helped identified the more appropriate options to study in further detail and eliminated the poorer options from further study. In an effort to adjust and account for the importance of each of the project criteria, each of the evaluation criteria was assigned a weighting factor. Table 1 shows ten project criteria established by AMTRAK for the Niantic River Bridge as well as the weighting factors for each.

#### Table 1

Niantic River Bridge Project Evaluation Criteria

Criteria	Weighting Factor
1. Construction Cost	25
2. Ease of Construction	10
3. Difficulty in Environmental Documentation and Permitting	20
4. Visual Aesthetics	10
5. Construction Impacts on Rail Operations	25
6. Construction Impacts on Electric Traction Power Distribution	20
7. Construction Impacts on Marine Operations	10
8. Final Horizontal Navigational Clearance	10
9. Final Vertical Navigational Clearance (Closed Position)	10
10. Future Maintenance Costs	15

After review of the Evaluation Matrix and completion of a more detailed study taking into account all ten project criteria, the following four options were selected for a more detailed study:

- Option 1B Replace the existing bridge in kind.
- Option 4C Replace the existing bridge on-line with a rolling lift bascule girder span.
- Option 6B Off-line replacement with a 120foot trunnion bascule girder span.
- Option 6C Off-line replacement with a 120foot rolling lift bascule girder span.

From the Evaluation Matrix results, Option 6B was identified as the most appropriate option for replacement. The recommended option, which calls for replacing the existing bascule span and approach spans off-line with a trunnion bascule span, will provide a new draw span with increased horizontal and vertical (span down) clearances offering many years of reliable service with minimal impacts on the environment. The existing bridge and a rendering of the proposed bridge replacement option are shown in Figure 4. It is also recommended that the new approach alignment be placed on a fill embankment.



#### Figure 4 - Existing (top) and Proposed Bridge 116.74 over the Niantic River

The bridge off-line replacement study assumed a new bridge with the following features:

- A centerline approximately 50' south of the centerline of the existing bridge.
- The bridge layout would consist of three deck plate girder approach spans and one 120' through plate girder bascule span providing approximately 110' of horizontal navigation clearance.
- Approximately one mile of track would require realignment. The new approach track would be constructed on either a fill embankment or trestle type structure. For construction of the new approach track, a new fill embankment would be recommended to support the realigned track.
- A track profile grade would be constructed so as to provide 16' vertical clearance in the span down position. The track profile grade would be built into the embankment or the trestle construction. By raising the vertical clearance, it is estimated that nearly 80 percent of the current bridge openings could be eliminated.
- The off-line replacement would require the complete rebuilding of the overhead catenary system, however, this will eliminate the need to work around the system when constructing a similar on-line replacement.

• Pending results of a recommended hydraulics analysis, the navigation channel would be widened to provide 100' horizontal clearance.

#### **Trunnion Bascule or Rolling Bascule**

Two types of bascule spans were evaluated in the study of off-line bridge replacements: a rolling lift through plate girder and a trunnion through plate girder. Both bascule span types would provide nearly identical opening characteristics, yet would have the distinct differences summarized in Table 2.

#### Table 2

#### **Comparison of Off-line Bascule Spans**

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Characteristic	Trunnion Bascule (6B)	Rolling Bascule (6C)
Bascule Pier	Large, rectangular pit pier	2 relatively slender piers, similar in
		overall size to the existing piers
Counterweight	Placed below the bascule girder, using no visual obstructions.	Placed above tracks.
Machinery and Enclosure	Placed below the bascule girder, free from visual obstructions.	Placed above the tracks.
ET Termination Structures	No retracting termination structure at the bascule end is required, reducing the maintenance and inspection efforts.	Complex, retracting termination structure at bascule end of span requiring additional machinery, maintenance and inspection efforts.

Because of its low-profile appearance and simplified ET termination structures on the bascule span, Option 6B, a through plate girder trunnion bascule span, is the recommended off-line option. The aesthetics of the existing bridge would be significantly improved with the sleek, low profile appearance of the trunnion bascule span. The counterweight is placed below the span, with the bridge machinery also below the span at an elevation above mean high water. There are some drawbacks to using a trunnion bascule span. The large, rectangular pit pier may have negative hydraulic effects, an may produce an excessive amount of backwater.

#### **On-line or Off-line**

The advantages of an off-line alignment are numerous. The off-line replacement would make construction far easier than on-line bridge replacements. While construction effort is considerably greater than the on-line options due to the construction of the new embankment, the off-line option would allow the contractor greater scheduling flexibility while causing minimal disruptions to railroad operations.

During construction, coordination efforts between contractor activities and railroad operations would be simplified, as the majority of the contractor work would have little, if any, impact on rail operations. The majority of marine-based construction equipment would be placed south of the new construction, causing no interference with the existing overhead catenary lines. No track downtime would be required to modify the existing catenary system for construction purposes as would be necessary for the on-line replacement options. The off-line replacement would provide an increased channel width, and greater vertical clearance in the span down position. Finally, with the off-line option, the area immediately adjacent to the existing west abutment would be cleared and improvements to the west beachfront area would be made, accommodating local mariners and fishermen.

The off-line bridge replacement does have several disadvantages. The construction of the approach embankments would result in a longer construction period than that of similar on-line bridge replacements. The construction of the bridge portion could possibly outpace that of a similar on-line option due to more simplified steel erection procedures. However, the majority of necessary construction time would be involved with the construction of the embankments. The environmental impacts with an off-line replacement would be much greater than the on-line options, resulting in a more complex environmental permitting process.

# Amtrak Br. 124.09 over the Thames River

The American Bridge Company constructed the Thames River Bridge between 1917 and 1919 for the New York, New Haven, and Hartford Railroad. AMTRAK Bridge 124.09 over the Thames River was deemed eligible for the National Register in 1977, and was formally placed on the National Register on June 12, 1987. The bridge consists of two through truss approach spans at each end of a through truss bascule span. The five spans total 1,394 feet in length.

The structure is a double-track bridge supported by masonry piers and abutments originally constructed to accommodate four tracks. The 188-foot long bascule span is a Strauss heel trunnion design. The Strauss design was patented by Joseph B. Strauss in 1905 and is one of the two remaining in the State of Connecticut. Vertical clearance over mean high water is approximately 29 feet. Timber fenders extend both sides of the bridge on each side of the 150 foot wide channel. In the open position the draw span angle of opening is 82° 30', providing a 150 foot horizontal clear channel; however, the vertical clearance at the west fender is limited to about 130 feet. Approximately 12 feet out from the west fender the vertical clearance is unlimited. The structure is unusual in that the bascule span is supported by the approach truss spans at either end. The main trunnion bearing is supported by a cantilever extending from Span B, and the toe of the bascule span is supported by a cantilever extending from Span D.

#### **Project History**

Having been in service for nearly 80 years, the double track Strauss Heel Trunnion Bascule Span has experienced its share of structural, mechanical, and electrical problems. There have been two major repairs to the structure in recent history. Under the NECIP in 1978, deteriorated truss members and floor system members were strengthened. This significant effort improved the carrying capacity of the bridge and extended the structural life. The bascule span's movement requires the use of eight bearings, including two counterweight trunnion bearings, two main trunnion bearings, and four link pin bearings. A combination of high bearing pressure, a wide range of temperature variations, restricted access to the bearings, limited time available for maintenance, salt air infiltration, and former years with minimum preventative maintenance has contributed to the current state of deterioration. In the early 1990's, major repairs were undertaken to retrofit the counterweight trunnion bearings and bearing bolts. Although the bolts have been repaired, the reliability of the span's operation continues to deteriorate. Due to the abnormal behavior and wear in the counterweight trunnion bearings, there is a potential for the stresses in the bolts to increase; the ultimate risk is that the cap bolts could fail and put the bridge out of service, inhibiting both rail and marine traffic for an extended period of time. The prior structural problems with the bridge have been minor in nature, and were solved by fixing or replacing members that have been damaged or have deteriorated to the point where they are significantly less effective. No evidence of collision damage to main members has been documented. Deterioration of truss members, typically secondary and bracing members, as a result of excessive corrosion has been documented.

Unlike the Niantic River Bridge, the Thames River Bridge does not have a significant tie to the local community. As such, bridge aesthetics were not critical. Likewise, changes in the vertical or horizontal navigation clearances are not required.

## Structure Type Selection

To determine the most appropriate alternatives to study in-depth, four replacement or rehabilitation alternatives were identified for evaluation. The possible alternatives included:

- Option 1 Replace the existing draw span with a vertical lift span using the existing piers.
- Option 2 Rehabilitate the deficient mechanical, electrical, and structural components of the existing bascule span.
- Option 3 Replace the existing bascule span "in kind" with a new bascule span.
- Option 4 Retain the existing bascule span in its current condition (i.e., do nothing).

After completing the initial data collection and site investigations of the existing conditions, including structural, mechanical and electrical inspections, underwater inspection of existing piers 2 and 3, core samples of the piers, a bridge survey, and an initial bridge rating, the four options were evaluated and screened against ten project criteria established by AMTRAK. The criteria used to evaluate and screen the four options are summarized in Table 3.

#### Table 3

#### **Thames River Bridge Project Evaluation Criteria**

Criteria
1. Project impact on the environment during construction.
2. Historic significance of the existing bascule span.
3. Long term reliability and performance of the draw span.
4. Ease of constructibility.
<ol><li>Maintaining railroad operations during construction.</li></ol>
<ol><li>Long term railroad operations.</li></ol>
7. Satisfying navigational requirements during construction.
8. Construction cost.
<ol><li>Effect on the two existing approach trusses.</li></ol>
10. Impact on schedule.

Improvements to the horizontal navigation clearance or attention to aesthetic detail were not a part of the project criteria. An Evaluation Matrix summarizing the evaluations and comparisons of the four alternatives was prepared to compare the merits of the four options. In the matrix, options were graded based on the 10 Project Evaluation criteria. From the Evaluation Matrix, Option 1, that calls for replacing the existing bascule span with a new vertical lift span having lift span towers supported by the existing piers and approach truss Spans B and D, was identified as the most appropriate option. The recommended option will provide a new draw span, offering many years of reliable service with minimal impacts on the environment. Option 1 best satisfies railroad and marine interests during and after construction. A significant advantage of Option 1 is

that by reusing the existing piers, the opportunity to expedite the environmental review process utilizing a "Categorical Exclusion" or an "Environmental Assessment" resulting in a Finding of No Significant Impact (FONSI) classification is greatly enhanced. This option also offers the opportunity to maintain a predictable schedule of final design and contract document preparation, as the environmental and historic issues are more easily resolved.

The existing bridge and a rendering of the proposed bridge replacement option are shown in Figure 5.





#### Figure 5 - Existing (top) and Proposed Bridge 124.09 over the Thames River

While Option 1 is the recommended choice to meet the railroad's long term needs, several disadvantages

are introduced. One disadvantage of Option 1 is that the new lift span towers will be braced and supported by approach truss Spans B and D, which are nearly 80 years old. By tying into the existing approach truss spans, AMTRAK will be committed to retaining two old fixed trusses in the bridge for many years.

Two span types, a vertical lift span (Option 1) and a bascule span (Option 3), were evaluated for replacement of the existing Strauss heel trunnion bascule span. The vertical lift option was selected as the most appropriate. The necessary replacement span length is approaching the cost effective limits for an economical single leaf bascule span. However, a new bascule span replacement would be more economical than the recommended vertical lift span if no other project constraints were present. However, with project constraints against construction of new piers and the reuse of the approach truss spans, a Scherzer rolling lift or trunnion bascule span is not a likely solution. The lift span alternative (Option 1) permits the retention of the existing approach trusses and the existing piers with modifications.

The construction of the vertical lift alternative, including the existing pier modifications, erection of the towers, and construction of the counterweights can be accomplished with minimal interruptions to marine or rail traffic. The lift span would be erected off site and installed during the span change out period. Both rail and marine traffic would be interrupted for a short time while the span change out takes place; the rail closure would be limited to 4 days while the channel would be closed for a total of 12 days. Utilizing a bascule span as the replacement option would require a brief track closure of four days to remove the existing span and to float in a new bascule span. However, it would take three to six weeks to construct the new bascule span counterweight, closing the navigation channel to traffic for an extended period of time. Although Option 3, to replace the structure in-kind with a bascule span, is cost competitive with the vertical lift span, it could not provide the necessary long term reliability. Heel trunnion bascule spans were in favor for a brief period of time about 80 years ago. This type of structure is rarely, if ever, specified today because of better solutions for a movable span. For a railroad span of this length coupled with the project constraints, the lift span alternative was selected as the option with the best match with the project criteria.

Although major mechanical component replacement is rare, a vertical lift span significantly simplifies any necessary rehabilitation effort with respect to a bascule span. For example, the counterweight on the vertical lift span can be independently supported by the towers which allows for replacement and/or repair of any equipment, including the tower sheaves, shafts, and sheave bearings. Replacement of the main trunnion bearings, counterweight trunnion bearings, and counterweight link pins on a bascule span is difficult and expensive to do because falsework must be constructed to temporarily support the counterweight during trunnion bearing replacement. Typically, the falsework interferes with rail traffic, and trains must be detoured for several weeks while the trunnion bearings are replaced. As a result, rehabilitating the existing span was not viewed as a viable option.

#### **Design Considerations**

While the vertical lift replacement option calling for the reuse of Piers 2 and 3 proved to be the most likely rehabilitation or replacement option to meet the project criteria, several complex design issues had to be solved. Many of the design decisions were driven by construction issues as well as effects on the overall construction cost of the project.

#### Lift Span Support

When replacing older movable spans, a new, more reliable structure is provided while typically improving the horizontal and/or vertical navigation clearance, as described for the Niantic River Bridge. However, the project criteria for the Thames River Bridge did not call for changes to the horizontal navigation clearance; the vertical clearance requirement of 135 feet above mean high water is dictated by the fixed highway bridge to the north of the movable span.

The method in which the new lift span is to be supported was evaluated in terms of impacts on construction, long term operation and maintenance and cost effectiveness. Two methods of supporting the new lift span were evaluated:

• <u>On a Modified Pier</u> - Live load bearings would be installed on the modified piers to offer support for the new lift span. To support the lift span on the existing piers and not produce an increase in horizontal navigation clearance would result in a negative trickle down effect. A lift span approximately 24 feet longer would be required, and would result in: a greater load to lift, increased loads to the modified piers, increased bridge operating machinery requirements, removal of the end cantilevers of both Spans B and D, and an overall increase in the total project cost. This method of support was not selected.

On the Existing Cantilevers - During the span change out period, lift span bearings would be added to the end cantilevers of Spans B and D; the new lift span would be supported at these locations. By supporting the new lift span on the approach span end cantilevers, the new lift span length is nearly identical to the existing bascule span length, optimizing the length of the movable span for the given horizontal clearance. This method of support requires the replacement of both end floorbeams of the approach spans. but is believed to be a more straight forward and less time-consuming operation than removing the approach span cantilevers. It was concluded that supporting the new lift span in a similar manner as the existing span - - on live load bearings located on the approach spans B and D end cantilevers - - provided the greatest operation and economic benefit to the project.

#### **Lift Span Towers**

In order to minimize the impacts to rail operations during construction, the lift span towers are to be constructed entirely outside of the existing truss spans. Likewise, the tower design took into account the movement of the bascule span in any bracing scheme that may be used. The center-to-center tower column spacing is 50 feet. This spacing allows for the upstream column to be supported directly on the existing pier, after the relocation of the existing control house. However, because of the position of the existing truss spans on the downstream half of the piers, the downstream tower column falls entirely outside of the limits of the existing pier, thus requiring a modification to the piers.

Braced and unbraced tower configurations were evaluated. With the relatively short lift span length required, an unbraced tower configuration would have been a likely candidate. With the unbraced tower, large overturning moments at the base of the columns could be expected under both construction and final conditions. Because of the nature of the pier modifications and the large overturning moments at the base of the tower, the unbraced tower configuration was ruled out, as excessive construction cost and effort would be required to modify the piers for an unbraced tower.

A braced tower configuration consisting of two front tower columns and two rear tower columns was selected. The existing piers support the front tower columns, the rear tower columns are framed into the existing approach truss spans, and no construction takes place below mean high water. The connection of the rear tower columns to the existing truss spans was designed by connecting bracing members in a lattice pattern from the rectangular rear columns to the first approach truss vertical.

The lift tower for the vertical lift span is somewhat unconventional in that the counterweight sheaves are located 4 feet in front of the centerline of the front tower legs. To limit deflections the top of tower framing requires increased stiffness. The placement of the counterweight sheaves eccentric to the centerline of the front tower column produces a tensile force in the rear tower columns, resulting in "uplift" forces on approach trusses B and D. With this tower configuration, the overall ratings of the approach spans are improved, as dead load is removed from both spans.

Maintaining rail and marine operations during construction had to be considered during the design of the lift span towers. The towers are braced in both the longitudinal and transverse directions. At Pier 2, the construction of the tower must be completed without limiting the movement of the bascule span. To account for this, the Pier 2 tower will only have the top panel of tower bracing installed prior to removal of the existing bascule span. The remaining transverse tower bracing, including the tower portal strut, will be installed during the bascule span change-out.

#### **Existing Pier Modifications**

Reusing the existing bascule span piers as a means to minimize construction costs and interference with marine traffic was desirable. Reuse of the piers would also be much more readily acceptable from an environmental review standpoint. To limit the environmental permitting process and to speed the final design and construction, all final construction was required to take place above the mean high water elevation. Because of the lift span tower column spacing, existing piers 2 and 3 required modifications both in length and width in order to support the new towers.

A thorough review of the pier conditions was performed to assess the suitability for reuse. Concrete cores taken over the entire heights of Piers 2 and 3 indicate that the piers are in excellent condition internally. An underwater inspection of the piers from the mudline to the high water line indicated that the submerged portions of the piers are in very good condition and will not require any repairs for reuse. Visual inspection indicates that the portion above the high water line is also in very good condition. Existing soil pressures due to pier dead loads are approximately 6 tons per square foot. For a lift span replacement, loads to Pier 2 will not be increased due to the removal of the existing bascule counterweight. Additional loading to Pier 3 for the lift span alternate will result in total soil pressures of about 7 tons per square foot, well within the estimated 10 tons per square foot allowable. Based on visual inspections, pier cores, underwater inspections, and resulting soil bearing pressures, reuse of the existing piers is recommended for the new lift span.

#### **Bridge Operating System**

The issue of whether the operating equipment should be span driven or tower driven was considered. A tower drive system provides the force to raise or lower the lift span to the suspending rope sheaves located at the top of the tower. The motive power is then transmitted to the suspending ropes by friction between the suspending ropes and the suspending rope sheaves. As the unbalanced forces increase, the tendency for the suspending ropes to slip on the sheave increases. A span driven lift span has the drive machinery located on the span. The machinery is connected to operating ropes at each corner of the span. One rope at each corner, called a downhaul rope, is attached to an operating drum, and the other end is attached to the tower near the bottom of the tower. Another rope at each corner, called an uphaul rope, is attached to the same operating drum, and the other end is attached to the tower near the top of the tower. The ropes are anchored to the operating drum such that when the drum rotates in one direction, the downhaul rope unwinds from the operating drum and the uphaul rope winds onto the drum, causing the span to rise. With a span drive system, the magnitude of the unbalanced forces will not cause any rope slippage or span misalignment. For the Thames River Bridge, the magnitude of the unbalanced forces caused by wind or a heavy ice load, in combination with the unbalanced loads which occur as the suspending ropes shift from the span side to the counterweight side as the span rises, makes the span drive system more desirable than the tower drive system. As a result, we have considered the operating machinery to be of the span drive type when developing the costs for this project.

#### **Counterweight Removal**

Removal of the existing bascule span counterweight is on the critical path to ensuring that the span change-out period does not exceed the maximum time allotted by the Railroad and the United States Coast Guard. The existing counterweight is comprised of heavyweight concrete and structure steel framing and has a total weight of approximately 2000 tons. Complicating the situation is the fact that the majority of the counterweight mass is located entirely within the truss chords of Span B. Several methods of removing the counterweight were investigated:

- <u>Lower Counterweight to Rail Cars</u> After removing the counterweight from the bearings, the counterweight would be lowered onto rail cars and transported to the shore for demolition. This option was eliminated due to limited vertical clearances and load carrying capacity of the approach truss spans.
- Lower Counterweight to Barge After removing the counterweight from the bearings, the counterweight would be lowered down to a barge on the Thames River. This would require removing several panels of the Span B floor system to create a space large enough to allow the counterweight to pass. This option was eliminated as a possible removal scheme due to the additional construction effort required to repair the Span B floor system prior to reopening the bridge to rail traffic.
- <u>High Capacity Crane</u> Remove the counterweight vertically using one or more highcapacity cranes. This option was eliminated as a possible removal scheme due to excessive costs associated with the high-capacity cranes as well as limited clearances to the Span B top chord and the new lift span tower at Pier 2.
- <u>Independent Support System</u> Support the counterweight by an independent support system, allowing for complete removal of the counterweight to take place at a convenient time during the span change out period. This option proved to be the removal scheme that had the least impact on the remainder of the span change out period.

During the span change out period, a temporary falsework tower will be constructed to support the counterweight independently, allowing for the removal of the existing bascule span and installation of the new lift span to proceed without waiting for the counterweight to be completely removed. The falsework tower will be comprised of 4-36" diameter steel pipe piles driven to a depth approximately 170 feet below the water elevation. A driving template will be used for accurate placement of the piles as well as for bracing the tower above the mudline. The top of the tower will consist of a girder framing system from which the counterweight will be supported. Once the counterweight is supported by the falsework tower, the span change out can proceed; the counterweight will be demolished while being supported by the falsework and after the

completion of the construction steps necessary to reinstate rail service.

#### **Bascule Span Change-out Schedule**

The construction of the new vertical lift bridge will require periods of time when either marine traffic or both marine traffic and rail traffic will be stopped. The vertical lift option will require the use of barge mounted cranes working from the channel to erect the towers on the existing piers before the span change out occurs. This barge activity will affect marine traffic to some extent, but will be closely coordinated with the Coast Guard and the effects will be minimized. The tower erection will also require close communication with train movements so as not to interfere unduly. During the span change out period, the bridge will be closed to rail traffic for 4 days; the channel will be closed to marine traffic for approximately 12 days.

# Summary

While similar in structure type and genre, period of construction, geographic location, and current reliability of span operation, the structure type selection criteria used for assessing possible rehabilitation or replacement options is quite different. Both projects share the common project criteria of overall construction cost, impacts to rail and marine traffic during construction and improved reliability of the span operation. For the Niantic River Bridge, improved vertical clearance and improved appearance were critical criteria. Meanwhile, for the Thames River Bridge, aesthetics or changes to navigation clearances were not critical criteria. The preliminary design phase for both projects is complete. Final plans for the Thames River Bridge are also complete, while the review of the structure type selection report for the Niantic River Bridge is ongoing.

# Acknowledgements

The authors are pleased to have been involved with AMTRAK on the preliminary studies and designs for these very important bridge projects and would like to thank the Railroad for the opportunity to present this project.