Hawthorne Bridge
Spanning Willamette River on Hawthorne Boulevard
Portland
Multnomah County
Oregon

HAER OR-20

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PHOTOGRAPHS
WRITTEN HISTORICAL AND DESCRIPTIVE DATA

Historic American Engineering Record
National Park Service
U.S. Department of the Interior
Washington, DC 20013-7127

ADDENDUM
FOLLOWS...

HISTORIC AMERICAN ENGINEERING RECORD

HAWTHORNE BRIDGE
HAER OR-20

Location:	Spanning Willamette River on Hawthorne Boulevard and Madison Avenue, Portland, Multnomah County, Oregon UTM: Portland, Oregon Quad. 10/525835/5039810
Date of Construction:	1909-10
Structural Type:	Vertical lift bridge
Engineer:	Waddell & Harrington, Kansas City, Missouri
Fabricator:	Pennsylvania Steel Company, Steelton, Pennsylvania
Builder:	Superstructure--United Engineering & Construction Co., Portland, Oregon Substructure--Robert Wakefield & Co., Portland, Oregon
Owner:	City of Portland, Oregon, 1910-13 Multnomah County, Oregon, 1913-present
Use:	Vehicular and pedestrian bridge
Significance:	The Hawthorne Bridge is the oldest extant highway bridge in Portland, Oregon. It was designed by J.A.L. Waddell, at that time America's pioneer in major vertical lift bridges, and was the third major vertical lift bridge built in the United States. Waddell's two earlier vertical lift bridges, the South Halstead Street Bridge in Chicago (1892), and the Keithsburg Bridge in Keithsburg, Illinois (1910), have been replaced, thus making the Hawthorne Bridge the oldest extant major vertical lift bridge in the United States.
Project Information:	Documentation of the Hawthorne Bridge is part of the Oregon Historic Bridge Recording Project, conducted during the summer of 1990 under the co-sponsorship of HABS/HAER and the Oregon Department of Transportation. Researched and written by Gary Link, HAER Historian, 1990. Edited and transmitted by Lola Bennett, HAER Historian, 1992.
Related Documentation:	See also HAER OR-55, Willamette River Bridges.

HISTORY

The first bridge built at the location of the Hawthorne Bridge was a wooden swing span of the Pratt truss design, connecting Madison Street and Hawthorne Avenue, and was called the Madison Street Bridge. It was owned by the Madison Street Bridge Company and built by the Pacific Bridge Company. It opened January 11, 1891 as a toll bridge. On November 11, 1891 the City of Portland bought the bridge and abolished tolls on it. It was of poor design and was badly buffetted by the the streetcars of the Mt. Tabor Railway Line. In 1900 the bridge was replaced by another wooden swing span, the last wooden bridge built across the Willamette River in Portland, the second Madison Street Bridge. This bridge had six Howe truss spans, each 190 feet long and a 312-feet long swing span. When fully opened, it provided 150 feet of lateral clearance for river traffic. Its piers were comprised of two connecting sheet iron cylinders, filled with concrete and founded on piles.[1]

In 1902 a major fire that burned several blocks of east side riverfront buildings swept across the Madison Bridge's east approach. Portlanders finally recognized the need to build steel bridges rather than wooden ones. In June 1907, voters authorized a bond issue of $450,000 to build a new bridge at Madison Street.[2] In the summer of 1909 contractors began construction on the third bridge at Madison Street and Hawthorne Avenue--this one to be called the Hawthorne Bridge. It was a steel vertical lift bridge designed by the firm of Waddell and Harrington, consulting engineers from Kansas City, Missouri.

DESCRIPTION

The Hawthorne Bridge consists of five secondary spans and one vertical lift span. Starting on the west side, the first span is 246' long, the lift span is 250' long, and the remaining secondary spans are 246', 213', 213' and 212' long. The piers are reinforced concrete shafts resting on concrete bases which are founded on piles. The deck is steel grid. The steel superstructure is painted yellow ochre. Approaches connect the bridge on the west side to Madison Street, Main Street, and Front Avenue. On the east side the bridge connects to Hawthorne Boulevard, Water Avenue and Union Avenue.[3]

The lift span of the Hawthorne Bridge can raise 110' for a vertical clearance of 160 feet at mean low water. The span may be lifted to full height in less than one minute. The width of the truss is 23', center to center, for an inner roadway clearance of 20'. Traffic lanes also run along the outside of the truss, one on each side, with widths of 12' each. Along the outside roadways run wood-plank pedestrian sidewalks which are 6' wide. The lanes and sidewalks outside the truss are supported by cantilevered floorbeams. The machinery house is located atop the center of the truss; just below is the operators house, suspended above the roadway deck for a clear view of traffic in both directions. When first built, the total weight of the lift span was 885 tons including flooring and machinery.[4]

The lift towers rise 167' from the piers to the center of the main sheaves. The tower posts rest on the piers and the inclined back legs are attached to the truss of the adjacent fixed spans. Each tower weighs 128 tons. In each tower is suspended one concrete counterweight. Each counterweight is made of 200 cubic yards of concrete built around steel frames and originally weighing 442 tons. Auxillary concrete pieces weighing 1,500 lbs. may be added to either the counterweight or the lift span for balance. Each counterweight is 21' wide, 37'-3" high; and 6'-10" thick. Each is suspended by twenty-four cables, twelve on each end, which pass over the 9-foot diameter main sheaves (large pulleys) atop the tower. From there the cables pass down to hanger posts at the ends of the truss, where they are attached to equalizers which distribute the loads of the cables equally.[5]

Two 125-horsepower motors operate the lift span. Either one has sufficient power to operate the span alone. The motors operate two main shafts, each having at its end two 3½-foot drums which wind the operating cables. From these drums the cables run out to the ends of the truss. There, the cables which lift the span (uphaul cables) pass under sheaves then up the tower posts to connections near the top. The cables which lower the span (downhaul cables) pass over sheaves at the end of the span, then down to connections near the bottom of the tower posts. These connections have turnbuckles for adjusting the tension of the cables. During the movement of the span, the counterweights are stabilized by members riveted to their steel frames, which project out and engage guides in the tower posts. The lift span is stablized by spring-loaded rollers at the top and bottom of the truss which run inside guides along the tower posts.[6]

The description of the secondary span trusses and road-decks follows the same as the lift span, except that the sidewalks of the secondary spans are made of concrete. The seven piers are made of reinforced concrete and rise 100' from the seals at their foundations. The piers are supported by concrete-filled timber caissons, founded on timber piles.

CONSTRUCTION

The Hawthorne Bridge was designed by Waddell & Harrington, Consulting Engineers from Kansas City, Missouri, a firm which held the patent for the vertical lift design. The Pennsylvania Steel Company of Steelton, Pennsylvania, fabricated the steel superstructure, which was erected by the United Engineering and Construction Company of Portland. Robert Wakefield & Company of Portland constructed the substructure.

The concrete bases and piers were built in open-crib cofferdams. Piles were driven through the cribs then cut off and sealed. The seal was poured underwater by using a long hose, called a tremie, to pass the concrete directly to the crib. After the seal was poured the water was pumped out of the cofferdam and the rest of the pier was poured in open air.

The fixed spans were erected in place. In order to keep the channel clear for river traffic, the lift span was erected downstream on falsework. When the span was completed, certain bents of the falsework were removed and three barges floated under to carry the span into place. Falsework was also built on top of the barges 45' high to elevate the span sufficiently to clear the piers. Once the barges were in place at the bridge, water was let into their bottoms in order to lower the span onto the piers. After the span was in place and attached to the cables and tower guides it was immediately lifted to clear the channel while adjustments were made.[7]

To construct the bridge, nearly 6 million pounds of structural steel and 16,200 pounds of reinforcing steel were used. Concrete for the counterweights, piers and bases totaled over 10,000 cubic yards. 42,149 linear feet of piles were driven for the bases, approaches and dolphins. The steel cables for the operating ropes and counterweight ropes weighed over 31,500 lbs.[8]

RENOVATIONS

The steel superstructure of the Hawthorne Bridge remains essentially unchanged from the original. Much work, however, has been done on the roadway deck and approaches. The original deck was wood planking that allowed water to seep through, resulting in almost constant maintenance. In 1931 the bridge was redecked, moving the streetcar rails from the lanes outside the truss to the inner lanes. In 1941 the west approaches were raised as part of improvements connected with Harbor Drive, a roadway which no longer exists.[9]

In 1945 the entire bridge deck was replaced with steel grate. Also, one foot of width was taken from the sidewalks and added to the outer lanes. In 1956 through 1959 approaches on both sides were totally reconstructed. The east ramp to Grand Avenue was raised to clear Water Street

and temporary trestles built to connect the bridge to Union and Grand Avenues. This work anticipated a planned interchange with the Marquam Bridge. After these plans were discarded, these trestle ramps became permanent.[10]

In 1985 inspectors dicovered cracks in the main sheaves. Multnomah County closed the bridge for emergency repairs which lasted to the following August. All eight sheaves were replaced. Guides which stabilize span movement were upgraded, as were the cable equalizers. In the machinery house, the shafts and all but three gears were preplaced. Also, a chain was added to balance the shift of the weight of the cable system during span movement.[11]

ENDNOTES

1. "Lift-Span of the Hawthorne Avenue Bridge, Portland, Oregon," Engineering Record 63 (April 8, 1911) p.381; Fred Lockley, History of the Columbia River Valley from The Dalles to the Sea (Chicago: S.J. Clarke, 1928), p.537; E. Kimbark MacColl, The Shaping of a City: Business and Politics in Portland, Oregon, 1889 to 1915 (Portland: The Georgian Press, 1976), pp.149-153; Percy Maddox, City on the Willamette: The Story of Portland, Oregon (Portland: Binfords & Mort, 1952), p.180.

2. MacColl, p.345; Sharon Wood, The Portland Bridge Book (Portland: Oregon Historical Society Press, 1989), p.37.

3. Multnomah County (Oregon), "Bridge Operation and Maintenance: Hawthorne Avenue Bridge, Portland, Oregon," Final Record Drawing, 1913; Wood, p.42.

4. "Lift-Span of the Hawthorne Avenue Bridge, Portland, Oregon," Engineering Record 63 (8 April 1911), p.381.

5. W.P. Hardesty, "The New Hawthorne Avenue Bridge at Portland, Oregon," Engineering News 65 (9 March 1911), p.279.

6. Bart Bonney, interview, July 11, 1990.

7. "Lift Span of the Hawthorne Avenue Bridge, Portland, Oregon," Engineering Record 63 (8 April 1911), p.381.

8. Multnomah County, Final Record Drawing, 1913.

9. Herbert K. Beals, National Register of Historic Places Nomination Form, "Hawthorne Bridge," 1986; Jack Ostergren, "Hawthorne Bridges Take Punishment From City's Storms," Oregon Journal, 2 July 1968.

10. Bonney, Interview, 20 August 1990; "How the Hawthorne Bridge, Portland, Got Its Face Lifted," Pacific Builder and Engineer 51 (November 1945), pp.44-45.

11. Bonney, July 11, 1990; Oregon Department of Transportation, Environmental Section, Maxine Banks, Memo to File, 27 June 1985.

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Columbia Cascades Support Office
National Park Service
909 First Avenue
Seattle, Washington 98104-1060

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HISTORIC AMERICAN ENGINEERING RECORD

ADDENDUM TO:

HAWTHORNE BRIDGE

(HAER No. OR-20)

This report is an addendum to a 5-page report previously transmitted to the Library of Congress in 1992

Location:	**Spanning the Willamette River on Hawthorne Boulevard and Madison Street, Portland, Multnomah County, Oregon** **UTM: Portland, Oregon** **Quad: 10/525835/5039810**
Date of Construction:	**1909-10**
Structural Type:	**Vertical lift bridge**
Engineer:	**Waddell & Harrington, Kansas City, MO**
Fabricator:	**Pennsylvania Steel Company, Steelton, PA**
Builder:	**Superstructure and Approaches - United Engineering & Construction Co., Portland, OR; Substructure - Robert Wakefield & Co., Portland, OR**
Present Owner:	**City of Portland, OR, 1910-1913; Multnomah County, OR, 1913-present**
Present Use:	**Vehicular and pedestrian bridge**
Significance:	**The Hawthorne Bridge is the oldest extant vertical lift bridge in the United States. It is the oldest of Portland's Willamette bridges, initiating the replacement of earlier swing spans. Designed by Waddell & Harrington, as the firm's earliest surviving lift bridge it reveals how Harrington managed the transition from Waddell's South Halsted Street prototype to the "standard" vertical lift form. Reconfiguration of its approaches, replacement of its wooden deck by steel, and other modifications embody 90 years of highway engineering history.**

Historian: **Researched and written by Judith A. McGaw**

Project Information: **Documentation of the Hawthorne Bridge is part of the Willamette River Bridges Recording Project, conducted during the summer of 1999 under the co-sponsorship of HAER and the Oregon Department of Transportation in cooperation with Multnomah County. It extends preliminary work conducted under the Oregon Historic Bridge Recording Project with the same co-sponsors in the summer of 1990.**

Related Documentation: **See also HAER No. OR-55, HAER No. OR-20, HAER No. OR-21 and addendum.**

In February 1911, John Lyle Harrington came to Portland, Oregon, to inspect the recently completed Hawthorne Bridge on behalf of Waddell & Harrington, consulting engineers for the project. He conveyed the gist of his observations in a letter to the city's Mayor and Executive Board. "If the metal work is kept properly painted, the machinery and the floor properly maintained, the structure should be permanent, for it is designed to carry the heaviest probable street railway and vehicle traffic and it is substantially and well built throughout."[1]

Harrington knew whereof he spoke. He had designed the structure; the plans, he pronounced, had "been carried out with fidelity." That the bridge still stands and, more important, operates, nearly ninety years later testifies to his skill and that of the people who carried out his plans: in 1909 and in all the years since.[2]

Background

The Hawthorne Bridge is the earliest extant vehicular bridge on the Willamette River in Portland. It is one of three river crossings constructed between 1909 and 1913 to replace earlier swing spans. The first swing bridges had linked the city of Portland, on the Willamette's west bank, with the city of East Portland, rapidly becoming Portland's residential center. The bridges intensified the eastward shift of population, contributing to the consolidation of East Portland and Albina (another east side community) into the City of Portland in July of 1891.[3]

In January of 1891, the Madison Street Bridge had been completed, connecting Hawthorne Avenue on the east side with Madison Street on the west. Like the earlier Morrison Street and Steel Bridges, the Madison Street was a privately owned toll bridge. Proponents of consolidation had pledged to make all trans-Willamette structures within the city free. The Madison Street bridge became the first free bridge when City Council authorized its purchase for $142,500, slightly less than its original cost, in November 1891. Like the earlier Morrison Street Bridge, the Madison was a wooden truss structure (Pratt). Beset with problems almost from the outset, the bridge suffered principally from being too lightly built for the heavy traffic it came to carry, including a street railway to which the city granted a thirty year lease at an extremely modest $100 a month rent. When another wooden swing span (Howe truss) replaced the first

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[1] John Lyle Harrington to His Honor the Mayor et. al., 2/24/1911, 1911 Council Documents, Improvements - Bridges, 1911, City Archives, Portland, OR.

[2] Harrington to Mayor, 2/24/1911. On the contention that Harrington designed the Hawthorne Bridge, see below.

[3] E. Kimbark MacColl, *The Shaping of a City: Business and Politics in Portland, Oregon, 1885 to 1915* (Portland: The Georgian Press, 1976), 80, 119, and passim; Sharon Wood, *The Portland Bridge Book* (Portland: Oregon Historical Society Press, 1989), 92.

Madison Street Bridge in 1900, the city simply continued the lease.[4]

By the time the city faced the decision to build new, heavy bridges suited to the demands of early 20th century traffic, Portland, like many American cities of the era, had begun seriously to reconsider its earlier willingness to tailor most government decisions to suit business. In particular, state and local governments had begun efforts to regulate corporations such as the railroads and street railways, or at least to curtail public subsidies of them. This threatened to change the rules of the game for bridge building. In the case of the Hawthorne Bridge, conflict with the Portland Railway Light and Power Company, which controlled all local street railways as well as the local electric company by 1907, delayed the onset of construction so long that the rickety 1900 Madison Street structure went out of service before work could start on the new bridge. Voters had approved a 1907 city charter authorizing a bond issue for a new bridge, but the PRL&P refused to accept the $15,000 annual rent specified for its use of the new structure and threatened court action if construction commenced. Although its earlier franchise was now widely viewed locally as a giveaway, President B. S. Josselyn, an Easterner brought in to manage for the Eastern capitalists who owned the corporation, demanded that the 1891 terms continue in effect for the full thirty years.[5]

Rather than risk a lengthy legal challenge, City Council placed the issue before the voters again in 1909. Voters also considered a countermeasure for a Market Street bridge, slightly upriver from the old Madison Street structure, but offering a more direct crossing and one more unambiguously free of PRL&P rights. When a new bridge over the old Madison to Hawthorne route was once again authorized, construction of what had come to be called the Hawthorne Avenue Bridge proceeded. Relations with the PRL&P were temporarily smoothed over by the election of Mayor Simon, a railroad lawyer and quintessential old-style Portland politician. Not surprisingly, Simon allowed the PRL&P to continue at its old rent. It took two years in the courts for City Council to collect full rent under the new charter provisions.[6]

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[4] MacColl, *Shaping of a City*, 149-53; Fred Lockley, *History of the Columbia River Valley from The Dalles to the Sea* (Chicago: S. J. Clarke, 1928), I, 537; "Lift-Span of the Hawthorne Avenue Bridge, Portland, Oregon," *Engineering Record* 63 (8 April, 1911), 381. Note that Hawthorne Avenue is now known as Boulevard. The bridge is generally referred to simply as the Hawthorne.

[5] E. Kimbark MacColl with Harry H. Stein, *Merchants, Money and Power: The Portland Establishment, 1843-1913* (Portland: The Georgian Press, 1988), 381-420; "Plans of Madison Span Are Ordered," *Oregonian*, 5/1/1909, 11.

[6] MacColl, Merchants, *Money and Power*, 416-420, 433; Agreement, Waddell & Harrington and City of Portland, 5/20/1909, 1909 Council Documents, Improvements-Bridges, 1909, City Archives, Portland, OR; Charter and General Ordinances of the City of Portland, Oregon in force 15 April, 1910 (City of Portland, Oregon, 1910), 54-59.

Interestingly, 1960s debates over redevelopment in what was called the South Auditorium area revisited these 1909 debates over the bridge's location, Market Street being one proposed alternative. The discussion assumed that the Hawthorne Bridge's days were numbered so that any redevelopment plan should keep the probable

In 1909, then, one crucial factor shaped the new Hawthorne Bridge. There was a desperate need for a new bridge, a legacy of the political uncertainty that had made any earlier decision to proceed impossible. Haste was now imperative, but so was the assurance that the new bridge would not present the problems that had plagued its predecessors. More than anything else, these concerns explain the City's choice of consulting engineers.

Finding a Consulting Engineer

After passage of the 1907 bond issue, City Engineer D. W. Taylor hired J. B. C. Lockwood, Consulting Engineer, to prepare preliminary plans and cost estimates for the new bridge. Lockwood, a graduate of Ames College in his home state of Iowa, had come to Seattle in the mid-1880s and served as first president of Puget Sound Bridge and Dredge, founded in 1889. He had arrived in Portland relatively recently and served as Consulting Chief Engineer for the Port of Portland Commission, an agency authorized by the state to maintain and deepen the shipping channel between Portland and the ocean, a function that included reviewing and authorizing bridge construction on the Willamette. More important, from the outset the Commission was dominated by Portland business and political leaders, many of them more closely allied with railroad than with shipping interests.[7]

As chief engineer for the Port, Lockwood knew what it took to get bridges approved by the various political authorities concerned. He was also in a good position to learn the latest about nationwide bridge building developments, a topic on which railroads needed to stay posted. In 1906, for example, he was part of the Port of Portland delegation that toured Chicago's rich collection of movable bridges in the company of Ralph Modjeski, Chief Engineer for the Portland-Vancouver Bridges that James J. Hill's railroads were building locally. Both Lockwood's fee for his Hawthorne Bridge work ($500) and his other interactions with the City Engineer suggest that, while happy to be of service, he was not looking to take on the work of consulting engineer for the bridge's construction. Lockwood completed his task by mid-1908.[8]

Although available documents offer lots of clues, we catch only oblique glimpses of the

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route of a new bridge in mind. Particular emphasis fell on the skew of the Hawthorne relative to the river, which the Market route would eliminate. Planning Board, Land Use - Downtown Plan File, New Hawthorne Bridge, 1965-69, Multnomah County, Department of Environmental Service, Division of Transportation, Yeon Annex Records Center, Portland, Oregon (hereinafter, Yeon Records Center).

[7] D. W. Taylor, City Engineer, to the Honorable Mayor, et. al., 4/27/1908, 1908 Council Documents, Improvements - Bridge 1908, City Archives, Portland, OR; "Services Set for Engineer," *Oregonian*, 12/4/1945, 7; *Portland City Directory*, 1910; MacColl, *Merchants, Money and Power*, 292-293.

[8] Ralph Modjeski to J. C. Flanders, Portland & Seattle Railway, 2/2/1906, Modjeski Letterbooks, National Museum of American History, Smithsonian Institution (hereinafter Modjeski Letterbooks); D. W. Taylor, City Engineer, to the Honorable Mayor, et. al., 4/27/1908, 1908 Council Documents, Improvements - Bridge 1908, City Archives, Portland, OR.

next year's developments. One relevant set of activities was taking place at the Oregon Railway and Navigation Company, which was preparing to build a replacement for its Steel Bridge, a mile downstream from the Hawthorne. As early as 1908, its legal department was explaining to its general manager and its chief engineer that permission to build had to be obtained both from the Port of Portland Commission, acting on behalf of the State of Oregon, and the Secretary of War, acting on behalf of the U.S. government. By mid-1909 the chief engineer had exchanged several letters with the Port, although no plans had been drafted. By September the OR&N had decided to use Waddell & Harrington as consulting engineers and was preparing a contract. A reasonable surmise is that the Portland-based railroad had been in touch with Waddell & Harrington since early 1909.[9]

On the city's side, we know the Oregonian reported that the Executive Board hired Waddell & Harrington to prepare plans and specifications on 30 April, 1909. Five days later, the secretary of the local Civil Service Commission replied to a query from the Mayor and Executive Board that there were no eligibles to fill vacancies in the position of Consulting Bridge Engineer. On 20 May, 1909, Waddell & Harrington signed an agreement with the City of Portland, although, because the bond issue vote was pending, the contract was written with a Market Street Bridge contingency provision.[10]

Portland was a small place with an even smaller circle of leaders, many of them closely tied to local railroad interests. Both the OR&N and the City of Portland faced a similar problem: the need for a solidly built bridge that could withstand heavy traffic, open and close for river vessels without undue delay, and not require replacement within a few years. Lockwood had seen J. A. L. Waddell's South Halsted Street vertical lift bridge during his Chicago tour. In all likelihood, his connections at the Port made him aware of Waddell & Harrington's then current efforts to refine the Halsted Street prototype in new railroad bridges at North Kansas City, Missouri, and at Keithsburg, Illinois. He might also have heard of Waddell & Harrington via his former firm, Puget Sound Bridge and Dredge. In April, 1909, they had lost out to a Waddell & Harrington lift bridge in the competition to complete the Pend d'Oreille River bridge at Sandpoint, Idaho. He almost certainly called the firm and the new technology to the City's attention.[11]

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[9] W. W. Cotton to J. P. O'Brien, General Manager, OR&N, 1/29/1908, Union Pacific Collection, Oregon Historical Society, Box 40 (hereinafter UP Collection); A. C. Spencer to George W. Boschke, Chief Engineer, OR&N, 7/31/1909, UP Collection, Box 41; W. W. Cotton to G. W. Boschke, 10/11/1909, UP Collection, Box 44.

[10] "Plans of Madison Span Ordered," 11; W. W. McIntosh, Secretary, Civil Service Commission, to Hon. Mayor, et. al., 5/5/1909, and Waddell & Harrington and City of Portland, 5/20/1909, both in 1909 Council Documents, Improvements-Bridges 1909, City Archives, Portland, OR.

[11] The Modjeski letter cited earlier includes a reference to vertical lift bridges, which Modjeski expressed reservations about. He noted that the other committee members favored a bascule and that Mr. Lockwood probably would too "although he would not commit himself." Modjeski to Flanders, Modjeski Letterbooks; HAER NO. MO-2 traces the history of the A.S.B. Bridge in North Kansas City. On Keithsburg, see the untitled note in *Engineering*

But City Council also had direct access to the latest railroad information. Historically many councilmen served the railroads; even those who didn't took free passes. If the OR&N had recognized the merits of Waddell & Harrington's new lift bridges, at least some Council members would have heard. In all likelihood, then, the name Waddell & Harrington cropped up in discussions from multiple sources, making them seem a particularly good choice. The belated inquiry to the Civil Service Commission suggests the need to avoid violating the newer reform legislation while responding to the bridge emergency by conducting business through the usual inside channels. In any event, the latest solutions to the problem confronting Portland were being developed elsewhere in the United States. Railroads such as the OR&N, a Harriman-controlled corporation allied with the Union Pacific, tapped national information networks when they made engineering decisions. Portland's selection of the same engineers made good technical sense at a time of rapidly changing bridge building practice.[12]

Waddell and, especially, Harrington

Nothing dramatizes the advantage of hiring a firm like Waddell & Harrington better than the fact that almost as soon as the June 9, 1909 charter vote authorized Hawthorne bridge bonds, the firm had prepared specifications and drawings for the bridge. Their printed "General Specifications" were already at hand, but readying the 24 typewritten pages of "Special Specifications" and the 15 sheets of blueprints that accompanied them required a firm with established expertise in the problems of heavy steel bridge construction.[13]

On the other hand, it is important to remember that the firm Portland hired to design its Hawthorne Bridge was not the Waddell & Harrington famed for creating the modern vertical lift bridge. In May, 1909, the firm had completed no lift bridges. Chicago's South Halsted Street Bridge, designed by Waddell and finished in 1894, had a number of deficiencies, some of which

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News, 60 (1908), 598. See also, J.A.L. Waddell, *Bridge Engineering* (New York: John Wiley & Sons, 1925), I, 723-724; *Pend d'Oreille Review* (Sandpoint, Idaho), 4/16/1909, p. 1. The "d'" has subsequently been dropped from the river's name. Waddell's account calls the community Sand Point, although the two-word version of the name had ceased to be used well before 1909.

[12] MacColl, *Merchants, Money and Power*, 248-251, 393-394. For a sense of the rapidity with which movable bridge technology was changing during this era, see Waddell, *Bridge Engineering*, I, passim; Ernest E. Howard and various commentators, "Vertical Lift Bridges," *Transactions of the American Society of Civil Engineers*, 84 (1921), 580-695; Donald M. Becker, "Development of the Chicago Type Bascule Bridge," *Proceedings of the American Society of Civil Engineers* (February, 1943), 263-293; J. B. Strauss, "Bascule Bridges," *Proceedings of The Second Pan American Scientific Congress: Section V, Engineering* (Washington: Government Printing Office, 1917), VI, 304-322, hereinafter *Pan American Proceedings*. On the importance of access to good information networks in eras of rapid technological change, see my *Most Wonderful Machine: Mechanization and Social Change in Berkshire Paper Making* (Princeton: Princeton University Press, 1989), *passim*.

[13] 1909 Hawthorne Bridge Specifications, SPARC 2012-30, City Archives, Portland, OR.

Waddell recognized immediately and enumerated in his 1897 *De Pontibus*. And, like most prototypes, the bridge was expensive to build and expensive to operate; new technologies become good solutions only by undergoing the process of refinement that makes them affordable and reliable.[14]

Although Waddell's explanation of why he built no additional lift bridges for a decade and a half has the self-promotional ring of many of his autobiographical remarks, his discussion of why he again began building them specifies two important preconditions. First, he had joined in partnership with John Lyle Harrington. Second, changes made to the machinery at South Halsted Street made it operate far more effectively.[15]

In 1909, Waddell was an established figure, widely known for his several books and numerous articles. After working for others, including the Canadian Pacific Railway and several institutions of higher education, he had become a highly successful bridge designer and consultant in Kansas City, Missouri. Nearly fifteen years his junior, Harrington brought strikingly different experience to the new partnership. Whereas Waddell had published major works on iron bridges and had represented the Phoenix Iron and Phoenix Bridge companies, Harrington was young enough to have learned his trade in the developing steel industry. He also brought mechanical engineering expertise honed in his work for C. W. Hunt Company and for a Canadian division of American Locomotive. Waddell, writing in Bridge Engineering years later noted that this experience "enabled the firm to effect many valuable improvements in operation, not only in [the firm's first vertical lift bridge design], but also in other vertical lift bridges built later." In the same vein, but somewhat more effusively, Ernest E. Howard's participant's eye view of lift bridge development underscore Harrington's central role: he "took up the lift-bridge idea after it had been dormant for more than a dozen years. Bringing experience in mechanical engineering as well as in bridge design to the problem, he recreated and revived the lift bridge as a rational machine, and led the way in developing the modern designs and in securing their adoption."[16]

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[14] J. A. L. Waddell, *De Pontibus: A Pocketbook for Engineers* (New York: John Wiley and Son, 1912), 108-114. Waddell initially voiced these criticisms in a paper in *Transactions of the American Society of Civil Engineers*, published within a few months of the bridge's completion. Waddell, *Bridge Engineering*, I, 717, 721.

[15] Waddell, *Bridge Engineering*, I, 723.

[16] Susan Schmidt Horning, "John Alexander Low Waddell," and Eric DeLony, "John Lyle Harrington," both in *American National Biography*, ed. John A. Garraty and Mark C. Carnes (New York: Oxford University Press, 1999); Waddell, *Bridge Engineering*, I, 724; Howard, "Vertical Lift Bridges," 695. Howard is hardly an unbiased source, but he was well placed to observe these developments. Originally Waddell's protege, he worked closely with Harrington, especially on the A.S.B. and Steel Bridges, and joined Harrington to create Harrington, Howard & Ash in 1914 when Waddell & Harrington dissolved. Kathi Ann Brown, *Diversity by Design: Celebrating 75 Years of Howard Needles Tammen & Bergendoff, 1914-1989* (Kansas City: The Lowell Press, 1989). On Phoenix's attempts to avoid shifting from iron to steel see Thomas J. Misa, *A Nation of Steel: The Making of Modern America, 1865-1925* (Baltimore: Johns Hopkins University Press, 1995) 50-60.

When Portland hired Waddell & Harrington, South Halsted Street Bridge was operating more reliably and cheaply largely because a major 1907 investment had replaced its original steam engine with electric motors, reducing vibration as well as operating expenses. Buoyed by that development, the firm was pursuing three other lift bridge ventures. It was involved in discussions that would culminate in the building of the A.S.B. Bridge in North Kansas City, a revival of earlier projects for which Waddell had submitted rather elaborate and expensive designs. A short, light, man-powered lift span completing a nearly two-mile-long wooden wagon bridge in remote Sandpoint, Idaho, was nearing completion, but it would not have impressed Portland citizens as meeting their needs. And the firm was supervising the erection of its design for the Iowa Central Railroad's Mississippi River bridge at Keithsburg, Illinois, whose distinctive feature was its ability to accommodate the Mississippi's notorious channel changes through having its lift span moved to other piers. But the Keithsburg bridge, although it did offer a model for Portland's vertical lift span, did not begin operating until mid-1910.[17]

Clearly, Portland hired Waddell & Harrington based more on the promise of its vertical lift bridges than of their proven superiority. Waddell's and Harrington's years of experience building other sorts of bridges must have offered reassurance, especially because it included many heavy steel structures of the sort Portland wanted. Portland's history of struggles with slow and unpredictable swing spans helped make the prospect of a lift bridge appealing; whatever the defects of the South Halsted Street Bridge, Lockwood and other members of the Port delegation could confirm that it opened and closed more rapidly than nearby swing spans, taking nearly one-third less time according to Waddell. Plans for the firm's new Keithsburg and North Kansas City bridges promised even more of what the city was looking for: a sturdy, reliable, speedy movable bridge.[18]

Equally important, Waddell & Harrington could promise speedy completion of the work. What the firm proposed for Portland had enough similarities to the Keithsburg project that nearly

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[17] "Repairs to the So. Halsted St. Lift Bridge over the Chicago River," *Engineering News*, 69 (May 1, 1913) 920. My sense that the earlier versions of the North Kansas City Bridge were unduly elaborate derives from comparing Waddell's description in *De Pontibus*, 114-118 with HAER NO. MO-2; see also, Waddell, *Bridge Engineering*, 726-728. Waddell's conclusion that "there is a fair chance of its being finished some day with modifications tending to cheapen the work" is vintage Waddell in its insensitivity to legitimate criticism of his work. The Sandpoint bridge does not survive and the Keithsburg structure sustained heavy damage in a fire and further damage during efforts to remove damaged sections. Of the lift-span apparatus, only the damaged east tower remains. Here and in what follows, my assessments of these bridges rest on a visit to the remains of the Keithsburg bridge and a review of photographs, newspaper accounts, and other local history materials at the Bonner County Historical Society, Sandpoint, Idaho, and the Mercer County Historical Society, Aledo, Illinois. My thanks to the staffs of each of these institutions for accommodating my unseasonal visits and making the brief time I had available very productive. See also untitled note, *Engineering News*, 598; Waddell, *Bridge Engineering*, 724; Horatio P. Van Cleve, "The Mechanical Features of the Vertical-Lift Bridge," *Transactions of the American Society of Mechanical Engineers*, 40 (1918), 1019-1022.

[18] Waddell, *De Pontibus*, 113.

half of the drawings included as part of the Hawthorne Bridge specifications were for Keithsburg. And it was able to offer "complete detail drawings" for the Hawthorne within 60 days of the contract's award. Terms of the contract called for successful bidders to complete the bridge within ten months of signing on, predicated, in turn, on the substructure being completed within eight months and far enough advanced within five months for work on the superstructure to begin. Bids were due 21 June, 1909; contracts were signed a week later on June 28.[19]

Construction[20]

As it turned out, less than eighteen months later, Waddell & Harrington, through its resident engineer, C. K. Allen, notified the city that its bridge was ready for use. Although that pace seems rapid ninety years later, Portland residents complained bitterly. Departing from the measured phrases of the legal opinion he was offering, the City Attorney observed, "it is a well known fact, in the minds of not only the city officials but in the public generally that there was gross delay on the part of the Contractor."[21]

The story of construction difficulties and achievements begins with the work of Robert Wakefield, contractor for the substructure. The 65-year-old Wakefield brought a wealth of experience to the task. Of English birth and education, he had arrived in America while still in his teens. He gained extensive technological experience, including several years spent as Union Pacific's superintendent of tracks and bridges, before arriving in Portland in 1887. His accomplishments in the late 19th century included erection of Portland's first steel building, for Wells Fargo, and serving as a contractor for the city's "magnificent" Union Station. Farther south, he built a steel bridge across the Willamette at Albany. By 1909 he had completed many projects for the OR&N, with whom he would sign the Portland Steel Bridge contract while still completing the Hawthorne. He was certainly a well-known and well-connected local figure, perhaps accounting for United Engineering & Construction Company's derisive reference to him

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[19] 1909 Hawthorne Bridge Specifications, City Archives; John Lyle Harrington to His Honor the Mayor et. al., 3/1/1911, 1911 Council Documents, Improvements - Bridges, 1911, City Archives, Portland, OR.

[20] Here and in the subsequent descriptions of bridge components I have generally avoided repetition of material covered in HAER NO. OR-20, emphasizing, instead, aspects not treated in that preliminary report and corrections made possible by more thorough scrutiny. The reader needs to combine the two reports for complete coverage.

[21] C. K. Allen, Resident Engineer, Waddell & Harrington to His Honor the Mayor et. al., 12/19/1910, 1910 Council Documents, Improvements - Bridges, 1910, City Archives, Portland, OR; Frank S. Grant, City Attorney to A. L. Barbur, Auditor, 7/13/1911, 1911 Council Documents, Improvements - Bridges, 1911, City Archives, Portland, OR.

as "the City's contractor" during later disputes over remuneration.[22]

Like many successful businessmen who had come up through the ranks, Wakefield's success derived especially from "his popularity with his employees, with whom he was always willing to cooperate," an asset of inestimable value to a contractor who persistently took on new technological challenges. But personal skill and willing workers could not command the Willamette. The nicely worked out plans for sequential completion of the river piers of the Hawthorne Bridge had to be scrapped in response to high water. Because the east end of the bridge had a clearer approach area well-supplied with railroad connections, the superstructure contractor planned to build from east to west and expected piers to be completed in that order. Instead, after starting piers 1 through 4 (numbering from east to west) between September 1 and 16, 1909, new pier starts halted until late February, 1910, when they commenced from the west (numbers 7 through 5 in that order). Completion dates ranged from mid-February for the two eastern piers, to July and August 1910 for the important lift span piers (numbers 5 and 6). Harrington, charged with adjudicating opposing claims for added costs and for construction delay penalties, attributed 109 days' delay to high water.[23]

At the time, *Engineering News* found the 145-foot height of the lift span piers (measured from the bottom of the piles) especially noteworthy. Because the bridge was being built in the Pacific Northwest, the availability of 110 to 120 foot wooden piles simplified the task. Fifty foot high wooden cofferdams were first sunk 15 feet into the river bottom. Then piles, 65 to 105 per pier, were driven another 45 feet below the crib bottom. After using a tremie, which pumped a thick mass of concrete through the water to the bottom of the cofferdam, water was pumped out and the surface of this "seal course" of concrete scraped to remove a thin top layer, the only concrete that suffered damage through contact with the water when using this technique. Next, with the cofferdam pumped dry, the contractor's men cut off the piles and poured the remaining concrete in the open air. Naturally, since the cofferdam was 50 feet high, leaving only 35 feet above river bottom, and mean low water was about 35 feet at the lift span, high water easily

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[22] *The Oregonian Souvenir* (Portland: October 1, 1892), 99; "Wakefield Funeral Set," *Oregonian*, 2/15/1920, 7; UP Collection, OR&N Letterbooks, *passim*; United Engineering & Construction Co. to the Executive Board and Its Bridge Committee, 7/28/1911, 1911 Council Documents, Improvements - Bridges, 1911, City Archives, Portland, OR. Wakefield was certainly a vital 65-year-old. He went on to complete several other important local bridges, including the first steel span fabricated in Portland, that over the Clackamas River on the Oregon City car line. Shortly before his death at age 75 he completed the Marion-Polk County bridge over the Willamette at Salem.

[23] "Wakefield Funeral Set," 7; John Lyle Harrington to His Honor the Mayor et. al., 3/1/1911, and United Engineering & Construction to Executive Board and Its Bridge Committee, 7/26/1911, both in 1911 Council Documents, Improvements - Bridges, 1911, City Archives, Portland, OR. The sequence, reconstructed from United Engineering's account, makes perfect sense in view of Portland's rainy season and the location of the river channel, although the original account portrays it as "jumping from one pier to another, all over the river." That characterization may accurately express poor communications between the contractors that left United in continuing uncertainty.

delayed construction. Failure to foresee this possibility suggests the relative novelty of the challenges Wakefield undertook.[24]

United Engineering & Construction Co., contractor for the superstructure, was also a local firm. Its president, Drake C. O'Reilly was well-connected politically through his early membership in the Arlington, Waverly, and Multnomah Athletic Clubs. And, like many local movers and shakers, he served as a director of the Port of Portland. After working for Union Pacific in Omaha and Denver, he arrived in Portland in 1891 and became the OR&N's freight agent. Shortly thereafter, he joined with a partner to build the Columbia Southern through eastern Oregon, a railroad subsequently acquired by Union Pacific. Best known for the Oregon Round Lumber and Diamond-O Navigation companies, which he founded and operated with his two brothers, like many businessmen in this relatively small city, O'Reilly helped create a number of shorter-lived firms, United Engineering being one. Day to day operations of the company rested with A. S. Eldredge, its Vice-President, General Manager, and Engineer.[25]

O'Reilly, though, was probably the more important figure in the developments that created delays. As the reform-minded Portland Municipal Association reported in 1911, final bridge costs ran $31,000 to $52,000 over the original bid largely because Mayor Simon brokered a delayed decision to widen the outside lanes to accommodate the new and larger cars of the PRL&P. The result was a deck nearly three times as wide as the space between its trusses, the 19 foot overhang of the floor beams on either side posing challenges of lateral stability not initially envisioned. In part, Waddell & Harrington responded by asking for more rigid connections in the cantilever support structure and by increasing the amount of steel in the structure with new, heavier floorbeams 60 inches deep. Concern that heavily laden street railway cars running along one side might tilt the lift span and cause a tragedy also prompted the addition of cantilever stabilizing brackets on the substructure placed so as to receive the very ends of the cantilever brackets supporting the lift span deck. Like many features worked out on the Hawthorne Bridge, Harrington's creative solution to this unexpected problem became standard practice for lift bridges, codified in Waddell's Bridge Engineering. Steel rails for the PRL&P were another last-

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[24] W. P. Hardesty, "The New Hawthorne Avenue Bridge at Portland, Ore.," *Engineering News*, 65 (9 March, 1911), 279-280. Piers 1 and 7 had 65 piles each; piers 2, 3, and 4, had 70 each; and piers 5 and 6 had 105 each. Hawthorne Avenue Bridge, Details of Piers 5 & 6, 5/20/1909 and Details of Piers 1, 2, 3, 4, & 7, 4/10/1909, Drawings in Multnomah County Bridge Shop, Portland, OR. I am indebted to Ed Wortman, P.E., Engineering Services Administrator for the Multnomah County Division of Transportation Bridge Section, for a clear explanation of the tremie technique.

[25] Joseph Simon, Mayor, to Honorable County Court, 12/19/1910, 1910 Council Documents, Improvements - Bridges 1910, City Archives, Portland, OR; "D.C. O'Reilly Dies at 82," *Oregonian*, 10/3/1948, Section 2, 33; "Drake O'Reilly, Transportation Leader Here, Dies," *Oregon Journal*, 10/2/1948, 1; "The New Hawthorne Avenue Bridge," 280.

minute upgrade. The other principal belated addition was lights on the bridge and approaches.[26]

Although subsequent conflicts focused on Wakefield's failure to complete the piers by November 1909, erection diagrams and other shop drawings supplied by the Bridge and Construction Department of Pennsylvania Steel, the fabricator, bear revision dates as late as April 1910, supporting United's contention that Waddell & Harrington's last minute changes in steel orders occasioned both delays and increased costs. These drawings also confirm that riveting practice on the bridge conformed to Waddell's strictures in *De Pontibus*. Holes of 15/16 inch diameter accommodated 7/8 inch diameter rivets, the specifications for sturdy railroad construction. Workmen achieved this precision by punching 3/4 inch holes and reaming them to size. This practice assured strong and reliable joints because it eliminated the tiny cracks that punching created at the edges of holes. Patterns of rivets display the symmetry Waddell considered "the acme of artistic designing." And, in accord with Waddell's recognition that cost-saving attempts to eliminate field riveting had produced elevated structures of insufficient rigidity, shop drawings called for riveting important connections only after falsework was removed and truss spans rested on their final supports.[27]

Once they were able to commence work in March 1910, United compensated for delays in pier construction by working Sundays and nights. The scarcity of work at the time must have helped them find willing men among the iron workers and other skilled tradesmen who made successful bridge erection possible. About 60% of the bridge, three spans and two towers, went up between 13 July, when the first lift span pier was ready, and 13 October. At the start of this period, United Engineering also supplied the girders Wakefield needed to incorporate into the reinforced tops of the lift span piers.[28]

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[26] MacColl, *Shaping of a City*, 400; "The New Hawthorne Avenue Bridge," 279; United Engineering & Construction to Executive Board and Its Bridge Committee, 7/26/1911, 1911 Council Documents, Improvements - Bridges 1911, City Archives, Portland, OR; Hovey, *Movable Bridges*, I, 225. I am indebted to Ed Wortman, Multnomah County Bridge Engineer, for calling my attention to the lateral stabilizing system added belatedly and to the account in Waddell, *Bridge Engineering*, 746. Waddell's discussion makes clear why this presented itself as a new problem in the early development of the lift bridge. "In an ordinary span of this type the uplift at the corner due to the overturning moment of the live load on the bracketed portion is resisted by the deadload reaction there; but in the case of the lift-span there is no such reaction; consequently, there is nothing to resist the said overturning effect except the unbalanced load of the cables (if any), the starting friction of the sheave-journals, and the holding down power of the operating ropes and bridge locks."

[27] Hawthorne Bridge Drawings, 1909-1910, Multnomah County Bridge Shop, Portland, OR; Waddell, *De Pontibus*, 22, 24, 164-165, 255-256; J. E. Gordon, *Structures or Why Things Don't Fall Down* (New York: Da Capo Press, 1978), 143. Waddell makes many of the same points with additional examples in Bridge Engineering, published well after the Hawthorne's completion. Waddell's phrasing concerning aesthetics comes from his "Vertical Lift Bridges," *Pan American Proceedings*, 174.

[28] United Engineering & Construction to Executive Board and Its Bridge Committee, 7/26/1911 and John Lyle Harrington to His Honor the Mayor et. al., 2/24/1911, both in 1911 Council Documents, Improvements - Bridges 1911, City Archives, Portland, OR; Hawthorne Bridge, Detail of Piers 5 & 6, 5/20/1909, Drawing at

The lift span was constructed downstream on falsework devised so as to permit barges to enter below it. When the lift span piers were ready to receive it, three scows were braced together and enough water let into them that their decks could get under the construction falsework. Then, one at a time, the barges had the water pumped out and, as they rose, falsework built of 12 X 12 timber on each barge lifted the span free of its original falsework. To assure that the span rode 2 feet 5 inches above its bridge pier seats, careful advance calculations took into account a multitude of relevant factors, including probable river stage and draft of the barges under a combined load of an 880 ton lift span and 70 tons of falsework. Precision was especially important because the span's spring-loaded longitudinal guide rollers, designed to press firmly against guide angles on the towers, could only be compressed to 16 inches and had to pass through a 24 inch space at each span end.[29]

Steamers moved in downstream and between the barges. They first allowed the four mile per hour diagonal river current at the bridge's location to swing the span square and they then worked the span across the river and upstream to the piers. A system of cables and windlasses guided the span into position on the bridge, the counterweight cables were attached to the hangers, and the guide angles and rollers, which had needed some play, had their bolts firmly and finally tightened down. Water was again let into the barges, freeing the span from the barge falsework. After the barges moved away, the lift span was lowered enough to raise the counterweights from their falsework. Shortly thereafter, with counterweight falsework removed and operating cables and their machinery connected, the span was raised to permit passage of river traffic. Most final adjustments could be made with the span elevated so as not to disrupt shipping.[30]

Construction of the giant counterweights, each weighing 420 tons, had awaited completion of the towers within which they would operate. Their size required that they be poured in place, near the tops of the towers, around their internal steel frame. Since such an

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Multnomah County Bridge Shop, Portland, OR.

The "alarming rate" of "labor unemployment" had prompted two local unions to write City Council as early as 1908 urging the use of local firms and immediate action to build the new bridge. IBEW Local 317 to City Council, 7/13/1908 and Brotherhood of Painters, Decorators, and Paperhangers of America, Local 10, 7/31/1908, 1908 Council Documents, Improvements - Bridges, 1908, City Archives, Portland, OR. There is every indication that local firms would have been used in any case.

[29] "The New Hawthorne Avenue Bridge," 280; "Lift-Span of the Hawthorne Avenue Bridge, Portland, Ore.," *Engineering Record*, 63, 4/8/1911, 381-382. Ed Wortman, Multnomah County Bridge Engineer, first called my attention to the challenge these guide rollers presented when the lift span was put in place. His work on the 1998-99 bridge renovations had acquainted him with the challenge first hand and led him to wonder how it had been managed initially. Although published accounts did not note its importance, Wortman pointed out that waiting until cool weather (the lift span was floated into place in November, 1910) was crucial so as to minimize the amount of expansion in the metal work. Had the project kept to its original timetable, the lift span would have been moved into place during the cool, early spring of 1909.

[30] "Lift-Span of the Hawthorne Bridge," 381-382; "The New Hawthorne Avenue Bridge," 280.

operation was quite new, Waddell & Harrington had taken pains to be quite specific about it when writing specifications. They noted, for example, that during fabrication, the weights should be placed about three feet lower than their ultimate height, a provision that anticipated the initial placement of the lift span 2.5 feet higher than its ultimate location. The counterweights were completed 1 November, 1910, shortly after the 9 foot main sheaves, designed to carry the counterweight cables, had been lifted onto the towers. Except for minor alterations and a few areas requiring cleaning and painting, the span was ready for presentation to the city on 19 December, 1910. Under the amended 1907 City Charter provisions, Mayor Simon accepted the bridge and then turned it over to Multnomah County Engineer Stutsman, who assumed responsibility for its control and operation, although the City retained ownership until 1913.[31]

Political maneuvering notwithstanding, much of the delay encountered in the Hawthorne Bridge's construction derives from the reality that its engineers and contractors were engaged in a very new venture. *Engineering News* summed up the problem succinctly when it referred to the Hawthorne as a "rare type." With essentially no direct precedents to go on, how to erect the heavy movable span, how to maintain its lateral and longitudinal stability during construction and thereafter, and how to coordinate the assembly of its various components demanded repeated technological creativity. For example, the plans to build the counterweights in place and to move the lift span into position only after all other components were present incorporated important lessons learned on the Keithsburg bridge only months earlier. Its substantially lighter counterweights had been lifted into position and its span had been installed before the operating machinery arrived. In combination, these decisions meant the bridge blockaded river traffic for several weeks and incurred costly fines. Although new procedures were obviously necessary, any such change required great care in reformulating plans. The surprise is not that construction took longer than expected, but that the contractors, fabricators, and engineers managed the feat so expeditiously.[32]

It is also worth noting the repeated evidence that, combined with at least some formal education, informal training through work with the railroads prepared a whole generation of men

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[31] Areas needing painting included an area under the west span which had been scorched by fire and painting the machinery which, as was traditional, probably involved a bright array of colors. United Engineering & Construction to Executive Board and Its Bridge Committee, 7/26/1911, 1911 Council Documents, Improvements - Bridges 1911, City Archives, Portland, OR; 1909 Hawthorne Bridge Specifications, City Archives, Portland, OR, 15; C. K. Allen, Resident Engineer to His Honor the Mayor et. al., 12/19/1910 and Joseph Simon, Mayor, to Honorable County Court, 12/19/1910 both in 1910 Council Documents, Improvements - Bridges 1910, City Archives, Portland, OR. United Engineering's figure of 420 tons for each counterweight differs from the 442 ton figure that they were "designed to weigh" cited in Engineering News and HAER NO. OR-20. That difference left the bridge span-heavy by about the 5% that came to be standard practice. George A. Hool and W. S. Kinne, *Movable and Long-Span Steel Bridges* (New York: McGraw-Hill, 1943), 173.

[32] *The Times Record* (Aledo, Illinois), 3/24/1910, p. 13; 4/7/1910, p. 13; 4/14/1910, p. 13. The Keithsburg counterweights were a little more than half the weight of those on the Hawthorne. Use of furnace slag in the heavier, east counterweight meant the Keithsburg counterweights were even more compact.

to assume such technological challenges. The ambitious building programs of the various Western railroads and the challenges of operating over unprecedented distances and topography and through novel climate presented repeated opportunities to innovate. Steel fabricators had also originally honed their skills on railroad contracts. The success of the bridge building venture was clearly attributable to an array of such well-prepared men as well as to John Lyle Harrington.[33]

The Hawthorne Bridge

Like any complex technology, the Hawthorne Bridge poses special challenges to describe. Technologies are not abstractions, but highly specific material things, which means they change over time. This may be especially true of large civil engineering works located in urban areas. In any event, it is true of the Hawthorne Bridge, which has changed continually since 1909. By the time John Lyle Harrington arrived to inspect it in February 1911, United Engineering had completed the short list of items C. K. Allen had identified as awaiting completion, but Harrington noted that a controller required alteration and that the counterweight cables still needed dressing, a periodic application of grease.[34]

To see the bridge, then, we necessarily select a particular moment. Here, I choose early 1911 because that is when Harrington officially called the Hawthorne Bridge complete. Looking at the bridge at such an early moment offers a unique glimpse not only of the structure but also of a crucial instant in Waddell & Harrington's development of the vertical lift bridge. Once we have seen the 1911 bridge, we can turn our attention to some of the principal ways it has changed.

Although Waddell & Harrington served as consulting engineers, there is every reason to give Harrington credit for much of what made the Hawthorne a distinct advance over the South Halsted Street Bridge. Harrington is the partner who spent time in Portland. He signed all relevant correspondence during construction and responded to queries that arose thereafter. Indeed, when W. A. Eatchel, Superintendent of Properties for Multnomah County, wrote to discuss 1921 repairs, he directed his inquiry to the new firm of Harrington, Howard & Ash, with "Attention: *Mr. Harrington*" prominent and suitably underscored. And he closed his letter by noting, "My object in writing you is because it is *your bridge* and I feel that you are interested in

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[33] Misa, *A Nation of Steel*, passim.

[34] John Lyle Harrington to His Honor the Mayor et. al., 2/24/1911, 1911 Council Documents, Improvements - Bridges 1911, City Archives, Portland, OR. Workers had complained of the Westinghouse controller sparking. Harrington reported that parts for its repair had arrived; they were finally installed by early September. J. J. Doyle and M. Welch to Board of County Commissioners, 7/12/1911 and C. K. Allen, Resident Engineer, to T. M. Hurlburt, City Engineer, 9/7/1911, both in 1911 Council Documents.

the life of this structure by giving it the best possible care."[35]

The Hawthorne Bridge of 1911 was strikingly large. Its 250' 10 1/8" lift span surpassed any yet built and most of those under construction. A decade later only a handful of lift spans exceeded this length, none substantially. By contrast, the Hawthorne challenged its engineers to produce a span nearly twice the length of that at South Halsted Street. East to west, truss spans of 212' 8.5", 213' 2", 213' 2.1", 246' 10.5", and 246' 3.5" flanked the lift span to carry traffic across the river. As noted earlier, its deck was unusually wide relative to the distance between its trusses, a mere 23' 3" center to center. Outside each truss the bridge extended another 19' 4.5", providing 10' 9" wide passageways for street railways and other traffic and 7' sidewalks in addition to room for the railings and light fixtures located between the traffic and pedestrian areas.[36]

Harrington handled the design problems posed by a much longer lift span as he did a number of the Hawthorne's challenges: by relying on his experience engineering Keithsburg's Mississippi River bridge with its 234' lift span. Because the Keithsburg Bridge's lift span and most of its mechanical features no longer exist and the bridge received scant contemporary attention, only occasional direct evidence of the borrowing survives. The process, however, is fully consistent with a pattern that Waddell & Harrington evidently initiated with these two bridges. Over the period between 1907 and 1912, when the new lift bridge technology achieved definition, the firm repeatedly built pairs of bridges that enabled it to benefit from what it had learned on the first bridge and refine that technology on the second. Thus, the telescoping lift of the A.S.B. Bridge paved the way for Portland's Steel Bridge; the interchangeable span feature of Keithsburg was developed in the Arkansas River bridge linking Van Buren and Fort Smith, Arkansas; and the 50' man-powered Sandpoint, Idaho, highway bridge served as the prototype for the 50' man-powered Morgan's Louisiana & Texas Railway Bridge over Big Choctaw Bayou,

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[35] Council Documents, Improvements - Bridges, *passim*; Eatchel to Harrington, Howard & Ash, 5/7/1921, Multnomah County Roadmaster's Records, Oregon Historical Society. Underscoring in the original, italic emphasis added.

[36] Span lengths cited are from center to center of piers. My figures differ slightly from those in HAER No. OR-20, which relied on published sources. They come from drawings produced by the Multnomah County Highway Department as part of redecking plans in 1930 and, again, in 1944. Most span length measurements differ from Waddell & Harrington's May 1909 Plan by less than an inch; only one, river span 3 (counting from east to west), differed by between one and two inches. Figures for width are from 1930 plans only. Hawthorne Bridge, Map and Plan, 5/26/1909 (Waddell & Harrington); Profile of Present Bridge, 4/1930 (Multnomah County Roadmaster); Plan for Re-Decking, 8/1944 (Multnomah County Highway Department), All in Multnomah County Bridge Shop, Portland, OR. Comparative dimensions of other vertical lift bridges are summarized in Howard, "Vertical Lift Bridges," 585-586 and passim and in Hardesty & Hanover, Consulting Engineers, Corporate brochure, 1/1953, in Morrison Bridge Construction Files, Yeon Records Center. The only substantially longer lift span completed within the next decade was the North Kansas City A.S.B. Bridge. Because that bridge's lift span moved by having its hangers telescope within the posts of a fixed truss span above, its design avoided many of the challenges of creating a long movable span.

Louisiana.[37]

The single most prominent improvement pioneered at Keithsburg and refined on the Hawthorne Bridge was the articulation of separate counterbalancing and operating rope systems, a feature central to most later vertical lift bridges. On the South Halsted Street Bridge, the uphaul cables ran over the main sheaves and the downhaul cables connected to the counterweights, features that also characterized the counterweight cables. All cables connected to the lift span and none to the towers. As a result the bridge used relatively large amounts of operating cable and its sheaves and ropes made high maintenance demands. In contrast with Waddell's 1893 patent for this early system, Waddell & Harrington's 1909 patent for the system incorporated in the Hawthorne Bridge displays the simple elegance in mechanical engineering that Harrington contributed to the firm. Heavy counterweight cables connect to the counterweights at one end and to the lift span at the other, traveling over the large main sheaves in the process and assuring a rough balance as the span lifts and lowers. Lighter operating cables connect to operating drums on the lift span and to either the top or bottom of the tower. When the drums rotate in one direction, the span is lifted by winding the uphaul cables and paying out the downhaul ones; reversing the direction reverses the process and lowers the span. Wear and tear is concentrated on the operating cables which are less costly and, mechanically speaking, relatively easy to replace. By contrast, the heavy, expensive counterweight cables experience little wear and tear because the main sheaves are so large they bend relatively little. This is a special boon because their replacement poses real challenges in maintaining counterweight and lift span stability.[38]

The Hawthorne Bridge was also the first modern lift bridge to house its machinery and operator in a building placed between the top chords at the center of the lift span, the standard solution to the problem thereafter. The location simplified the problem of keeping the span in

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[37] Waddell, "Vertical Lift Bridges," 174-179; Howard, "Vertical Lift Bridges," 585-586 and *passim*; Hardesty & Hanover Corporate Brochure, 1/1953, 32-34; HAER NO. MO-2; Otis Ellis Hovey, *Movable Bridges*, (New York: John Wiley & Sons, 1926), I, 156-157. That the Sandpoint lift was man-powered is my deduction from the photographs and contemporary descriptions in the Bonner County Historical Society collections. Like the M. L. & T. Bridge, human power was an option not only because of the lightness of the span, but also because it was built high enough that it needed to open only infrequently, at high water. *Pend d'Oreille Review*, 4/16/1909, p. 1.

[38] My understanding of South Halsted Street's operation is derived from Waddell, *De Pontibus*, 108-112; Hovey, *Movable Bridges*, I, 152-153; U.S. Patent No. 506,571, J. A. L. Waddell, Lift Bridge, 10/10/1893. U.S. Patent No. 932,359, J. A. L. Waddell and John Lyle Harrington, Lift-Bridge, 8/24/1909 derives from an application filed 8/3/1908, about the time that construction of the Keithsburg bridge began. Van Cleve, "Mechanical Features of the Vertical-Lift Bridge," 1019-1022 confirms the pioneering role of Keithsburg. Hovey, *Movable Bridges*, I, 152-156 makes clear the salient characteristics of most later vertical lift bridge operating and counterweight systems. Study of documentary evidence of subsequent cable replacements on the Hawthorne Bridge and discussions with Ed Wortman, Multnomah County Bridge Engineer, helped clarify the essential advantages of the system. The Portland HAER bridge historians benefitted from electronic correspondence with the Chicago HAER bridge historians, at work simultaneously; Justin Spivey kindly supplied copies of the patents used here and later.

balance because the various operating ropes, although running in opposite directions, could be of the same length. At South Halsted Street, the engines and drums had been placed below the street on one of the approaches, a solution necessitated by the use of a heavy steam engine. Only the operator was housed at mid-span. At Keithsburg, to economize on the steel used in the trusses and compensate for the heavy dead load of its gasoline engines, the operating house was placed at one end of the lift span, resulting in unequal stretches of the operating ropes and "jerky motion" of the span when operators could not keep up with the ropes' repeated need for readjustment. Subsequent discussions have evidently forgotten this history. They generally emphasize that the top and center location provides the operator a good vantage on traffic, although visits to operators' houses make clear that, although traffic on the approach spans is visible, often traffic on the lift span is not. It is worth noting that since the Hawthorne Bridge was the first modern vertical lift bridge built with electric motors, its designers had less weight in the machine room to contend with, giving them more flexibility in choosing a machine room location.[39]

Other important features also show the Hawthorne Bridge as achieving a standard that subsequent vertical lift bridges maintained. Its steel-framed concrete counterweights are one obvious example. South Halsted Street had used cast iron counterweights. Although not built until later, the A.S.B. North Kansas City bridge was actually the first Waddell & Harrington bridge planned with concrete counterweights. Keithsburg had steel-frame concrete counterweights, although to compensate for more than twenty tons additional weight on its east end, the east counterweight incorporated slag from a nearby blast furnace in its concrete.

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[39] By contrast, one of Waddell's "lessons" from South Halsted Street was that in future bridges he would remove both the machinery and the operator to a house located in one of the towers. Waddell, *De Pontibus*, 113-114 (also reiterated in Bridge Engineering and other subsequent publications). The original Hawthorne Bridge operator's house was slightly higher than the current one. It remains visible as the frame structure between the machinery house and the current operator's house. In addition to visits to operators' houses, reading debates over the elimination of gatemen made me aware that operators' ability to see pedestrians and vehicles on the bridge was limited both by the floor and walls of the structure that housed them and by the trusses.

Hovey, *Movable Bridges*, I, 154 identifies the added weight of the operator's house and machinery house as the principal liabilities of the now-standard solution. On Keithsburg, see Waddell, "Vertical Lift Bridges," 174 (also reiterated in *Bridge Engineering*). Van Cleve, "Mechanical Features of the Vertical-Lift Bridge," 1021-1023, claims that the problems at Keithsburg were discovered when the Hawthorne Bridge was nearly complete and the location of the operator's house changed at that time. I have found no supporting evidence for this claim in shop drawings. Keithsburg was experiencing other, more serious mechanical problems as late as mid-June, forcing it to close and await return of machinery shipped east for repair. It's operators would not have noticed problems manifest in regular operation until about the time Hawthorne lift span construction commenced, making changes in steel fabrication plans unlikely. *Times Record* (Aledo), 6/16/1910, p. 13.

At least in print, Waddell more readily took responsibility for his achievements than for his failures. The power plant and its location at South Halsted Street is blamed on others and the mistake at Keithsburg is portrayed as having no source and, in any case, "of but little importance," the chief lesson being that one should never violate the aesthetic imperative of symmetry.

Moving away from cast iron fit into a more general pattern; in accord with Waddell's post-Halsted Street reflections, the Hawthorne's machinery was cast steel rather than cast iron. And, improving on Keithsburg, the Hawthorne Bridge had all its gears mounted in the same frame, a more compact arrangement generally followed for subsequent vertical lift bridges.[40]

The Hawthorne also eliminated two components used on South Halsted Street, the hydraulic buffers used to cushion the span's coming to rest in both its raised and its lowered positions, and the chains used to balance its cables. These were clearly Harrington's contributions; Waddell later protested that he "was persuaded, rather against his will to omit" the buffers and counterweight chains "on the plea that with electric power these were not necessary" and that he intended to use them in some future bridges. Correspondence between Multnomah County, its bridge operators, and Waddell & Harrington over minor repairs needed in 1911 includes a statement by the operators that the cable needed balancing and that the operators had understood that this "was ordered done by Mr. Waddell," simultaneously suggesting considerable local familiarity with early lift bridge technology and offering evidence that Waddell's differences with Harrington were aired in Portland during the bridge's construction. C. K. Allen, Resident Engineer, writing on behalf of Waddell & Harrington denied that Waddell had issued such an order and summed up the new state of the art: "On Halsted street bridge erected a good many years ago in Chicago, this was done, but it has been found better to provide a reserve of power in the operating machinery to take care of any unbalanced load from this cause, than to complicate the bridge by extra chains, or other devices," a concern with mechanical simplicity that fits what we know of Harrington. Although this Hawthorne innovation characterized many subsequent lift bridges, more recent standards now call for balance chains on bridges with a lift higher than 40 feet; the 1985 refurbishing of the Hawthorne followed that recommendation and installed them. The shifts in what engineers understand as the "best" solution nicely illustrate how the changing perceptions of power as a scarce or abundant resource shape technological choice.[41]

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[40] Hovey, *Movable Bridges*, I, 152-156; Waddell, "Vertical Lift Bridges", 172-174; *Times Record* (Aledo), 4/14/1910, p. 13; Van Cleve, "Mechanical Features of the Vertical-Lift Bridge," 1022-1023.

[41] Waddell, "Vertical Lift Bridges," 173; C. K. Allen to Honorable Mayor et. al., 7/21/1911 and Multnomah County Court to J.(sic) K. Allen with attached letter from J. J. Doyle and M. Welch to Multnomah County Commissioners, 7/12/1911, all in 1911 Council Documents, Improvements - Bridges, 1911, City Archives, Portland, OR; A. E. Schmidt, P.E., Project Manager, Sverdrup & Parcel to Stan Ghezzi, P.E., Structural Engineer, Multnomah County, 5/14/1985, Phase I Hawthorne Bridge Repairs, 1985, Yeon Records Center. Allen's reply identified Doyle and Welch as operators; by 1924, correspondence identifies Doyle as "Foreman, Hawthorne Bridge." J. J. Doyle to Eatchel, 1/29/1924, Roadmaster's Records, Oregon Historical Society, Portland, OR. By the time he authored *Bridge Engineering*, Waddell appreciated that the choice to include balance chains depended on a host of economic factors that offset one another and varied from bridge to bridge, offering a glimpse of Waddell at his best. Waddell, *Bridge Engineering*, I, 722-723.

The new 1985 balance chains were ultimately removed; installing them retroactively had precluded their being placed at the counterweight's center of gravity and, in consequence, they altered the counterweight's balance

While many important components of the 1911 Hawthorne represented the emerging standard of lift bridge design, a number of its components reflected transitional stages in the development of this bridge type. Most notable are the equalizers. These devices, generally described as functioning to maintain equal loads on all counterweight ropes, were located between the ropes and the weights they carried. On the South Halsted Street counterweight cables, the comparable devices were not called equalizers, probably because they were not designed to be self-adjusting. Instead, a rather complex and imperfectly described feature of the early Waddell patent connected loops of two cables to the counterweight through a roller device. The patent asserted that "the loops and cables can be adjusted . . . so that the strain on the cables will be equalized." [See Figure 1, Appendix.] Waddell makes no claims for the device in the patent, suggesting that he was not especially pleased with it.[42]

The equalizers on the Hawthorne Bridge are a long step in the direction of the "standard" equalizer. They consist of sets of straight, horizontal balance bars, each with three pins lined up across it. The two end pins are attached to two rope sockets and the middle pin to the equalizer plate. They closely resemble an equalizer shown in Waddell & Harrington's 1910 lift bridge patent and referred to by that name. [See Figure 2, Appendix.] That patent provides for two similar equalizers, one to connect cable and counterweight and one to connect cable and lift span, the only essential differences being those devised to make the somewhat different connections. The patent application dates to 1908, suggesting that these devices were worked out for use at Keithsburg. Although the patent depicts and describes them, it fails to enumerate these devices in its concluding list of claims, suggesting that they too were viewed as imperfect solutions.[43]

Multnomah County experience would certainly support that assessment. The Hawthorne Bridge equalizers pose real challenges during cable replacement, since removing (or breaking) one rope attached to a particular horizontal bar suddenly transfers all the weight to the remaining rope. [See Figure 3, Appendix.] When refurbished in 1985, many were also found to have "frozen" in a fixed position, precluding any functional benefit. Following the precedent of Keithsburg, the Hawthorne Bridge uses a more elaborate version of these equalizers to connect its counterweight ropes to the corners of the lift span. It manages to bring twelve ropes to bear on a single connecting pin. The connection at the counterweight is also made through equalizers, although these only combine four ropes. Standard practice came to omit equalizers at the lift

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and caused them to hang out of level. The most recent, 1998-9 refurbishing of the bridge finally removed the chains that had merely been disconnected earlier. Conversations with Ed Wortman, Multnomah County Bridge Engineer, clarified this history.

[42] U. S. Patent No. 506,571, J. A. L. Waddell, Vertical Lift Bridge, 10/10/1893.

[43] U.S. Patent No. 953,307, J. A. L. Waddell and J. L. Harrington, Lift Bridge, 3/29/1910; Drawing number 55719, Counterweight Rope Replacement, Willamette River (Hawthorne) Bridge Painting and Deck Replacement, August 1997, Multnomah County Bridge Shop; Van Cleve, "Mechanical Features of the Vertical-Lift Bridge," 1022.

span connection and retain them at the counterweight connection.[44]

Comparison of the Hawthorne equalizer with that on the 1912 Steel Bridge shows how quickly this aspect of lift bridge technology developed. The Steel Bridge's equalizers are essentially those considered standard in the 1920s. [See Figures 4 and 5, Appendix] They are also confined to the counterweight connections. Comparison also dramatizes what a long stride the Hawthorne equalizer was over its predecessor; relatively modest differences separate it from the later standard, most of them conferring greater stability. In the longer perspective, though, it is worth noting that by the 1920s, some authorities on lift bridges were asking whether equalizers were needed at all and arguing that they generally failed to perform the function attributed to them. At least one perceptive engineer had made the same observations about the time the Hawthorne was constructed. By the mid-1920s, systems more like turnbuckles, permitting periodic manual adjustment with the use of jacks, began replacing equalizers. Although simpler and less cumbersome, this newer "standard" solution embodies the essential principle of the early Waddell equalizing mechanism, a history of development that serves as a useful corrective to the assumption that progress narratives constitute technological history.[45]

Of course, in many respects, the Hawthorne Bridge emulated the pioneering South Halsted Street vertical lift bridge, otherwise we would not identify them as members of the same class. This was true of small features as well as large. The span guides are a good example. Mounted at both the tops and the bottoms of the hanger posts at the four corners of the lift span, these guides were of two sorts. Longitudinal guides contained heavy springs designed to compensate for changes in the distance between the lift span and the forward face of the adjacent tower so that as the metal expanded and contracted daily and seasonally, the face rollers remained in contact. Transverse guide rollers, by contrast, were designed to make contact with the outside faces of the tower columns only when forces such as wind pressure caused lateral movement in the span. The two sets of span guides replicated the system used on South Halsted Street, incorporated into Waddell's earlier plan for the North Kansas City Bridge, and retained at

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[44] Memo from Stan Ghezzi to Hawthorne Bridge - Unit 1 Contract File re Meeting with Riedel International July 9, 1985, Phase I Hawthorne Bridge Repairs 1985, Yeon Records Center; Van Cleve, "Mechanical Features of the Vertical-Lift Bridge," 1022. I conclude that Keithsburg had its principal equalizers at its lift span as well as smaller ones at its counterweights based primarily on scrutiny of surviving photographs in the Aledo County Historical Society collection. My understanding of the history of the Hawthorne equalizers relies as well on conversations with Ed Wortman, Multnomah County Bridge Engineer.

[45] See Historic American Engineering Record (HAER), National Park Service, U.S. Department of the Interior, "Addendum to Steel Bridge," HAER No. OR-21for more on how the Steel Bridge served to develop the standard equalizer. Van Cleve, "Mechanical Features of the Vertical-Lift Bridge," 1022-1023; Steel Bridge drawings supplied from the files of HNTB, Courtesy of Bill James, P.E.; E. E. Howard, "Vertical Lift Bridges," comment by Victor H. Cochrane, 664-668 and reply by Howard, 688.

Keithsburg.[46]

Over time, despite or perhaps because of Waddell & Harrington's precise calculations, the spring-loaded guides came to operate less effectively. Slight increases in the distances between lift span and towers or changes in the behavior of the springs meant that the spring-loaded face guides no longer made contact during cold weather. Moreover, the changing value of energy made engineers more critical of any component that exerted pressure and, thus, increased the force needed to move the span. The longitudinal guides were slated for replacement when Sverdrup & Parcel's 1985 plans for the bridge sought ways "to reduce the applied torque necessary to operate the span by about one-half." As it turned out, though, designing a replacement proved too time consuming for an emergency repair schedule that sought to minimize the time the bridge would be out of service. At the last minute the contractor and county decided simply to refurbish the existing system by replacing the springs and installing a new guide track wearing surface on the tower face, replacing an earlier wearing strip. The early longitudinal guides system remain on the bridge, but, perhaps because of the delicacy of the original design, the refurbished system does not function effectively.[47]

The Hawthorne Bridge also includes a guide system for its counterweights, something the South Halsted Street Bridge, with its smaller cast iron counterweights, evidently made do without. The counterweight guides are relatively simple steel jaws riveted to the four inner corners of the counterweight's steel frame and engaging Z-bars running along the inside tower surfaces. Like the span guides, this counterweight guide system survives, although it functions only with considerable wear on the Z-bar.[48]

A final feature of the 1911 Hawthorne Bridge, its span locks, also shows the bridge as a work-in-transition for Waddell & Harrington. South Halsted Street had lacked such devices,

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[46] Hawthorne Avenue Bridge, Castings, Pennsylvania Steel Co. Shop Drawing, 2/11/1910; Waddell, *De Pontibus*, 110, 116; Van Cleve, "Mechanical Features of the Vertical-Lift Bridge," 1020-1021. Originally, longitudinal guides were placed at both top and bottom chords; only the bottom chord rollers remain.

[47] Hardesty, "The New Hawthorne Avenue Bridge," 279. A. E. Schmidt, Project Manager, Sverdrup & Parcel to Stan Ghezzi, Structural Engineer, Multnomah County, 5/14/1985 and 5/22/1985; Stan Ghezzi to File, re. Hawthorne Bridge Emergency Repairs Contract I0042C, 7/3/1985; Stan Ghezzi to Hawthorne Bridge Unit I Contract File, re. Meeting with Riedel International Inc., 7/9/1985; Unit I Hawthorne Bridge Repairs, Span Guide Rehabilitation, Drawing Number SGR-001, 7/16/1985; Unit I Hawthorne Bridge Repairs, Inspector's Daily Reports, 5/13/1985 to 8/21/1985 all in Yeon Records Center. This discussion depends heavily on conversations with Ed Wortman, Multnomah County Bridge Engineer. In essence the original system was not designed to permit removal and replacement of the springs. The refurbished system has been made to work only by essentially disabling the new springs and adjusting the system seasonally.

Within a few years of its use on the Hawthorne, Van Cleve reported that the spring-loaded rollers had been "found somewhat objectionable and . . . improved upon in some later bridges." "Mechanical Features of the Vertical-Lift Bridge," 1020-1021.

[48] Hardesty, "The New Hawthorne Avenue Bridge," 279. Again, information on the recent functioning of the system comes from Ed Wortman, Multnomah County Bridge Engineer.

relying instead on pressure from its operating ropes to hold the lift span in place on the piers. By contrast, the Hawthorne Bridge, like the Keithsburg span, was equipped with a rather complex double latch and counterweight mechanism that locked automatically and could be released manually or electrically. After initial testing, there is no evidence that the span locks worked effectively. If, as suggested earlier, the bridge started out span heavy, locks may initially have seemed redundant; there is also early evidence that they functioned effectively only when assisted by the span's extra weight. If they managed to function in the bridge's first few years, the imbalance that wrenched the span free during a 1914 fire certainly disabled them thereafter. In any event, they represent Waddell & Harrington's initial attempt at a span lock, continued on later bridges in modified form.[49]

Ironically, in 1985 when consultants evaluated the bridge's various components they found that "the span is held in the seated position by maintaining tension in the downhaul ropes," as had been the case on the South Halsted Street Bridge. While the Hawthorne's original span lock system had been pioneering, it had left so little local evidence that the consultant concluded: "since the bridge has been in service for some 70 years without span locks, we see no problem with continued operation in the present mode until the span and counterweight have been balanced. Recent measurement indicates a span-heavy condition." Since 1992 the bridge boasts span locks once again, but its reliance on being span-heavy for most of its existence is equally representative of subsequent developments in lift bridge technology.[50]

From the perspective of ordinary Portland citizens, the fact that Harrington's experience designing their bridge had produced many important features of a new bridge type was less important than the basic fact that the new bridge worked. Indeed, that was essentially why engineers continued to replicate its features. It should come as no surprise, then, that when E. E. Howard surveyed the type for the American Society of Civil Engineers a decade later, he featured more recent structures in his detailed analysis, but turned to the Hawthorne Bridge in his concluding remarks. Comparing it to the adjacent 1905 Morrison, an excellent swing span, he reported that he had "seen a steamboat pass the Morrison Bridge, travel the 1,200 ft. to the Hawthorne Bridge, and the latter would open, pass the boat, close, and have traffic moving before the Morrison Bridge had traffic moving." He offered 1915-16 figures from the Board of County Commissioners to show that the Hawthorne consistently averaged half the opening time of other county spans on the Willamette (two swing spans and a Rall bascule at the time), that its

[49] Waddell, *De Pontibus*, 112; Hawthorne Avenue Bridge, Hand Operation of Bridge Locks, 8/29/1910, and Details of Bridge Locks, 7/29/1910, Drawings at Multnomah County Bridge Shop, Portland, OR; Van Cleve, "Mechanical Features of the Vertical-Lift Bridge," 1021, 1024.

[50] A. E. Schmidt, Project Manager, Sverdrup & Parcel, to Stan Ghezzi, Structural Engineer, Multnomah County, 5/14/1985 and 7/10/1985, Yeon Records Center; Hawthorne Bridge Rehabilitation Phase II, Miscellaneous Documents 1991-93, Yeon Records Center; Hawthorne Bridge No. 2757G, Phase II Rehabilitation, Sheets 19 and 20 of 46, Span Lock System and Span Lock System Details, June and July 1991, Drawings in Multnomah County Bridge Shop; Hool and Kinne, *Movable and Long-Span Steel Bridges*, 173-174.

minimum opening time ("gong to gong") was about a minute, and that its modest 5 cents per opening energy costs were equaled only by the other local lift bridge, the Steel. Portland had gotten the bridge it had hoped for.[51]

Getting to Know the Bridge: Early Maintenance and Repair

If creating the Hawthorne Bridge had challenged the ingenuity of J. A. L. Waddell and John Lyle Harrington and the construction know-how of Robert Wakefield and United Engineering, operating, maintaining, and repairing the novel structure also required the ability to respond creatively. Multnomah County, charged with operating the bridge from the outset and assuming ownership in 1913, proved fortunate in its employees. As noted earlier, operators J. J. Doyle and M. Welch performed a thorough inspection shortly after the County assumed control, displaying in the process considerable understanding of the new technology. In addition to noting several items the contractor needed to repair or complete, they identified a number of concerns that have challenged County engineering staffs ever since. The history of the bridge's early life is a history of initial responses to these concerns.

One early and continuing challenge was learning to accommodate the bridge's fluctuating shape and altered behavior as it experienced temperature changes. Expansion joints are one good example. Details of the bridge's initial expansion joints are sketchy; Doyle and Welch began their report by finding "the Expansion Rollers at the northwest corner of the west fixed span out of place." A decade later, W. A. Eatchel, County Superintendent of Properties, reported directly to Harrington that "where the expansion plates were at the expansion joints, I am taking them out and instead of replacing we are providing an angle iron bolted to the decking of the bridge to hold the pavement, and also act as an expansion joint." Its chief virtue, he noted was that it would be "far less complicated to handle than the present expansion plates." As was often the case in his correspondence with County officials, Harrington expressed genuine interest in their experiments. After receiving the sketch he had requested, he concluded that in essence the County was solving the problem by leaving the joint open, creating a two-inch space that caused him some concern. Nonetheless, he asked to be kept "informed of any difficulties you may have in maintaining the joint you have used, for expansion joints are the most troublesome of all the little items about a bridge."[52]

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[51] E.E. Howard, "Vertical Lift Bridges," 69-71. Howard presents a table using data from Multnomah County Commissioners' records. He notes that time is from "gong to gong" meaning that time during which the spans are being cleared is included. As several county engineers have pointed out to me, these figures make no sense if taken as described: a full open/close cycle. As gong to gong figures they remain impressive if one assumes they recorded the length of a half cycle, an opening or a closing. Such an interpretation also makes these figures consistent with others quoted for the bridge's early years.

[52] Doyle and Welch to Board of County Commissioners, Copy attached to Multnomah County Court to J.[*sic*] K. Allen, 7/12/1911, City Council Documents 1911, Improvements - Bridges, 1911, City Archives, Portland,

Predictably, a number of problems centered on metal's expansion when heated. The PRL&P's rails and their underlying apron plates proved especially troublesome during the bridge's first hot summer. C. K. Allen, still in Portland as Waddell & Harrington's Resident Engineer for the Steel Bridge, grew a bit impatient with complaints, noting that these sorts of problems were inherent on bridges with railway track and that "the proper supervision of the track would avoid any repition [*sic*] of interruption of traffic from this cause" because rails should be adjusted as soon as "creeping became evident" rather than waiting until "it becomes serious enough to interfere with the opening and closing of the draw."[53]

People who counted lumber as a leading industry and had grown accustomed to the annual cycle of rainy and dry seasons were probably less surprised than the outsider might be to discover another seasonal change in the bridge. During the summer dry season, its wood deck lost so much weight in moisture that the lift span became lighter than its balancing counterweights. By 1921, "Fred," an employee reporting on various bridge conditions to Superintendent Eatchel, simply noted routine practice: "owing to weather conditions the lift has to be weighted down in the summer time." The County had evidently followed Allen's 1911 suggestion to make some additional concrete balancing blocks like those already used to add and subtract weight on the counterweight.[54]

Its wooden deck also afforded County workers their most dramatic opportunity to learn about the new bridge. When fire struck in 1914, the wood lift span deck, made especially flammable by the creosote used to preserve it, burned enough to reduce its weight substantially.

OR; W. A. Eatchel to John Lyle Harrington, 5/26/1921, and John Lyle Harrington to W. A. Eatchel, 7/18/1921, Multnomah County Roadmaster's Records, Oregon Historical Society, Portland, OR. Elsewhere, Harrington refers to expansion joints as "always a troublesome thing." John Lyle Harrington to W. A. Eatchel, 7/1/1921, Multnomah County Roadmaster's Records, Oregon Historical Society, Portland, OR.

[53] C. K. Allen to Honorable Mayor and Members of the Executive Board, 7/21/1911, City Council Documents 1911, Improvements - Bridges, 1911, City Archives, Portland, OR. Part of Allen's dismay derived from subsidiary damage the improperly adjusted apron plates ended up doing, splitting the ties at one end of the bridge so badly that they needed replacement. Allen to T. M. Hurlburt, City Engineer, 9/7/1911, City Council Documents 1911, Improvements - Bridges, 1911, City Archives, Portland, OR.

[54] Fred to W. A. Eatchel, 7/5/1921, Multnomah County Roadmaster's Records, Oregon Historical Society, Portland, OR. The tenor of this report makes it very likely that the author was Fred Tietjen, foreman for bridges and ferries for Multnomah County (*Oregonian*, 9/10/1927, 10). C. K. Allen to Honorable Mayor and Members of the Executive Board, 7/21/1921, City Council Documents 1911, Improvement - Bridges, 1911, City Archives, Portland, OR. These accounts at least suggest that the bridge's span locks were inadequate unless the bridge was kept span heavy.

Waddell, whose immense range of concerns nicely balanced Harrington's sharp focus on mechanical innovation, had mentioned the problem of wood drying out and the potential solution of added weight, but he deemed the problem unlikely to occur, expecting accumulated dirt to balance the modest weight loss. He was evidently thinking only of the loss of weight as new wood aged rather than the regular loss associated with the Pacific Northwest's relatively unusual seasonal extremes. Waddell, *De Pontibus*, 117-118.

The lift deck flew up and the counterweights crashed down. When the smoke cleared, it revealed four broken down haul cables and bent ends on the 18" I-beams near the lift span on the adjacent fixed spans. Nonetheless, the County managed repairs expeditiously enough that the bridge reopened ten days later. A temporary arrangements of brackets and wedges compensated for the I-beams' deformation until 1921, when plans to apply a new road surface led County Bridge Engineer A. K. Grondahl to argue for their replacement. Although straightening the beams would have been an equally good solution, the region's small market meant that the only steel firm with a straightening press had gone out of business. In addition to learning the skills of making quick, temporary repairs, skills subsequently put to good use after periodic ship collisions with the bridge, the bridge's behavior during the 1914 fire gave County bridge workers considerable confidence in the mechanism and structure. They were well-prepared to allay fears of catastrophic failure that occasionally troubled other County residents.[55]

In their first decade on the bridge, County employees also learned a great deal about routine maintenance. Among the earliest suggestions they offered were those intended to simplify maintenance tasks: planking to prevent debris from accumulating around the guard rail, changes in the turnbuckles so workmen could get at them without having to swing down from the top of the tower in a boatswain's chair, and covers to keep ice and snow out of the counterweight and idler sheaves. Most important, they learned the importance of routine lubrication to the bridge's continued health. By September 1911 workmen had already noticed that the compound was not adequately lubricating the main sheave bearings and had persuaded the County Commissioners to replace the compound cups with oil cups.[56]

As Harrington had indicated, the bridge's survival would ultimately depend on such behavior. He would have been especially pleased, therefore, to learn of Fred Tietjen, County Foreman for Bridges and Ferries in the 1920s. In 1924, R. W. Tobin, President of the Wire Rope Lubricating Company of Trenton, New Jersey, took the time to write W. A. Eatchel, County Roadmaster, after visiting his local agents, John A. Roebling's Sons. "I visited your Hawthorne

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[55] H. B. Chapman to Public Belt Railroad Commission, n.d.; Public Belt Railroad Commission, City of New Orleans, to Mayor, City of Portland, 11/10/1924; W. A. Eatchel to Harrington, Howard & Ash, 5/7/1921; John Lyle Harrington to W. A. Eatchel, 5/17/1921; W. A. Eatchel to John Lyle Harrington, 5/26/21; Fred to W. A. Eatchel, 7/5/1921 all in Multnomah County Roadmaster's Records, Oregon Historical Society, Portland, OR. One of the many, often anonymous, men who kept the bridge operating, Grondahl was another railroad trained engineer. After working for several companies, including the O.-W.R.&N., Grondahl passed the U.S. highway engineer civil service examination in 1919, although his only formal education had been two years study for the Lutheran ministry at Augsburg College in Minneapolis. *Oregon Voter*, 61, 5/10/1930, 24-25; *Oregon Voter*, 57, 5/25/1929, 20. On the high flammability of creosote see Clay McShane, *Down the Asphalt Path: The Automobile and the American City* (New York: Columbia University Press, 1994), 60.

[56] Doyle and Welch to Board of County Commissioners, copy in Multnomah County Court to J.[*sic*] K. Allen, 7/12/1911; C. K. Allen to Honorable Mayor et. al., 7/21/1911; Multnomah County Commissioners to A. L. Barbur, Auditor, City of Portland, 9/21/1911 all in City Council Documents 1911, Improvements - Bridges, 1911, City Archives, Portland, OR.

Bridge . . . to look over the matter of lubrication of the ropes . . . While there I met Mr. Tietgen [*sic*] in charge of these bridges, and as I come in contact with many of the practical men in charge of bridges, want to emphasize to you how fortunate it is that you have men who are as interested in their work as Mr. Tietgen and his assistant are. Your ropes are in better shape than any on many bridges of the same nature I have inspected, and believe good work such as Mr. Tietgen is doing should be commended."[57]

Following Harrington's Directions: Maintenance

Nearly nine decades worth of maintenance and repair records exist for the Hawthorne Bridge. They offer a remarkable perspective on the original structure and provide the raw materials for answering the most important questions about the bridge: why is it still here? Of necessity, what follows selects a few aspects of that ninety-year history for detailed scrutiny. My discussion of maintenance focuses on the bridge's cables largely because the people who operated and used the bridge also focused on its cables. Naturally, because they were unfamiliar, the slender steel ropes carrying hundreds of tons of weight evoked concern. Because vertical lift bridges were new, outsiders also wrote to learn from the Hawthorne experience how well these ropes held up.[58]

Answering their questions involved first making a distinction between the eight, 1" operating ropes, which were "throw away items" not expected to last, and the forty-eight, 1.5" counterweight ropes, whose size, strength, and expense matched the crucial role they played in supporting heavy weights and made their longevity important. As noted earlier, four of the original operating ropes broke under the wrenching they received during the 1914 fire. Another broke in 1921. By 1924 all of these cables had been replaced. Breaks tended to occur near the sockets where the wire was most likely to be bent; Foreman Fred Tietjen also blamed exposure to acid in the process of attaching the wire to the socket. More fundamental, though, was the fact that the uphaul and downhaul ropes repeatedly wound and unwound around three and a half foot

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[57] R. W. Tobin to W. A. Eatchel, 3/18/1924, Multnomah County Roadmaster's Records, Oregon Historical Society, Portland, OR. Other items in the Roadmaster's correspondence identify Tietjen as bridge foreman and place him in that position from at least 1920 to 1927. *Oregonian*, 9/10/1927, 10.

[58] Although I will make brief reference to various maintenance activities on the Hawthorne, I have chosen to use each of the three early spans on the Willamette as a window on a different maintenance activity. Cables are featured here. On painting, see Historic American Engineering Record (HAER), National Park Service, U.S. Department of the Interior, "Broadway Bridge," HAER No. OR-22. On lubrication, see Historic American Engineering Record (HAER), National Park Service, U.S. Department of the Interior, "Steel Bridge," HAER No. OR-21. Paving receives some treatment in each of these reports. At least a few engineers also continued to harbor mistrust of counterweight cables. See, for example, Comment by Victor H. Cochrane, as part of the Discussion of E. E. Howard, "Vertical Lift Bridges," 658-681. Waddell identified prejudice against wire rope by railroad and municipal officials as a continuing bar to lift bridge diffusion. Waddell, published comment with Van Cleve, "Mechanical Features of the Vertical-Lift Bridge," 1041.

drums, subjecting them to repeated bending of a sort that the counterweight ropes, running over nine foot sheaves, did not experience. Moreover, as remains true, the operating ropes were often slack so that they experienced additional wear and tear from slapping against the surfaces meant to support them and, occasionally, the upper chord of the bridge. Tietjen attributed this slackness to the fact that "all turns on the Drums are right handed instead of right and left." In any event, in addition to regular lubrication, County personnel learned to perform regular inspection and plan on regular replacement of these ropes.[59]

The heavy, expensive counterweight cables were another matter altogether. Because they carried the weight of the span and its balancing counterweights, a break would have had more serious consequences. Likewise, because they bore weight continuously, removing and replacing these ropes was and remains a challenging task, not one to be undertaken frequently. As employees of Multnomah County and its contractor learned once again in 1998-99, before removing each cable, some method must be found to prevent dramatic shifts in the equalizers when ropes are removed. As it turned out, the procedure originally devised for the 1998-99 replacement, which called for paired compensating turnbuckle adjustments prior to each rope's removal, could not be carried out. Even with the use of a specially designed jacking apparatus, the turnbuckles remained under too much tension to permit adjustment. A new system of rigid blocking of the equalizers had to be devised midway through the job, a procedure consultants had initially tried to avoid because of "the unique reactions of the equalizer as individual rope loads

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[59] The recent, 1998-99, repair and maintenance work on the bridge included replacement of the operating rope drums, which had been replaced at least once before, in 1970. Subsequently, engineers have noticed somewhat more slackness and have also become aware that the original system of cable connections to the drums provided a relatively easy mode of adjustment that they now lack. My understanding of these features has benefitted from discussions with Ed Wortman, Multnomah County Bridge Engineer, and from a tour with Jon Henrichsen, P.E., Electrical/Mechanical Engineer Associate, Department of Environmental Services, Division of Transportation - Bridges, Multnomah County, 17 September, 1999.

Fred to W. A. Eatchel, 7/5/1921 and H. B. Chapman to Public Belt Railway Commission, about 11/10/1924, both in Multnomah County Roadmaster's Records, Oregon Historical Society, Portland, OR. A 1931 inspection, for example, identified an operating rope pulling from its socket, permitting its replacement before it broke. Roadmaster to Hon. Board of County Commissioners, 8/26/1931, Multnomah County Roadmaster's Records, Oregon Historical Society, Portland, OR. Occasional cable breaks continued; a 1985 news account recalled one in 1962 and one in 1959. Steve Erickson, "Aging Hawthorne a troubled bridge over Willamette waters," *Oregonian* clipping in April, 1985 sheave emergency files, Yeon Records Center.

Tietjen's remarks about acid occur in the context of his reference to the connections as "babitted," almost certainly an erroneous reference to what would have been and remains a zinc connection. My discussions with Ed Wortman persuade me that the subjection of the ends of the ropes to greater bending stresses suffices to explain their propensity to break near the sockets. The phrase "throw away item" is Wortman's. South Halsted Street Bridge, the only vertical lift bridge that could provide data to guide Multnomah County personnel, had two operating cable changes in its first twenty years. E. E. Howard, "The Cables of the Halsted St. Lift Bridge at Chicago," *Engineering News*, 69, August 21, 1918, 371-372 [a letter to the editor on behalf of Waddell & Harrington].

changed." According to the contractor, total costs of designing and implementing the new procedure amounted to $69,297, not including rope costs.[60]

Given their crucial role, high cost, and relative novelty, the counterweight cables received close attention from Multnomah County personnel from the outset. As noted earlier, County employees performed annual lubrication well and faithfully. By 1931, rope replacement received serious consideration. County Engineer, M. E. Reed expressed concern because the County Commissioners had economized on a 1921 redecking job by substituting Douglas fir for lightweight Port Orford cedar. The change had added thirty tons to the lift span deck; the counterweight cables carried 18.2 tons each rather than the 16 tons originally planned, although the factor of safety, Reed calculated, was still a reassuring 3.5.[61]

What made Reed's situation difficult was its relative novelty. Fortunately, he had another nearby early vertical lift bridge from which he could learn: the O.-W.R.&N.'s Steel Bridge. He consulted with the Railroad's Chief Engineer and its Bridge Engineer about his dilemma. He also contacted the local representative of John A. Roebling's Sons, the ropes' manufacturer. Shortly thereafter, A. T. Brown, representing Roebling, and the County Engineer rode up and down on the end of the lift span so as to examine the section of the cable that operated over the counterweight sheaves; they could not delay traffic, so this was the only inspection method possible. Brown's conclusions reiterated earlier findings. The cables had been well lubricated and internal corrosion was unlikely. He estimated that wear on the outside wires was less than 20%. None of this was cause for concern.[62]

On the other hand, lift bridge specifications had been created in the twenty years since the bridge had been built. The bridge's original hemp-centered Plow Steel ropes made up of six strands of nineteen wires each (6X19) had tested to destruction at 179,300 pounds, slightly over their catalog strength. Because the counterweight sheaves had been grooved for these original

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[60] John Lindenthal, Project Manager, to Marty Anderson, ODOT, 3/9/1999; L. E. Niemann, Abhe & Svoboda, Inc., to John Lindenthal, 11/25/1998 and 2/20/1999, all in Hawthorne Paint & Deck Replacement #11986, Abhe & Svoboda Inc. Construction Records #28 of 28, Yeon Records Center. These figures, supplied by the contractor, do not include the added costs resulting from delays in the carefully orchestrated sequence of other jobs that had to await counterweight rope changes.

[61] M.E.R. to Mr. Buck, 5/28/1931, Multnomah County Roadmaster's Records, Oregon Historical Society, Portland, OR. Reed's calculations don't quite add up nor do they jibe with data supplied by Tietjen a decade earlier. Tietjen gives a load per cable of 16 ton and a safety factor of 4.3; using his figures, a 18.2 ton load, which Reed quoted, would give a safety factor of 3.8. If Reed's 4.8 safety factor for the original bridge is correct, the ropes in 1931 had a safety factor of 4.2; if his 63.1 ton maximum load figure is correct, the original safety factor was 3.9 and the 1931 safety factor, 3.5. These differences are no doubt rooted in the fundamental difficulty of arriving at precise weights for lift span and counterweights.

[62] M. E. R. to Mr. Buck, 5/28/1931; E. R. Taylor, John A. Roebling's Sons, Trenton, NJ, Memo. Re. Hawthorne Street Bridge, 6/3/1931, Multnomah County Roadmaster's Records, Oregon Historical Society, Portland, OR.

1.5" ropes, installing the new, thicker ropes now recommended was impractical. Roebling recommended instead the substitution of a newer 6X19 Blue Center Steel Rope with Independent Wire Rope Center whose catalogue strength was 199,000 pounds. Thus, Roebling managed to recommend rope replacement while simultaneously asserting the quality of its original product.[63]

Despite Reed's and Roebling's recommendations, the beleaguered County Commissioners, faced with depression era financial constraints compounded by the recent, costly St. Johns Bridge construction, decided to bank on the assurances that the ropes had more than adequate strength left. Replacement awaited an improved economy. Not until 1941 were the original counterweight cables replaced with the stronger Blue Steel Center Rope recommended in 1931. Samples of the new ropes tested to destruction at 220,000 pounds. And, following 1931 recommendations, the new cables, unlike the original ones, were prestressed to remove all constructional stretch, the stretch associated with their newness. This procedure was new in 1931, but established in 1941.[64]

The County contract made provisions to have portions of the old rope tested to destruction, offering a unique perspective on the Hawthorne's original cables. Close examination in 1941 showed less wear than had been estimated after cursory examination a decade earlier. The section of cable exposed repeatedly to movement over the sheave had a section about one-quarter of its circumference where wires had worn to 85% of their original diameter. Fourteen wires had broken in the worst lay. Nonetheless, even that worst lay tested to an ultimate strength of 154,700 pounds (86% of its original strength). Another section, which showed no wear because it did not contact the sheave, tested at 169,400 pounds, or about 95% of its original strength. Although these tests substantiated continuing strength, internal examination showed the rope centers had dried out and the hemp had degenerated to the point where the wire strands lacked proper support. Internal nicking as the unbalanced strands moved against one another would probably have accelerated the rate of fatigue. And internal corrosion had set in, also

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[63] M. E. R. to Mr. Buck, 5/28/1931; E. R. Taylor, John A. Roebling's Sons, Trenton, NJ, Memo. Re. Hawthorne Street Bridge, 6/3/1931; A. T. Brown, John A. Roebling's Sons, to Geo. W. Buck, County Road Master, 7/1/1931, all in Multnomah County Roadmaster's Records, Oregon Historical Society, Portland, OR.

Several years after the Hawthorne Bridge's completion, the Bureau of Standards had just begun studies of the life of cables operating over sheaves. The only earlier study, by the Institute of Civil Engineers, had placed the probable life of such cables at over twenty years. E. E. Howard, "Cables of Halsted St.," 372.

[64] Carl Abbott, Portland: *Planning, Politics, and Growth in a Twentieth-Century City* (Lincoln: University of Nebraska Press, 1983), 99-100; Description of Work to Be Done and Special Provisions, Specifications and Contract Agreement for County Highway Construction, Hawthorne Bridge, Replacement of Counterweight Cables, 1940; Geo. W. Buck, Roadmaster, Notice to Bidders, 12/10/1940, both in Yeon Records Center; Robert J. Cole, Notary, Certification of Test Results, 4/10/1941; G. H. Cutter, John A. Roebling's Sons, Trenton, NJ, Memo. Re. Hawthorne Bridge, 1/30/1941, both in Hawthorne Counterweight Ropes 1975, Yeon Records Center. Elastic stretch, the normal behavior of the rope under working tension, was factored in by measuring the ropes under tension. In consequence, whereas the old ropes had lengthened about a foot in thirty years, the new ropes were expected to show only a slight lengthening attributable to the kneading action of their operating over the sheaves.

making more rapid deterioration likely. The ropes had lasted well for thirty years. They were replaced when they needed to be.[65]

The new cables remained in service until 1976. After 1970 they were subjected to formal annual inspection procedures which specified several grounds for condemnation based on various measures of wear. In 1976, the Hawthorne's second set of counterweight ropes were replaced with a third set: Improved Plow Steel 6X25 ropes fabricated by E. H. Edwards Company of South San Francisco, CA. The new ropes had sisal cores and had to meet a minimum 199,000 pounds ultimate strength test. They were, then, roughly equivalent to their predecessors. The contract specified the need to build "a suitable support system for the equalizer linkage at the drawspan" so as to "redistribute the loads among the other cables" while individual ropes were replaced. This part of the operation went smoothly.[66]

Problems occurred when the contractor attempted to save himself the trouble of tensioning every cable before cutting and socketing, the procedure used to factor in the ropes' elastic stretch. He performed tensioning on two "test cables" and applied the formula derived from that experience to the remaining ten cables destined for the northeast corner. As it turned out, though, the stretch of the various ropes was not consistent and the equalizers ended up out-of-level, requiring individual adjustments of all twelve northeast turnbuckles. In the interim, the "binding" of the east counterweight on the north guide bars occasioned delays for the electrical contractor engaged in a simultaneous replacement of the bridge's motors. Needless to say, the remaining ropes were individually tensioned and socketed as called for in the job specifications, eliminating the need for turnbuckle adjustments. The contractor also delayed cable lubrication from September, when all cables were replaced, until February. Unsurprisingly, the cold cables rendered the lubricant viscous and the coating uneven. The County decided to postpone lubrication until warm July weather.[67]

The current or fourth set of cables was installed in 1998-99. Although only a little more than twenty years had elapsed, the County decided that while it was immobilizing the bridge for other repairs, changing both counterweight and operating cables made sense. The cost of a

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[65] M. Hall, Wire Rope Engineering Division, John A. Roebling's Sons Company, Trenton, NJ, to Gilpin Construction Company, Renewal Contractors, Memo. re. Hawthorne Bridge Lift Ropes, 7/9/1941, in Hawthorne Counterweight Ropes 1975, Yeon Records Center.

[66] Kenneth H. Wheatley, Bridge Engineer, Hawthorne Bridge Rope Inspection & Tentative Standards, 4/7/1970; Special Provisions and Supplemental Standards for Highway Construction, Cable Replacement, Hawthorne Bridge, FAUS 0970, 2/26/1976; Ken Wheatley, Resident Engineer's Project Critique, Contract No. 8337, 8/2/1977, all in Yeon Records Center.

[67] Ken Wheatley, Resident Engineer's Project Critique, Contract No. 8337, 8/2/1977; Special Provisions and Supplemental Standards for Highway Construction, Cable Replacement, Hawthorne Bridge, FAUS 0970, 2/26/1976; Inspector's Daily Report, Contract #8337, 11/2/76; Ron Wong, Asst. Engineer, to Marion A Craft, Oregon State Highway Department, re. Hawthorne Bridge Contract No. 8320, Bridge Control Movement, 12/21/1976.

separate cable replacement job would have more than offset savings achieved by using the cables a few additional years. The bridge engineers selected a stronger grade of rope, Extra Improved Plow Steel ropes with polypropylene cores, largely because they were adding extra weight to the bridge and wanted to keep the factor of safety at around 5. The new ropes tested at an average breaking strength of 232,000. AASHTO standards, not promulgated until twenty-eight years after the bridge's creation, now called for an even higher 8 to 1 safety ratio on new bridges, one that could only be achieved on the Hawthorne by altering the size or number of cables, necessitating associated changes too extensive to be feasible. As in 1941, though, the development of these standards encouraged improvements to maintain the highest practical safety standards.[68]

The demands of the job also encouraged change. When 6X25 ropes were unavailable, 6X26 ropes were substituted to keep on schedule. As noted above, delays nonetheless occurred, mostly because counterweight cable changes occur so infrequently that individual memory cannot provide guidance. Historical memory can serve, but has been hard to tap. Finding ways to learn from the bridge's history grows more important over time. As the span ages, its equalizer system appears more and more exotic and potentially troublesome to the consultants who examine it; the failed cable change plan departed from earlier practice principally because the consultant feared the "marginal capacity of some equalizer components" and the equalizer's "unique reactions."[69]

Adapting to New Conditions: Decks

Regular maintenance offers only part of the explanation for the bridge's survival. In order to continue functioning as an important river crossing in a major city, the Hawthorne Bridge has also needed to adapt to new conditions. Changes in traffic have made the most persistent demands. Although automobiles and trucks made up part of the traffic for which the bridge was designed, figures for 1913-14 show their numbers to have been a modest 1,640 per day, only slightly more than the 1,240 horse-drawn vehicles using the bridge. About as many people crossed on foot as in both sorts of vehicles combined. By far the greatest demands, though, were

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[68] Jon P. Henrichsen, Multnomah County Bridge Engineer, to author, e-mail correspondence, 9/27/1999; Hawthorne Paint & Deck Replacement, #11986, Abhe & Svoboda Inc., Binder 1 of 28, p. 172, Yeon Records Center. The 1985 evaluation of the bridge by Sverdrup & Parcel had pointed out that the load on the cables exceeded AASHTO Standards but, noting the good County maintenance record and nearly sixty year total life of the two previous sets of cables, recommended waiving the new requirements. A. E. Schmidt to Stan Ghezzi, 5/14/1985, Summary of Sverdrup & Parcel Hawthorne Bridge Investigation, Yeon Records Center. Discussions with Ed Wortman, Multnomah County Bridge Engineer also aided understanding of these developments.

[69] Work or Change Order Supporting Data, Contract No. C11986, John Lindenthal, Project Manager, 2/27/1998 and attached WireCo Product Bulletin and Modjeski and Masters Transmittal Cover Sheet, Yeon Records Center; L. E. Niemann, Abhe & Svoboda, to John Lindenthal, 2/20/1999, Hawthorne Paint & Deck Replacement, #11986, Binder 28 of 28, Yeon Records Center.

made by the street cars; 1,818 trips a day carried 36,273 passengers across the bridge. The following year, city traffic engineers studied the role of the new "jitney" buses. On the Hawthorne, these carried 2,368 passengers in eight hours.[70]

One essential aspect of the bridge's survival is its adaptation to the automobile that came to dominate it. By the 1960s, before the new Interstate freeway bridges relieved its load, the Hawthorne carried nearly 35,000 gasoline-powered vehicles daily, but no regular horse-drawn traffic. Streetcar patrons had dwindled to 3,300 a day in the 1950s, resulting in the elimination of interurban service before the decade's end. Four decades later, despite considerable efforts to encourage alternative modes of travel, the Hawthorne served an estimated 30,000 car trips a day along with 700 bus trips, 2,000 pedestrian crossings, and 2,000 bicycle trips.[71]

The wooden deck placed on the original bridge carried its traffic mix adequately. When it was replaced in 1921, it had slightly exceeded its initial ten-year estimated life expectancy. Vehicular traffic between the trusses was carried on a 4" creosoted wood block surface set in a layer of hot tar and asphalt on a 4" creosoted plank base. The wood block surface was coated with tar and asphalt and topped with coarse sand. The roadway was designed to slope gently from its center to promote drainage, reducing decay and assuring better traction. To accommodate the streetcar rails, the outer deck had a 2" plank wearing surface placed perpendicular to the rails on a 3" wood base.[72]

Plans to expand the light asphalt coating into a "bitulithic wearing surface" originated in 1918 with the City's Department of Public Works. Although the County owned the bridge after 1913, the City retained responsibility for traffic, so traffic concerns motivated the shift. Block paving had been considered especially well-suited to horse-drawn traffic because the cracks between blocks fit the protruding calk on horseshoes and afforded traction. As auto use increased, though, Portland prepared to join other American cities in dramatically increasing its use of asphalt. To be precise, what they installed was asphaltic concrete, a mixture of an oil-based binder with a weight-supporting mixture of gravel and sand, a combination designed to

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[70] Traffic Survey Summary Willamette River Bridges, 11/18/1914; A. S. Kirkpatrick, Traffic Engineer, City of Portland, Table Indicating Total Traffic Movement over the Trans-River Bridges and the Effect of "Jitney" Bus Operation, 3/3/1915, Documents from the files of Sharon Wood Wortman.

[71] Bureau of Traffic Engineering, Portland, Oregon, Traffic Volumes on Portland Bridges, 5/26/1978, Document from the Files of Sharon Wood Wortman; P. C. Northrop, Roadmaster, to Board of County Commissioners, 3/21/1956, Yeon Records Center; Cay Humphryes, Hawthorne Bridge Painting and Deck Replacement Project, Public Outreach and Information Program, 4/15/1998, Contract No. 11986, File: Con. 5-17, Yeon Records Center. The 3,300 interurban patrons constituted less than 4% of persons using the bridge each day.

[72] "Hawthorne Avenue" Information Sheet Accompanying Letter to H. E. Pulver, 8/3/1922, City Engineer's Correspondence, City Archives, Portland, OR; Hawthorne Avenue Bridge, Cross Section of Floor System, 9/25/1909, Original Waddell & Harrington Drawing at Multnomah County Bridge Shop, Portland, OR; 1909 Hawthorne Bridge Specifications, SPARC 2012-30, City Archives, Portland, OR. The subdeck had an estimated life expectancy of twenty years.

withstand the abuse automobile and truck tires inflicted on roadways.[73]

Installing an asphalt wearing surface on the bridge still involved using plenty of wood. In 1921, the County laid additional wood ties under the deck and replaced the 4" plank base. Engineers solved the problem of getting the asphalt to adhere by applying a dryer 1" binder course under a 2" wearing surface. They laid the planking lengthwise without cracks; experience locally, supplemented by that of other Oregon communities had shown that the cracks or butt cleats sometimes used to keep bridge pavement from slipping simply made the pavement rough and wavy. The County also determined that paving up to the current streetcar Trails would not work; when the City refused to replace them with grooved rails, the County simply planked the area around the car tracks, expecting to add asphalt when the city replaced the old rails.[74]

Although Roadmaster Eatchel assured John Lyle Harrington, who evinced continuing interest in the challenge of making asphalt paving stick, that the new pavement would last fifteen years, the bridge received another new deck in 1930. Several simultaneous changes designed to smooth traffic flow encouraged early redecking. By the late 1920s, concern over "rapid increase in automobile traffic" prompted proposals ranging from replacing the bridge with one capable of carrying more cars to converting the sidewalks into two additional lanes of traffic. In part because a recent spate of new bridge construction convinced many that the Hawthorne Bridge would soon be replaced, the County settled for modest changes. A new, higher western approach was underway, so a new, progressively higher deck surface on the westernmost fixed span was designed to meet the new approach. The streetcar tracks, whose outside location required the cars to cross traffic lanes at both ends of the bridge, were relocated to the center lanes, necessitating additional stringers to support the tracks and new decking over these supports. The outer lanes, which lacked paving around the rails and needed to have the rails removed, also needed redecking. The basic components of the new deck mirrored those of 1921, although the contract's list of acceptable asphalt mixtures reflected the elaboration of asphalt technology in the interim. New procedures and products now assured a stable base by painting a thin coat of hot asphalt on the deck before laying a 2" asphaltic concrete surface. The new surface could also grip the tops of the nails that attached the wood decking to supporting wood ties. The nails were

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[73] R. E. Kremers, Chief, Bureau of Highways and Bridges, Department of Public Works, to O. Laurgaard, City Engineer, City Engineer's Correspondence, 1/21/1918, City Archives, Portland, OR; McShane, Asphalt Path, 57-80; Clay McShane, "Transforming the Use of Urban Space: A Look at the Revolution in Street Pavements, 1880-1924," *Journal of Urban History*, 5 (May, 1979), 280-281.

[74] W. A. Eatchel to John Lyle Harrington, 5/26/1921 and 7/11/1921, Multnomah County Roadmaster's Records, Oregon Historical Society, Portland, OR. Contemporary records provide no evidence to confirm Reed's 1931 statement that an earlier Port Orford cedar deck was replaced by one of Douglas Fir at this time. The original specifications mention only Douglas Fir. On the other hand, they do not make special reference to the lift deck paving, which is where the lighter wood could have made a difference. M. E. R. to Mr. Buck, 5/28/1931, Multnomah County Roadmaster's Records, Oregon Historical Society, Portland, OR.

left projecting .5" for that purpose.[75]

Although the ties supporting the new deck got a creosote bath, the planks resting on them remained untreated, mostly because its owners anticipated building a new bridge and saw no need for a long-lasting deck. By 1944, the consequences of that decision created a situation so dire that the various state and federal agencies, including the War Production Board, working together to concentrate labor and materials in war production, agreed that the Hawthorne Bridge had to have a new deck. The area along the street railway tracks had especially deteriorated because it proved impossible to make the rail to asphalt connections tight enough to keep water from reaching the wooden subdeck. After giving the dimensions of the center roadway, the County explained to the Public Roads Administration of the Federal Works Agency that: "Nearly one-half of this area is plank patches and more are being added almost daily....The previously mentioned wood ties and sub floor are so badly decayed they will not support the pavement and when the floor is replaced with new plank the decay in the ties is such that the floor cannot be fastened to the ties." The system of plank patches was costing about $500 a month. Over this surface 14,800 cars, 3,800 trucks, and 1,400 streetcars and buses traveled each day, public transit carrying more than two million monthly riders.[76]

Under these circumstances, the County decided to replace the Hawthorne's wood and asphalt deck with steel grate. At first glance this appears strange in view of wartime materials rationing, but considerable effort early in the war had been directed toward increasing steel production. Wood had been neglected and by 1944 the County found steel "a less critical material than wood." They also had considerable experience with accidents on wood and asphalt

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[75] W. A. Eatchel to John Lyle Harrington, 5/26/1921, Multnomah County Roadmaster's Records, Oregon Historical Society, Portland, OR; F. T. Fowler, Bridge Engineer, to O. Laurgaard, City Engineer, 7/30/1929; County Commissioner to C. A. McClure, Secretary, City Planning Commission, 7/23/1929; City Planning Commission to Board of County Commissioners, 3/24/1930, all in City Engineer's Correspondence, City Archives, Portland, OR. 1930 Specifications and Contract Agreement, Hawthorne Bridge, Yeon Records Center; Hawthorne Bridge, Timber Deck, July 1930, and Raised Timber Deck, December 1930, Drawings at Multnomah County Bridge Shop. Other, more elaborate plans included jacking up the west end of the west fixed span, which would have required cutting the connections between its top chord and the counterweight tower and fabricating new connections. A plan to move the lift span east so that it would line up better with other local drawbridges was also pursued to the point of preliminary estimates. Hawthorne Bridge, Plan for Elevating West End of Span 7, July 1930, Drawing at Multnomah County Bridge Shop.

The 1930 redecking also removed the original lights and rail that had separated pedestrians and traffic on the outer deck lanes. In consequence, the outer lane was widened to 11' and the sidewalk to 7' 1.25".

[76] 1930 Specifications and Contract Agreement, Hawthorne Bridge, Yeon Records Center; Geo. W. Buck, Roadmaster, to Hon. Board of County Commissioners, 3/17/1944; Multnomah County Construction Application and Accompanying Handwritten Draft of Text, Public Roads Administration, Federal Works Agency, 6/6/1944, both in Reconstruction and Redecking, Hawthorne Bridge, Agreements with L. H. Hoffman, 10/19/1944, Yeon Records Center.

pavement and expected steel grate to reduce skidding and increase safety.[77]

Once again, the County combined redecking operations with other changes designed to ease traffic flow. Portland's leaders had just signaled their commitment to rebuild the city for the auto by bringing Robert Moses to town to prepare a new urban plan. Not surprisingly, then, the Hawthorne's sidewalks were trimmed to a meager 5' 6.25", allowing the outside traffic lanes to expand to 12'. Taking advantage of increased clearance, trolley buses were shifted to the outside, although streetcars remained in the center lanes.[78]

Given the emergency conditions on the bridge and the delays occasioned by wartime paperwork, the County and its contractor gave speed priority in the redecking work. The need to keep the bridge open to traffic increased pressure to expedite the job. Because this was Portland's first steel bridge deck, the County and its contractor relied on the Irving Subway Grating Company's specifications for guidance. As instructed, they welded every fourth decking bar to the supporting 10" steel channel (every third on the lift span). They also avoided the need for additional stringers on the outside lanes by using a more economical system: welding the ends of the lateral channels to heavy longitudinal channels. Using steel grate decking was a new enough technology that these seemed reasonable choices.[79]

By 1957, the adverse consequences of these decisions were already apparent. Under heavy and growing post-war traffic, the system of attaching grating to the bridge allowed far too much movement. In places the Irving deck's longitudinal bars had worn grooves 3/16" deep into the supporting channel. Remedial action involved welding each and every decking bar to its lateral supports, using a somewhat longer (1.5" versus 1") weld. A regular inspection program, annual at first and monthly after 1996, helped avoid the risk of local failure creating a safety

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[77] Multnomah County Construction Application and Accompanying Handwritten Draft of Text, Public Road Administration, Federal Works Agency, 6/6/1944, and W. H. Lynch, District Engineer, Public Roads Administration, to Ray Fairbank, Multnomah County Bridge Engineer, 6/1/1944, both in Reconstruction and Redecking, Hawthorne Bridge, Agreements, 10/19/1944, Yeon Records Center; Eric Schatzberg to author, 8/24/1999.

[78] A. R. Fairbank, Bridge Engineer, Multnomah County, "Hawthorne Bridge Has Face Lift," typescript of article for *Pacific Builder and Engineer*, Reconstruction and Redecking, Hawthorne Bridge, Agreements, 10/19/1944, Yeon Records Center, published as "How Hawthorne Bridge, Portland, Got Its Face Lifted," (November 1945), 44-45; E. Kimbark MacColl, *The Growth of a City: Power and Politics in Portland, Oregon, 1915 to 1950* (Portland: The Georgian Press, 1979), 587; Abbott, Portland, 138-140.

[79] Specifications for Bridge Decking, Irving Subway Grating, Co., Reconstruction and Redecking, Hawthorne Bridge, Agreements, 10/19/1944, Yeon Records Center; Fairbank, "How Hawthorne Bridge Got Its Face Lifted," 44. Good information about the wear of open steel grid decks was finally becoming available in the late 1980s, thanks principally to the number of structures, like the Hawthorne Bridge, offering evidence of long-term performance. Hota V. S. Ganga Rao et. al., "Behavior and Design of Open Steel Grid Decks for Highway Bridges," Technical Report to WVDOH, 6/30/1988, attached to OBEC Consulting Engineers, Hawthorne Bridge Report - Structural, 1996, Yeon Records Center.

hazard. By 1996, though, many notches in the channel had worn to twice their maximum 1957 depth and by the time new decking was installed in 1998-99 some of the old decking had cut through the top flanges of its supports. Unlike their situation in 1945, County engineers now had some history to draw on. They also had the results of an additional 1996 consultant's report and a small body of technical literature. As a result, they decided to use heavier (5" versus 2.5") steel grid flooring and to add two stringers under the outside lanes. The increased strength of the new, thicker grating made it unnecessary to place supporting channel every 18" as had been done in 1945; the new channel was laid every 2.5'.[80]

Despite the problems, it is important to note that the 1945 decking job lasted more than fifty years. This contrasts sharply with redecking the bridge every decade so long as wood and asphalt remained the materials of choice. Moreover, using steel grate reduced the dead load by fifteen pounds per square foot, no small asset when trying to keep an aging structure healthy. Motorists in Portland, like their fellows elsewhere, complained loudly about the slipperiness of the first steel deck, so loudly, in fact, that the County instituted a costly program of welding steel studs to the deck surface in hopes of improving traction. It is worth recalling, though, that earlier motorists had complained that the wood deck needed more frequent applications of sand to reduce its slipperiness. All told, County engineers have effectively managed the unenviable task of adapting the bridge's deck to unanticipated traffic loads using initially unfamiliar materials.[81]

They also implemented changing public mandates for the bridge's use, translating these into changing deck configurations. The predominance of public transit had been evident in the wide outside lanes on the original structure. Its decline was manifest in the street railway's relocation to the narrow inner lanes and, in the 1950s, removal of tracks from the bridge; the County weighed 3,300 interurban riders against 82,700 other users and asserted: "we believe it is our duty to provide the greatest good for the greatest number." Automobiles, trucks, and buses, meanwhile, took the place of the street railways and, increasingly, crowded pedestrians to the margins of the bridge, evident in the progressive narrowing of the bridge sidewalks. Those sidewalks, which remained wood, also deteriorated. By the mid-1970s one of the daily tasks assigned bridge operators was to "check for loose sidewalk boards and repair as needed." By the late 1970s, nearly thirty-five years after it had provided a steel deck, the County finally provided

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[80] Moffatt, Nichol & Taylor, Structural Investigation and Report, Irving Steel Decking, Hawthorne Bridge, 7/16/1957, Yeon Records Center; OBEC Consulting Engineers, Hawthorne Bridge Report - Structural, 1996, including attached technical articles, Yeon Records Center; Willamette River (Hawthorne) Bridge Painting and Deck Replacement, Typical Sections, Drawing No. 55683, August 1997 and Steel Grid Bridge Flooring, Drawing No. 55684, August 1997, Yeon Records Center. Discussions with Ed Wortman and Jon Henrichsen, Multnomah County Bridge Engineers helped clarify how experience with the earlier decking shaped the recent redecking.

[81] Robert Nordlander, Director, Department of Environmental Services to Commissioner Dan Mosee, Re. Hawthorne Bridge Design, 4/2/1973; Board of County Commissioners to R. C. Northrop Roadmaster, 8/2/1961 and 1/31/1962, Hawthorne Bridge Emergency Purchases, both in Yeon Records Center.

reliable sidewalks: precast concrete on the fixed spans and steel plate pre-surfaced with epoxy and grit on the lift span.[82]

By the 1970s, though, changes were afoot locally and nationally, symbolized by the efforts of Portland Mayor and, later, U.S. Secretary of Transportation, Neil Goldschmidt. Pedestrians, people with disabilities, and, especially, bicyclists grew increasingly vocal. Although their numbers on the Hawthorne Bridge were barely more than the number of interurban riders last using the structure, by the early 1990s the Hawthorne district on the bridge's east side housed "very vocal and active citizens" whose commitment to walking and biking gave the Hawthorne more than twice the pedestrian and bicycle presence of the next most-used bridge. Through the Willamette River Crossing Accessibility Study, these groups found effective voice; through the Federal Congestion Mitigation and Air Quality program, an outgrowth of similar popular organizing nationally, the County found the $1,729,400 to respond. The 1998-99 redecking included floorbeam extensions that permitted new 10' 9" sidewalks alongside the new 11' 2.5" outside traffic lanes. Aluminum replaced the unsatisfactory steel plate lift span sidewalks. New ramps for non-vehicular users completed the system. Autos, pedestrians, and bicyclists all found themselves better accommodated on the bridge in 1999 than they had been in 1911, although space devoted to autos had receded from its mid-century high.[83]

Adapting to New Conditions: Ramps and Approaches

Like decks and sidewalks, ramps and approaches are mundane aspects of bridges often neglected in favor of the more glamorous river spans. Yet, especially in urban settings, no bridge can long survive without the ability to adapt to changes in the surrounding street and highway system. Ramps and approaches can provide that adaptability, making a crucial contribution to the persistence of historic structures such as the Hawthorne Bridge. This is not to suggest that adaptability invariably requires becoming part of the latest innovation in highway development. Although Americans often speak of technological progress as though the only choices are to embrace change or resist it, the Hawthorne Bridge survived essentially because it continued to

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[82] P. C. Northrop to Board of County Commissioners, 3/21/1956, Yeon Records Center; Don Briggs, Bridge Supervisor, Hawthorne Bridge Cleaning Schedule, 4/21/1975, Yeon Records Center; Contract 1979, Hawthorne Bridge Sidewalk, Project No. 909, Completed November 5, 1979, Yeon Records Center. The continuing low priority of pedestrians and other sidewalk users was evident in the County's unwillingness to spend an extra $15,000 for aluminum; the thin plates necessary to minimize the weight of the steel posed problems almost immediately because they tended to warp. Inspector's Daily Report, Hawthorne Bridge Sidewalk, 4/23/80, Yeon Records Center.

[83] For a nice treatment of Goldschmidt's relationship to larger forces at work locally and nationally, see Abbott, *Portland*, 175-181, 218-227. David Evans and Associates, Inc., Predesign Engineering for Painting and Deck Rehabilitation on the Hawthorne Bridge, Proposal, 1/8/1996, Yeon Records Center; Stan Ghezzi to Larry F. Nichols, 3/23/1998, Hawthorne Paint & Deck Replacement #11986, CON 5-2, Yeon Records Center; Willamette River (Hawthorne) Bridge, Deck Plan Spans 1 thru 5, Drawing No. 55680, August 1997, Yeon Records Center.

serve its vital original function of conveying local traffic even as new arterial and freeway routes developed around it. Its most difficult moments came when planners tapped it to serve other functions.

The Bridge's original approaches had been relatively simple affairs. On the west end a short, 160' timber trestle built on wood piles delivered traffic directly into Madison Street. On the east, where low lying former marsh flanked the river, a longer 630' timber trestle curved north into Hawthorne Avenue. These approaches essentially ended where existing streets began, suiting the bridge to serve existing local traffic. Although repairs of the timber structures and maintenance activities, such as paving, altered the bridge approaches in small ways, no substantive change occurred until 1930.[84]

The relative lack of change paralleled the absence of innovation by the Portland City Council, which controlled decisions about the streets connecting to the County-owned bridges. Despite two major plans by outside experts and local initiatives by the City Engineer and the Planning Commission, Portland weathered an astonishing 1920s growth in automobile usage with only piecemeal responses. Improvement of radial streets linked to the Willamette River bridges concentrated on Morrison and Burnside, reinforcing the preeminence of local traffic on Hawthorne. As population growth slowed and the depression loomed, Portland had even less incentive to build better streets. The only significant alteration of the Hawthorne Bridge approaches came as a result of the harbor improvements that City Engineer Olaf Laurgaard successfully promoted: removal of deteriorating downtown wharfs and warehouses and their replacement with a seawall to stabilize the west bank. In 1930, reconfiguration of trolley tracks over the bridge encouraged rebuilding the timber approaches and the west approach was elevated to accommodate the new west bank. In keeping with the essentially aesthetic arguments that had supported removal of the "unsightly" river front structures, the new west approach also received decorative concrete railings similar to those placed on several new Willamette bridges of the 1920s.[85]

By contrast, in the early 1940s Portland's political leaders reached a consensus that they needed to redesign their city to serve the auto. One result was the Harbor Drive Freeway, built along the Willamette in the area cleared by 1920s harbor improvement. The willingness of the state highway commission to supply $2.8 million of the estimated $4.05 million pricetag helped local voters agree to a bond issue for the balance. When completed in 1943, the six-lane freeway

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[84] "Lift-Span of the Hawthorne Avenue Bridge, Portland, Ore.," 381; Hawthorne Avenue Bridge, Map and Plan, 5/26/1909, Drawing at Multnomah County Bridge Shop. There is a slight discrepancy between engineering journal descriptions. *Engineering News* ("The New Hawthorne Avenue Bridge," 279) gives the combined original trestle lengths as 775', fifteen feet less than the sum of the trestles cited here from *Engineering Record*.

[85] Abbott, *Portland*, 95-98, 103-110; MacColl, *Growth of a City*, 315-324; 1930 Specifications and Contract Agreement, Hawthorne Bridge, Yeon Records Center; Hawthorne Bridge, West Approach and Abutment Details, April 1930, and Profile of Present Bridge, April 1930, Drawings at Multnomah County Bridge Shop. MacColl reports that a 1927 study cited in the Oregon Voter found Oregonians used more gas per motor vehicle registered than citizens of any northern or western state.

also removed congestion from downtown streets by rerouting the Pacific Highway (Oregon 99W) along the river front. New west approaches carried traffic from all the adjacent bridges over the new highway, but the Hawthorne approach also included two, modern circular ramps, allowing southbound traffic to enter or exit and helping boost bridge traffic to an all-time high over the next two decades. Selection of the Hawthorne to receive trans-Willamette traffic from Harbor Drive made sense principally because, of the several bridges along the freeway, it was farthest from the Steel Bridge, the river crossing for Ore. 99W traffic.[86]

Once the Hawthorne's west approach connected it to a major through route, pressure for further modifications to enhance traffic flow followed. In the late 1950s this took the form of new ramps to Harbor Drive, which also gave drivers access to Front Avenue, the city street that paralleled Harbor Drive to the west. A new set of one-way approaches carried traffic to the bridge along both Madison and Main, passing over a lowered Front Avenue on the way. In addition to smoothing traffic flow through downtown streets, the new approaches were wider, permitting an alternating 3/1 lane configuration over the bridge during rush hours, one proposed way to help the bridge carry more vehicles.[87]

The new construction featured precast, prestressed concrete stringers, and reinforced concrete bents and deck, choices that made economic sense because increased experience with and standardization of prestressed concrete work had lowered its costs while the recent steel strike settlement had increased steel prices. Although an established technique in Europe, prestressed concrete technology remained relatively new in America in the mid-1950s, making the Hawthorne west ramp an innovative structure. By contrast, the neighboring Morrison bridge, completed only a year earlier, but begun before the steel strike, used steel stringers. After completion of the I-405 freeway in 1973 rendered Harbor Drive redundant and allowed its replacement with a waterfront park, minor changes have permitted the Hawthorne's 1959 ramps to continue providing the local downtown access most Hawthorne Bridge users sought.[88]

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[86] Oregon Department of Transportation, Environmental Impacts: Closure of Harbor Drive, 6/28/72, pp. 6-7, Yeon Records Center; DeLeuw, Cather & Company, Harbor Drive Study, Prepared for Harbor Drive Task Force, 12/14/1970, pp. 5-11, Yeon Records Center; Erickson, "Aging Hawthorne a Troubled Bridge," Hawthorne Bridge, 1985 Sheave Emergency, Yeon Records Center; Aerial Photographs, Morrison and Hawthorne Bridges, 2/9/1955 and 2/12/1955, Yeon Records Center; MacColl, *The Growth of a City*, 496, 513-518; Abbott, *Portland*, 216. Initially the Morrison also had on/off ramps connected to the freeway's southbound lanes, although the off ramp from the freeway was a cramped loop designed to fit between the bridge and the adjacent Public Market. The new, 1958 Morrison lacked direct connections to Harbor Drive.

[87] Construction Specifications, West Approach, Hawthorne Bridge, Moffatt, Nichol & Taylor, 11/29/1957, Yeon Records Center; P. C. Northorp to Board of County Commissioners, 3/21/1956, Yeon Records Center; Final Construction Report, West Approaches, Hawthorne Bridge, 6/1959, Yeon Records Center. Although the 3/1 alternating lane system was proposed and made possible, I have found no evidence that it was implemented.

[88] Robert M. Bonney, Moffatt, Nichol & Taylor, to P. C. Northop, 4/19/1957 and Northrop to Moffatt, Nichol & Taylor, 4/22/1957, Yeon Records Center; Gerald K. Attig, Opinion on Hawthorne Bridge Relocation and

Developments on the east side followed a different trajectory. By 1944, the deck of the longer east approach had deteriorated so seriously that County engineers argued successfully for its wartime replacement. Since the expected life of the supporting trestle was only a matter of years, its replacement also won approval. But the structure remained essentially the same as its predecessor; steel stringers, channels, and grating were incorporated principally because wood was in short supply. The old-fashioned, no frills trestle chosen for the east side contrasted sharply with both the decorative 1930 and the modern 1941 west side structures.[89]

In the 1950s, the east approach became subject to the same pressures for improved traffic flow that motivated redesign of the west approach. And the same engineers, Moffatt, Nichol & Taylor, devised solutions for both. Naturally, they had many features in common. A new one-way couplet, Madison and Hawthorne on the east side, delivered traffic to and from the bridge. And, since most traffic was destined for east side residential areas, the new approach spans carried vehicles over the riverside industrial area to either the one-way radials or to Union and Grand, a one-way couplet of north/south arterials. A smaller Water Avenue ramp permitted industrial users to continue following their accustomed routes. East approach construction costs were kept low by using the same contractors, equipment, and techniques as on the nearby Morrison bridge, under construction at about the same time. Also, because the relative price of

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Portland Commons Conflict, 4/18/1969 in Planning Board, Land Use - Downtown Plan, New Hawthorne Bridge, 1965-68, Yeon Records Center.

Bonney's 1957 calculations showed an adjusted average cost per square foot of deck area for prestressed concrete stringers of $3.09 versus $4.40 for welded steel stringers. For fuller treatment of this technology see HAER No. OR-100, my report on the Morrison Bridge, completed slightly earlier under the direction of the same engineers.

Since the Harbor Drive ramps included lanes serving Front Avenue as well, they were merely modified when Harbor Drive was removed. The recent 1998-99 rehabilitation of the Hawthorne bridge included two non-structural changes to the west approach. The provision of sidewalk access from downtown to the south side of the bridge required addition of a stop sign where the ramp from northbound Front Avenue enters the bridge. And the City of Portland took advantage of the bridge renovations to discontinue use of the ramp from southbound Front Avenue which had relatively light usage and high accident levels. Ed Wortman, Multnomah County Bridge Engineer, supplied information about the 1998-99 decision making. He also drew on his experience studying with T. Y. Lin, who played a crucial role in the transfer of prestressed concrete technology to America, to provide context for Multnomah County's earlier choices.

[89] A. R. Fairbank, Bridge Engineer, to W. H. Lynch, District Engineer, 6/23/1944; Geo. W. Buck, Roadmaster, to W. H. Lynch, 7/15/1944; Board of County Commissioners to Geo. W. Buck, 10/20/1944, all in Reconstruction and Redecking, Hawthorne Bridge and East Approach, Agreements, 10/19/1944, Yeon Records Center; Plan for Re-Decking, Hawthorne Bridge, 8/1944, Drawing in Multnomah County Bridge Shop. Portland's movers and shakers generally continued to live on the west side, enforcing greater attention to west side amenities. MacColl, *Growth of a City, passim.*

traditional steel stringers remained competitive in 1956, the east approaches used steel.[90]

In essence the design of the east approach finally implemented the 1943 Moses plan for east side auto travel. Moses' vision still dominated Portland planning in the 1950s and led to a crucial technological choice in east side construction that would haunt Multnomah County bridge engineers for decades. Planners anticipated completion of an east bank freeway, part of the loop that lay at the center of Moses' Portland Improvement. Its expected trajectory meant that it might well include access ramps to the Hawthorne Bridge, so the County and its consultants decided not to spend any extra money building a permanent structure that might need replacement within a few years. Instead, they devised a semi-permanent transition structure between the bridge and the elevated approach ramps, which were expected to be permanent. Like its predecessors, the transition structure was founded on wooden piling, some of it a decade old and some of it spliced. Timber caps, bracing, and deck framing completed the structure, which was then topped with a concrete deck.[91]

These planned economies ran afoul of a different reality. When the I-5 freeway was completed along the east bank in 1966, it did not include connections to the Hawthorne Bridge; state highway planners recognized the need to preserve a few bridges for local travel. The "semi-permanent" construction of 1957 remained in place. The County Bridge Maintenance Division replaced some deteriorating caps and timbers in about 1981, but County officials expected to be able to wait until 1988 for complete replacement. In 1984 they were "caught by surprise" when a consultant's report found the structure so weakened that they recommended load limits. Competing financial demands of emergency mechanical work further delayed replacement, necessitating two emergency repair jobs totaling more than $300,000 in 1984 and 1988. In 1991-92, the bridge finally got a permanent link to its approach ramps at a cost of nearly $6 million.[92]

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[90] P. C. Northorp to Board of County Commissioners, 3/21/1956, Yeon Records Center; Hawthorne Bridge (New approaches, etc), General, 1954-1955), Yeon Records Center. As remains the case, the one-way sections of Hawthorne and Madison ended at 12th St.; Madison was chosen over Clay, the street south of Hawthorne, because it continued, whereas Clay ended at 12th.

[91] Abbott, *Portland*, 136, 207; Andrew C. Cotugno, Transportation Director, Metro, to Terry Ebersole, Regional Manager, UMTA, Region X, 5/22/1990, in Hawthorne Bridge Transition Structure, 1991, Yeon Records Center; Moffatt, Nichol & Taylor, Preliminary Report, East Approaches, Hawthorne Bridge, 4/12/1955, 7-8, Yeon Records Center; Moffatt, Nichol & Taylor, Final Construction Report, East Approaches, Hawthorne Bridge, 11/1957, Yeon Records Center. A few concrete bents and caps were used on the transition structure where especially long spans were needed to accommodate tractor trailers turning beneath it.

[92] Gerald K. Attig, Opinion on Hawthorne Bridge Relocation and Portland Commons Conflict, 4/18/1969, Planning Board, Land Use - Downtown Plan, New Hawthorne Bridge, 1965-68, Yeon Records Center [Attig served as design engineer for the Oregon Highway Commission when the Portland freeway system was on the drawing board.]; Larry F. Nicholas, County Engineer, to Jerry Butler, Portland Fire Bureau, 6/22/1984; Larry F. Nicholas to Sharon Jacox, Director, Purchasing Division, re. Hawthorne Bridge East Approach Rehabilitation, 6/22/1984; Hawthorne Bridge Emergency Repairs, East Approach Transition Structure of Hawthorne Bridge, Agreement, 7/24/1984; OBEC Consulting Engineers, Hawthorne Bridge Structural Investigation, 6/8/1984; Hawthorne Bridge

Perhaps because it was so long in the planning, the creation of the east transition structure managed to win praise from local citizens and prizes from regional and national organizations. The scope of the county's and consulting engineer's accomplishment well illustrates how difficult it had become by the 1990s to carry out major construction on a downtown bridge. The east approach now passed beneath the new Marquam I-5 freeway bridge, which was simultaneously undergoing seismic retrofitting and, in any case, had placed its footings in locations that imposed significant design constraints on the Hawthorne's east transition structure. Environmental legislation now made it necessary, before deciding on disposal methods, to perform chemical analysis on the wood used in 1957 and in each subsequent repair to determine what chemicals had been used to treat it. The new structure also passed over an area that the City had decided to develop as a river front Greenway. In exchange for City construction permits, the County was required to build in bike-pedestrian ramps from the transition structure to the river front and to construct that portion of the esplanade path located under its structure. The regional Joint Policy Advisory Committee on Transportation was in the midst of evaluating routes for a proposed Light Rail Transit (LRT) system, with the Hawthorne a serious enough contender to warrant placing additional stringers in the new construction. In the midst of transition structure design, the Oregon Department of Transportation upgraded its seismic design procedures which, after recalculation, meant that two existing concrete bents and a plate girder span within the project area could not be reused. And Portland's now vocal bike-pedestrian alliance made it expedient to provide temporary routes across the bridge during its closure. When the project nonetheless came in on time and under budget, it is not surprising that consulting engineers CH2M Hill, well known for helping Portland reinvent its downtown in the 1970s, won an Engineering Excellence Grand Award for the project.[93]

The project also went smoothly because of highly creative work by Ed Sale, Public Information Specialist, who put together a public relations program that won the Best of Show Award from the National Association of County Information Officers and an achievement award from the National Association of Counties. One key to Sale's success was his reliance on Portland's effective neighborhood associations, which had played a crucial role in revitalizing the city in the 1970s. But the project's public relations records show an impressive roster of other bases touched. Timely and accurate information went out to messenger services using the bridge, organizers of events accustomed to having their patrons use the bridge, Hawthorne

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1988 Temporary Repairs, East Transition Structure, Agreement, 4/26/1988; Hawthorne Bridge Transition Structure, Agreement, 10/10/1991, all in Yeon Records Center.

[93] W. E. Chuck Henley, Project Manager, Hawthorne Bridge Transition Structure Reconstruction Project Agenda Mandatory Pre-Bid Meeting, 9/20/1991; Richard Kuehn, Project Manager, CH2M Hill, to Stan Ghezzi, Structural Engineer, Multnomah County, 3/12/1991; Larry F. Nicholas to Felicia Trader, Director, Portland Office of Transportation, 5/30/1991; Hawthorne Bridge Transition Structure, "East Approach" General Contract Correspondence, Contract No. C11103, 10/10/1991; Betsey Williams, Director, Department of Environmental Services, to County Commissioners, 5/1/1993; Engineering Excellence Grand Award, Category G - Transportation, 1993, Consulting Engineers Council of Oregon, all in Yeon Records Center; Abbott, *Portland*, 218-219.

district business people, hotels whose guests might expect to travel across the span, and many others. Sale also pressed County personnel for early and firm decisions on closure dates to make the best use of public information announcements and exhibits in public plazas. He devised distinctive detour signs with the bridge logo. And he authored numerous letters in response to individual queries, including three different citizens who wrote to inquire why an existing black cottonwood tree near the bridge was missing from the final bridge plans.[94]

Sale's response to those writing about the tree nicely conveys a tone that pervades documents from the project: so many individuals and institutions now actively sought to shape Portland's bridges that effective communication had become crucial to the bridges' survival. He wrote in part:

> I spoke to our engineers and consultants, who were involved in the design of the bike path and esplanade area, in an attempt to understand why the tree was not shown on the final plans. I discovered that the reason was based on a need to maintain a federally recommended width for bike paths. To maintain the width, the design had to take into account the steep riverbank and the numerous piers supporting the new east approach structure and the expansion of the Marquam bridge. Based on these factors, the preliminary design indicated that the tree had to be removed because it was in the middle of the proposed bike path.
>
> We have looked at the design on the ground and feel that we can accommodate both the tree and the bike path. I would like to caution, though, that due to excavation associated with all construction projects, we always run a risk of impacting existing vegetation. Our goal is to retain the tree.
>
> Your passion for this issue is commendable. It is people such as yourself who are needed to remind others to take a closer look at issues and decisions.[95]

Preserving a Legacy: Mechanical Repairs

In order to understand how and why the Hawthorne Bridge has survived, we need tell one

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[94] Hawthorne Bridge Public Relations Program portfolio in 1991 East Transition Structure Agreements and related materials, Yeon Records Center; Abbott, *Portland,* 183-206.

[95] Ed Sale to Phyllis Reynolds, 2/7/1991 and similar letters to Steve Rice and Phyllis Kirk in Public Relations Program portfolio, 1991 East Transition Structure Agreements and related materials, Yeon Records Center. By contrast when Wylie M. Dyer, who had walked across the bridge for twenty-five years and patrolled it after Pearl Harbor, wrote to protest the closing of the Hawthorne Bridge sidewalks during the 1958-59 reconstruction of the west approach, County Roadmaster Northrup responded by citing the number of pedestrians (400) versus the number of cars (28,000) needing to use the bridge and simply stated that accommodating pedestrians would delay completion, failing to do "the greatest good for the majority of people." Wylie M. Dyer to Board of County Commissioners, 6/30/1958 and Northrop to Board of County Commissioners, 7/10/1958, Hawthorne Bridge, West Approach (General), Yeon Records Center.

final tale: that of mechanical repairs. Whereas the history of decks and approaches illustrates the importance of judicious innovation and the history of cable changes exemplifies the virtue of consistent maintenance and inspection, the history of mechanical repairs especially brings home how well built the bridge was to begin with. Although this section recounts the repairs that have replaced a number of the bridge's original components, the most important thing we learn by reviewing the bridge's mechanical history is that the structure performed several hundred thousand openings over seventy-five years before needing any but minor mechanical repairs. The Hawthorne Bridge's status as an innovator makes this performance especially impressive.[96]

One part of the original system was replaced a bit earlier. In 1975-76 the bridge underwent a renovation of its electrical system. New 150 horsepower General Electric DC motors replaced the original 125 horsepower Westinghouse ones. New controls, including an automatic trip switch to slow the lift span when it came within two feet of its highest and seated positions, were installed at the same time. Two silicon control rectifiers and 175 KVA transformers joined the rest of the new equipment, requiring a six foot extension of the machine house. The operator's house also received a new control console, linking it to the new electrical system and also allowing the County to implement its planned elimination of gatekeepers on its bridges. New warning gongs, neon signs, hydraulic vehicular and passenger gates, and a six-speaker public address system completed the installation.[97]

None of these changes came about because the old system had worn out. The local electric company set the stage for change when it notified the County it would cease supplying DC current. The County considered various options, including switching to AC, but elected to install transformers and rectifiers and retain DC motors because they served better to provide the torque (rotational force) needed on the County's several movable bridges. It made sense to replace the original motors while adding other new electrical equipment. Parts were no longer available for the aging motors so they had to be custom-made for any repair, resulting in high maintenance costs. Replacement also made sense as part of a larger program to protect the mechanical structure. The original controls had provided for manual acceleration and for deceleration with a hand brake. They included only one safety feature, a deadman switch that

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[96] A conservative estimate would place total bridge openings between 1910 and 1985, the date of the first major mechanical work, at about 200,000. The bridge opened more frequently in its early years (429 times a month in 1915-16) than in recent times (191 times a month in 1974-75; 240 times a month in 1996-98). Howard, "Vertical Lift Bridges," 694; Bebe Rucker to TTAC Interagency Coordination Transit Corridor Task Force, 9/10/1975, Hawthorne Bridge, 1991 East Transition Structure, Yeon Records Center; Ed Wortman, note to author, 11/23/99.

A similar story of impressive long-term performance might be told through an examination of the bridge's trusses and its substructure, including the fine job done by the men who performed the original riveting and the remarkable ability of the structural steel to withstand numerous ship and auto collisions over the years. Here, as elsewhere in this narrative, I have necessarily selected one example. Because the mechanical system was what made the bridge novel, it makes sense to focus there.

[97] Ken Wheatley, Resident Engineer's Project Critique, Contract No. 8320, 7/15/1977, Yeon Records Center; "Lift-Span of the Hawthorne Avenue Bridge," 381.

stopped the bridge abruptly when the operator's foot ceased to press it. Engineers of the 1970s feared the sudden deceleration might injure the bridge and wondered whether the aged deadman might fail, causing potentially catastrophic damage. Instead, County engineers wanted to build in automatic electrical braking and other speed control features to protect the bridge's mechanical components from being jarred by sudden starts and stops in routine operation as well as in emergency situations. No supplier would guarantee the performance of a modern drive package with the old motors.[98]

The old mechanical components continued to perform their tasks powered and eased by the new electrical system. Over the ensuing decade, County maintenance personnel continued routine inspection and maintenance. With a number of aging structures in their care, in 1985 County engineering and maintenance personnel, encouraged by the example of Seattle, decided to hire consultants Sverdrup & Parcel to assess all its Willamette River movable bridges and help plan timely improvements and the upgrading of an already solid maintenance program. The most immediate and dramatic result was the Hawthorne sheave crisis, an event that altered the bridge's history and, simultaneously, provides the historian an arresting perspective on the bridge's mechanical structure.[99]

A brief chronology supplies essential context for understanding the sheave crisis. Sverdrup & Parcel's inspection began on Monday, 15 April, 1985. The following day, their representative spoke by telephone with Stan Ghezzi, the Multnomah County Structural Engineer responsible for bridges. A formal letter dated 17 April, 1985 conveyed the same information: the inspectors had observed cracks in all eight counterweight sheaves. Sverdrup suggested several follow-up procedures: grinding down the surface to permit examination with a dye penetrant, punch-marking the cracks so that weekly examination could determine whether they were propagating, and further examination on Sunday, April 21, when the bridge could be closed to traffic and the sheaves rotated to display areas not yet examined. All this sounds measured, but the letter and, evidently, the telephone call, also sounded alarms. The cracks were termed a "serious potential hazard" and sheave failure, presumably the hazard referred to, identified as potentially causing "a catastrophic collapse of the lift span." Sverdrup urged that plans "immediately" be prepared in case further inspection revealed crack propagation and the counterweights needed to be supported. They also asserted that, despite the long, successful service of sheaves they now characterized as "castings of extremely poor quality," the County

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[98] Ken Wheatley, Bridge Engineer, to Oliver Domreis, Director, Public Works, 2/14/1975; George Frank, Pacific Engineering Corporation, to Kenneth Gervais and Kenneth Wheatley, Multnomah County, re. Project 75-090, 4/29/1975; Special Provisions and Supplemental Standard Specifications, Bridge Control Improvement, Hawthorne Bridge, FAUS 0970, 11/20/1975, all in Hawthorne Bridge, Yeon Records Center.

[99] Bart Bonney, Bridge Maintenance Supervisor, Multnomah County, Handwritten Memo in response to newspaper reports, 4/20/1985, Emergency 2, Hawthorne Bridge, Yeon Records Center.

should "initiate a program for their replacement immediately."[100]

On 18 April, Ghezzi confirmed by letter his telephone authorization the previous day of Sverdrup & Parcel to: design a support for the counterweights with the lift span closed, design a replacement for the counterweight sheave assemblies, explore the possibility of strengthening the existing sheaves, and prepare designs for operating sheave and span guide rehabilitation. That evening, County Executive Dennis Buchanan ordered the bridge closed and issued a press release that limited its quotations exclusively to the most alarming phrases from Sverdrup's letter. He added that County Engineer Larry Nicholas "said collapse of the lift span of the bridge would bring down the entire bridge." The following morning's *Oregonian* carried the story, quoted all the most frightening phrases from the consultant's letter, and added the County Executive's assertion that "We feel there is a risk to life, and we are not going to take that risk." By Saturday morning these quotations had been buttressed by others, also attributed to the County Executive, referring to "internal cracks" discovered through "ultrasound and X-ray equipment" and asserting that "the bridge could come down tomorrow." The bridge remained closed. Emergency authorization by the County Commissioners permitted repairs to begin in May, by which time Sverdrup had supplied a list of additional items that should be completed while the bridge remained closed. New sheaves and other mechanical repairs were completed by the end of August.[101]

At first glance the outcome of Sverdrup's findings seems foreordained. After all, who wants to travel across a bridge where more than 800,000 pounds of concrete and steel hangs from cracked 75-year-old steel castings of dubious quality? But much also rests on our interpretation of these events, including the reputation of an important historic engineering structure. It is worth asking a few more questions before rushing to judgment.

The central questions involve what voices were heard and what voices remained silent, at least as far as political decision makers and the general public were concerned. To begin with, we should note that the sense of multiple options and additional procedures articulated by Ghezzi and by the original Sverdrup letter had disappeared from the press release and the news reports. No public mention was made of rehabilitating the existing sheaves or of the need for additional scrutiny to determine whether the cracks represented a threat. The erroneous references to internal cracks and sophisticated technological procedures transformed the experts' preliminary assessments into certainties, an especially distressing error if it originated with the County Executive.

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[100] Larry F. Nicholas, County Engineer, to Don Eichman, Purchasing Division, 4/22/1985 and A. E. Schmidt, Sverdrup & Parcel, to Stan Ghezzi, 4/17/1985, Emergency 2, Hawthorne Bridge, Yeon Records Center.

[101] Stan Ghezzi to Thomas Gaffney, Sverdrup & Parcel, 4/18/1985; Dennis Buchanan, County Executive, For Immediate Release, 4/18/1985; Miscellaneous Oregonian clippings, 4/1985; Larry F. Nicholas to Don Eichman, 4/22/1985; A. E. Schmidt, Project Manager, Sverdrup & Parcel to Stan Ghezzi, 5/14/1985; Hawthorne Bridge, Mechanical Repairs, 1985, and Phase I files, all in Yeon Records Center. No internal cracks had been found; no ultrasonic or x-ray examination was performed.

Noticeably missing from the discussions were the voices of the "practical men" who had assumed custody of the bridge in its early years and faithfully maintained and inspected it in the interim. In contrast to the consulting engineers, who had spent a day on the bridge before they issued their pronouncement, County maintenance personnel had years of combined knowledge of the bridge. And because they handed their knowledge on to one another, it truly was combined. We get a glimpse of what they might have added to the deliberations thanks to Bart Bonney, Bridge Maintenance Supervisor, who placed a hand-written response to the news reports in the files. He writes:

> I saw those cracks two weeks after coming to work for Multnomah County (June 1980), they were brought to the attention of the Br. Maint. Foreman (who said they have been there a lot longer than he'd been with the county). An old timer on the crew felt the same way. It was also brought to the attention of the Bridge Engineer (he indicated it wasn't as serious as it looked). I however continued to monitor them on an inspection frequency of three months.
>
> When we painted the towers I inspected the cracks before sandblasting, after sandblasting and again after painting. Its my opinion they have been painted over at least twice and possibly three times. There was Black Graphite paint in the cracks (our records don't show when this system was applied), then an Alkyd system was applied over the Graphite system (1965). These two systems were removed and a complete Alkyd system applied in 1982.[102]

In addition to the obvious difficulties of communicating highly specific technological information to politicians and journalists impatient with complexity, the rush to judgment also reflected a profound contemporaneous change in the way civil engineering was treating cracks. Although fracture mechanics was not a new field, its potential to assess the cracks regularly encountered by both practical men and professional engineers was just being recognized among bridge engineers, a relatively traditional branch of the profession. John W. Fisher's now classic text had been published only in 1984. When the consulting engineers saw the sheave cracks, then, they were newly prepared to recognize their potential importance. Moreover, because this was new mathematical, computer-supported knowledge, they saw no need to depend on the testimony of maintenance workers as they might have a few years earlier. But since fracture

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[102] Bart Bonney, Handwritten Memo in Response to Newspaper Reports, 4/20/1985, Emergency 2, Hawthorne Bridge, Yeon Records Center. Since Bonney had brought back the suggestion for the Sverdrup study after discussing its benefits with City of Seattle personnel at a professional meeting and had supported its implementation, this was not a simple conflict of professional engineers versus men trained by doing. Bonney's testimony contrasts sharply with a statement, attributed to the County Executive, that no cracks were visible as of the 1982 paint job. The bridge was painted black until 1965 when an A.I.A. consultant devising a new color scheme for the Willamette River bridges chose yellow ochre for it. R. C. Northrop to Board of County Commissioners, 6/4/62, Yeon Records Center.

mechanics was new to them, they were also ill-prepared to communicate to politicians or even to the County Engineer the importance of following up through further investigation, regular inspection, and complex calculation to determine whether the cracks actually were hazardous and, if not, to monitor them.[103]

Although we will never know for certain, the recollections of maintenance workers at least suggest that the counterweight sheaves might not have reached the end of their useful lives. The characteristics cited by the Sverdrup engineers as demonstrating their initial poor quality-- "blow holes, porosity, evidence of sand inclusions, extreme surface irregularity, shrinkage cracks, and non-uniform sections" -- were more or less standard characteristics of large steel castings of the era. As one engineering scholar familiar both with historic structures and modern materials science points out: "To be rigid enough, the various parts generally have to be so thick that the stresses in them are very low... It follows that . . . even if the material is riddled with defects and stress concentrations, it probably does not matter very much ...."[104]

Assessing the quality of early 20th century steel castings required going beyond the general characterization Sverdrup & Parcel offered. This was something Waddell & Harrington, with its firm grounding in practice, knew how to do. As consulting engineers, the firm had subjected the eight original sheaves to careful inspection; six castings had failed to make the grade and had been replaced. County maintenance personnel continued to recognize that superficial defects did not necessarily mean poor quality, but those less experienced in the ways of early 20th century technology had lost this awareness.[105]

In the event, the historic castings were doomed. They were replaced by welded sheaves meeting 1985 AASHTO standards. While the lift span was immobilized, Sverdrup recommended a number of other changes be made. Many of these resulted from the earlier motor replacement, which had placed extra demands on a drive train designed for lower capacity motors; reduction in applied horsepower to solve this imbalance also meant looking for ways to reduce demands for power. The main drive pinion gear, heavily worn from excessive driving

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[103] Although the interpretation is mine, I am indebted to Ed Wortman, Multnomah County Bridge Engineer, for my understanding of fracture mechanics and its advent in civil and bridge engineering. John W. Fisher, Fatigue and Fracture in Steel Bridges: Case Studies (New York: John Wiley & Sons, 1984) remains an important text and Fisher continues to be the leading authority. See HAER NO. OR-22 addendum, my report on the Broadway Bridge, for an examination of the very different way the crack in the Rall wheel was treated only a few years earlier.

Here and elsewhere, it is important to note that Sverdrup subcontracted the mechanical inspection to Milton C. Stafford, which may have placed Sverdrup at an even greater disadvantage when communicating about the bridge's mechanical problems. Stafford, based in Bala Cynwyd, PA, would certainly have been familiar with the work of Fisher at Lehigh University in Bethlehem, PA.

[104] A. E. Schmidt to Stan Ghezzi, 4/17/1985, Emergency 2, Hawthorne Bridge, Yeon Records Center; Gordon, Structures, 133-134.

[105] Van Cleve, "Mechanical Features of the Vertical-Lift Bridge," 1027.

effort, deserved immediate replacement along with the shaft to which it was welded. As noted earlier, elimination of the spring-loaded roller guide system and adding balance chains were recommended to lower power requirements. The consultants also called for re-balancing the span and counterweights because changes over the years had made their relative weights uncertain, replacing the worn bushings and axles of the deflector sheaves that turned with the operating ropes, and rehabilitating the equalizer system to restore mobility at the pin connections and permit greater balance among the ropes. Because the consultants and County agreed there was a sheave crisis, all this work was scheduled for completion within a few months.[106]

Looking back, it is easy to see that mechanical repairs on a historic structure required a more thorough appreciation of the original design than an emergency repair schedule permitted. When the schedule did not permit fabrication of new span guides, the County and its contractor agreed to simply rehabilitate the system, which meant replacing the original springs. Evidently the original design never intended spring replacement so the rehabilitation involved cutting through structural members and re-welding, a job performed so poorly that engineers performing the later 1998-99 rehabilitation identified the results as dangerous. Similarly, in early August, 1985, when the consulting engineer and contractor found that the web plates connecting the hub and rim of sheave number 7 were misaligned, they accepted the machine shop work although it exceeded normal fabrication tolerances. And in late July, when the consultant learned that new gears did not fit the old shafts which were out-of-round, they recommended the "most timely" solution: turning down the shafts and chrome-plating them. The issue of how "time consuming" particular solutions would be also influenced equalizer renovation. And it meant a less than optimal choice of counterweight sheave bearings and postponement of span lock installation until a later date. Engineers charged with the bridge's subsequent maintenance and rehabilitation

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[106] Additional work performed in the summer of 1985 included live load shoe repair, bearing pedestal anchor bolt repair, and replacement of gusset plates on pier 5 bracing. Initial plans to replace the sheave bearings with anti-friction bearings because the existing bronze bushings exceeded current AASHTO stress standards ran afoul of the tight summer work schedule. Instead, the original bearings got new bronze bushings including new lubrication grooves. Note that the lubrication difficulties these were designed to solve are reminiscent of the ones recognized by County maintenance workers during the bridge's early years. A. E. Schmidt, Project Manager, to Stan Ghezzi, 5/14/1985 and 5/15/1985; Stan Ghezzi to Bob Bittner, Project Manager, Riedel International, 7/9/1985; Stan Ghezzi, Memo to File, re. Meeting with Riedel International, Inc., 7/9/1985 all in Hawthorne Bridge, Phase I, 1985, Yeon Records Center.

To be precise, as Schmidt explained in his letter to Ghezzi, the essential problem created by the more powerful motors was that gear trains are "normally designed to the capacity of driving motors, instead of the design loads, to anticipate the possibility of over-accelerating the system." Wear patterns confirmed that over-acceleration had taken its toll over the previous decade. One might add that the energy-frugal approach that determined the original motor choice had failed to anticipate declining operating efficiency as the structure aged, the problem that had motivated installing the more powerful motors.

have had reason to regret the haste that prompted a number of these choices.[107]

Combined with the built-in need to prefer quick solutions, emergency repairs did not permit the planning that assures optimal work organization and supervision. The results are manifest repeatedly in accounts of work progress. Stan Ghezzi's summary of events over the two days the contractor consumed in weighing the counterweights, although expressed in dead-pan engineering language, has all the makings of slapstick comedy. Each time the contractor attempted to start jacking, the absence of items such as shims or the presence of shims of the wrong dimensions enforced delay. After the shim problem on the west side was solved and work got underway, the east side crew ran out of shims and the job ground to a halt. The contractor had also failed to determine whether the available power source sufficed for the pumps lifting the load. When the circuit breakers blew, workers had to await the arrival of additional generators. One of these failed to work and had to be replaced. The failure, as it turned out, resulted from not turning the right switch. Additional problems, including an ironworker breaking a key piece of equipment when he knocked it from one of the towers, created further delays. Ghezzi calculated about eleven hours non-productive time which he attributed to "a lack of supervision . . . in monitoring the work and lack of prior planning."[108]

Daily reports authored by three different County inspectors underscore that poor planning and inadequate supervision plagued the project. Some of the problems are summarized in an "Injury Diary" prepared in early July and listing more than a dozen absences for doctor and dentist visits and a similar number of late arrivals by workers who, as specified in the Ironworkers' contract, nonetheless received overtime. The report's author concluded, "Productivity is low due to lack of direction from foremen . . . (I believe all workers are willing to work if given direction, but direction hasn't been supplied.)" Poor supervision also meant that workers repeatedly worked without the required safety lines, that parts removed from the bridge were left lying in hazardous locations, and that bolts on the counterweight falsework were not impact-wrenched on. Inspector Ronald H. Meier reported abuses such as ironworkers sitting down and smoking rather than sanding the equalizer pin holes; he found another curled up asleep beneath the bridge on one of the piers. But all the inspectors consistently identified poor supervision as the issue. When inspector Robert W. Clark found three ironworkers watching two others cut out a pin, he went to the office and found their superintendent reading the paper.

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[107] Stan Ghezzi to File, 7/3/1985; John L. Larson, Sverdrup & Parcel, to San Ghezzi, 8/6/1985 and two memoranda dated 7/22/1985; A. G. Schmidt to Stan Ghezzi, 5/15/1985; Robert B. Bittner, Vice President/Chief Estimator, Riedel International, to Stan Ghezzi, 7/5/1985, all in Hawthorne Bridge, Phase I, 1985, Yeon Records Center. Observations concerning the span guide rehabilitation come from Ed Wortman, Multnomah County Bridge Engineer. Discussions with Wortman and with Jon Henrichsen, Multnomah County Bridge Engineer, combined with a review of records from the 1998-99 repairs provide the basis for my conclusions.

[108] Stan Ghezzi to File, 7/3/1985, Hawthorne Bridge, 1985 Emergency Sheave Replacement, Yeon Records Center. The counterweights weighed 819,000 on the west side and 825,000 on the east. Please note earlier cautions against giving too much credence to any such precise weight figures.

Although the contractor made changes in supervisory personnel, the job climate had already been established. In mid-August, Inspector Clark summed up several months of frustration: "In my opinion if they would have worked any slower today you couldn't see them move."[109]

In addition to inadequate planning, many problems resulted because prior commitments kept supervisory personnel from joining this emergency job at the outset. Other problems were of a sort that the County might have resolved to its advantage had longer lead time been available. For example, the County had specified that all machine room work be performed by millwrights. Midway through, Riedel, the contractor, insisted on changing the terms of the job, expressing fear of conflicts between millwrights and ironworkers. Under time pressure, the County agreed to a compromise: a supervisor with extensive millwright experience would oversee the pinion, shaft, and coupling removal and replacement. A few days later, though, the removal work took place without anyone with millwright experience on site.[110]

Abetted by adequate time for planning, "Phase II," the 1992 completion of work called for in the original Sverdrup evaluation, went smoothly. Much of this work was non-mechanical, such as gore modification, rivet replacement, and floor beam repair. But time to think through their design and installation made the new span locks and buffers installed in this phase distinct improvements over their predecessors. Milton Stafford, Sverdrup's mechanical inspection sub-contractor, provided a critical review in early 1991 that helped assure that outcome. In addition to traffic control devices, a new emergency drive system and electrical modifications to link new components to the existing system completed this series of repairs.[111]

Phase II was notably lacking in the moments of high drama and low comedy characterizing the 1985 emergency repairs. The exception came as a result of the decision to keep the bridge open to pedestrians and bicyclists during simultaneous transition structure construction. Plans for how this might affect Phase II mechanical repairs had not been worked out. The ironworkers performing much of the job disliked having repeatedly to stop work and remove themselves and their tools from their workplaces in order to accommodate bridge openings, especially as they watched unruly pedestrians repeatedly delay openings. After the ironworkers presented a litany of complaints at a meeting called to resolve these problems, the

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[109] Injury Diary, 6/4-7/5, Hawthorne Bridge, Unit I, I-0042-C, 1985 Emergency Sheave Replacement; Multnomah County, Division of Public Works, Inspector's Daily Reports, 6/14/1985, 7/22/1985, 8/6/1985, 6/26/1985, 8/17/1985, and passim, 1985 Emergency Sheave Replacement; Stan Ghezzi to File, re. Meeting with Riedel International, Inc., 7/9/1985, and Robert Bittner, Project Manager, to Stan Ghezzi, 7/10/1985, Emergency 2, Hawthorne Bridge, all in Yeon Records Center.

[110] Stan Ghezzi to File, re. Meeting with Riedel International, Inc., 7/9/1985, and Robert Bittner, Project Manager, to Stan Ghezzi, 7/10/1985, Emergency 2, Hawthorne Bridge, Yeon Records Center; Multnomah County, Division of Public Works, Inspector's Daily Report, 7/13/1985.

[111] Hawthorne Bridge Truss and Lift Spans #2757G Section Bridge Rehabilitation Phase II, Agreements and Time-Line of Meetings and Correspondence Regarding Electrical Problems, 1992, Yeon Records Center; Clair Kuiper, ODOT Project Inspection Report, Contract No. C11118, 2/18/1993, Yeon Records Center.

contractor's representative exploded:

> This whole job would have been a whole hell of a lot better off if they would shut it down. . . you can't put in enough measures unless you hire some (#?*&) bodyguards to stand out there and physically keep people from going out and walking. You know I see people all of the time get off of the sidewalk and walk out there and look through the holes [in the decking] and (*$#@) like that. And its not like they don't have enough (#@$%) bridges for people to go across in this town either, you know.[112]

Mechanical repairs made up a relatively small component of the County's 1998-99 painting, deck replacement, and structural repair job, which substituted for the bridge's drab ochre paint job one setting dark green metal work against red counterweights and deck railing. The west counterweight got new guide rails to replace its worn Z-bar tower tracks. The operating sheaves were also replaced. As noted earlier, new operating drums were installed and all the wire ropes changed. A modernized electrical system, including computer-based controls, completed the list of alterations. Because the structural work and painting raised important environmental and noise pollution issues in addition to all the various social and political challenges that had become staples of recent repair and construction jobs, the 1998-99 project involved especially complex administrative issues. It is worth noting, then, that in contrast to the communications and planning problems that plagued many earlier efforts, a reader of 1998-99 correspondence, engineering plans, and inspectors' reports encounters little evidence of conflict and considerable attention to effective communication. Although engineers especially differ over the concept, this suggests the success of "Partnering," a strategy that required all those involved, including funding and permitting agencies, design consultants, contractors and subcontractors, and county, city, and state transportation department engineers to gather for several days at the outset and reach agreement on goals and priorities. The initial emphasis on interacting as partners rather than as adversaries clearly influenced the tone of later communication, making it easier to resolve differences.[113]

Conclusion: Why the Bridge is Still Here

Why is the Hawthorne Bridge still here? Historic civil engineering structures do not

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[112] Transcript of Safety Meeting, West End of Hawthorne Bridge, re. Raising and Lowering of the Lift Span, 4/16/1992, Hawthorne Bridge, Phase II, Yeon Records Center. The expletives were deleted in the original.

[113] These generalizations come from reviewing the full array of documents generated by the Hawthorne Paint and Deck Replacement, #11986, 1998-99, Yeon Records Center. Again, I have gleaned additional perspective through discussions with Ed Wortman, Multnomah County Bridge Engineer. As noted earlier, although not specified as parts of this job, work in 1998-99 uncovered a number of problems left over from the emergency work in 1985.

survive ninety years by chance, although chance certainly plays a role. One answer certainly lies in the quality of the original design and construction, documented throughout the preceding pages. The City of Portland wanted a permanent bridge to replace the temporary spans that had caused so many problems and Waddell & Harrington, with its ample experience building heavy steel structures and designing mechanical systems, was exceptionally well-prepared to provide one. Harrington cautioned the City to pay attention to routine maintenance, something earlier Portland bridges had required little of. Multnomah County took on these responsibilities from the outset and has received compliments from outside specialists on the quality of its maintenance ever since.

But Portland has never taken the permanence of the Hawthorne Bridge for granted. To the contrary, planners and others have repeatedly anticipated its replacement. Although they understood that the theoretical remaining life of the bridge in 1930 was sixteen years, the City Planning Commission advised the County that "owing to the rapid increase of automobile traffic it might be necessary to build a new bridge with greater road capacity even before the Hawthorne bridge had outlived its usefulness." In addition to depression era austerity budgets, the County decided to spend little money in its 1931 re-decking because it expected that within eight to ten years "there would be a new bridge built to replace it." A 1969 City Planning Commission discussion of the area near the bridge's western terminus began, "Doubtless the Hawthorne Bridge, which is now 60 years old, will be replaced in the not too distant future." Sverdrup's 1985 report noted that the superstructure had already exceeded its lifespan by Interstate Commerce Commission standards, but with recommended repairs they projected its demise could be delayed until 2015, barring "future regional traffic plans which may make the bridge functionally obsolete." Changes in traffic from what the bridge was originally designed to carry lay behind these and other prognostications, making the County's judicious innovations in decks, paving, approaches, and ramps especially important in explaining the bridge's survival. So too is the fact that the bridge was originally designed to support two electric railway trains crossing simultaneously, a combined load, including impact, of 224 tons, substantially more than the trucks that constitute its heaviest current users.[114]

Portland's political and social climate also helps explain the bridge's survival. Predictions that the bridge would be replaced and arguments that it should be replaced abounded between the 1930s and the early 1970s when the city directed its planning efforts toward accommodating

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[114] City Planning Commission to Board of County Commissioners, 3/24/1930, City Engineers Correspondence 1930-31, City Archives, Portland, OR; Geo. W. Buck, Roadmaster, to R. H. Baldock, State Highway Engineer, 3/7/1944, Reconstruction and Redecking, Hawthorne Bridge and East Approach, Agreements, 10/19/1944, Yeon Records Center; Portland City Planning Commission, Hawthorne Bridge Relocation-Portland Commons Conflict, 4/11/1969, Land Use, Downtown Plan File, New Hawthorne Bridge, 1965-69, City Archives, Portland, OR; Sverdrup & Parcel in association with Moffatt, Nichol & Bonney and Milton C. Commissioner D Stafford, Hawthorne Bridge Summary, from Willamette River Bridges Investigation Summary Report, October, 1986; Robert L. Nordlander, Director, Dept. of Environmental Services to an Mosee, 4/2/1972, (authored by Ken Wheatley, Bridge Engineer), Yeon Records Center.

automobiles. As the climate shifted to favor public transit riders, pedestrians, and bicyclists, the County has helped the bridge survive by incorporating the preferences of these groups in its plans and construction. The concentration of walkers and bicyclists in neighborhoods served by the bridge makes their influence even greater, especially since the bridge has always served as a local traffic conduit. Despite its cultural transformation, though, Portland was and remains an essentially conservative place; it takes its time about changing and needs to be persuaded that change is good. Its taxpayers' unwillingness to provide abundant funds reflects and encourages this climate. Portland's conservatism has given its historic bridges an edge and the need for frugality has increasingly favored repairing old structures rather than building new ones. Under these circumstances, assessing and planning for the Hawthorne's timely maintenance and repair has grown increasingly important and, again, the County has been responsive.[115]

Finally, human creativity brought the bridge into being and keeps it where it is. In a world with an abundance of vertical lift bridges, it is a bit breathtaking to recall that this structure was essentially unprecedented. Its survival is particularly important because it constitutes our best surviving record of how this significant bridge type came into being. Waddell and, especially, Harrington evinced remarkable ingenuity in Portland. But creativity did not end in 1911 when Harrington pronounced the structure permanent. Trying new pavements, decks, ramps, cables, and control systems requires an innovative spirit, and tailoring new components to a historic structure demands considerable ingenuity. So does conceiving the possibility of new deck configurations and better ways of planning timely maintenance and repair. Because it is truly unique, the bridge regularly reminds its engineers, operators, maintenance personnel, and users that they cannot take its behavior for granted, that they need to think before they act to alter it. It demands creative responses. In a world whose predictability often stultifies, this alone makes the Hawthorne Bridge a treasure worth preserving.[116]

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[115] MacColl, Growth of a City, passim; Abbott, Portland, passim.

[116] I have benefitted from the assistance of many people. I cannot acknowledge all of them by name, but wish especially to thank: Sharon Wood Wortman, HAER Historian and Portland's "Bridge Lady," my colleague on the project; Edward J. Wortman, P.E., Engineering Services Administrator, Department of Environmental Services, Division of Transportation-Bridges, Multnomah County; Jon Henrichsen, P.E., Electrical/Mechanical Engineer Associate, Department of Environmental Services, Division of Transportation-Bridges; Mary Hardy, Technical Service Assistant, Transportation Division, Multnomah County; Librarians and Archivists at the Oregon Historical Society, the Portland City Archives, and the Multnomah County Library, including the Wilson Rare Book Room; Robert Hadlow, Senior Environmental Coordinator, Oregon Department of Transportation; Richard O'Connor, Historian, HAER; Kate Larson, HAER Staff Member; Justin Spivey, HAER Historian; Eric DeLony, HAER Chief; Matt Roth; and Sweet Georgia Brown, my canine companion on many a bridge walk. Of course, all errors of fact or interpretation are my responsibility.

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