Not the Eads Bridge

An Exploration of Counterfactual History of Technology

JOHN K. BROWN

The Eads Bridge, formally named the St. Louis Bridge, became an icon of American technological accomplishment from its opening in July 1874. The press and public loved the new bridge for its unique design, clean aesthetic, and deliverance from the inconvenient ferry services across the Mississippi River. But most American civil engineers saw little to admire or emulate. Another two decades passed before structural steel became widely accepted in long-span bridges. James Eads's shallow arches never became a design paradigm in the United States.[1] Although his method of sinking the bridge piers to bedrock *was* widely emulated, for the Brooklyn Bridge and elsewhere, the designers of contemporary bridges across the Mississippi and Missouri rivers were skeptical about the need to land piers on bedrock. Would not piles driven into the sandy riverbed carry the loads while saving money? In the end, the high cost of the St. Louis Bridge decisively turned civil engineers away from Eads's approach. But he is revered as a brilliant designer; his bridge is a historic landmark of American civil engineering and remains in use today (fig. 1).

This presents a fascinating riddle: the public and historians have lionized Eads and his bridge, while contemporary engineers mostly condemned the design and stuck to their own paradigms. How to resolve this contradiction? That question is seldom suggested in the many histories of the

John K. Brown teaches the history of technology at the University of Virginia. The author presented earlier versions of this article at the Business History Conference and at the Society for Industrial Archeology, where he received valuable input. He thanks Mark Aldrich, Bernie Carlson, Sally Clarke, Robert Friedel, D. C. Jackson, Naomi Lamoreaux, Ed Russell, and *T&C*'s anonymous referees.

0040-165X/14/5503-0001/521–59

1. Histories of the bridge are cited in footnotes 17–19. Beyond critiques of his bridge, contemporary engineers tended to dislike Eads the man for three reasons: he succeeded in building the St. Louis Bridge without any formal training in engineering; he scorned engineering precedent; and he projected brash self-confidence. While the public would associate Eads with steel, his fellow engineers mostly saw brass in the man.

JULY
2014
VOL. 55

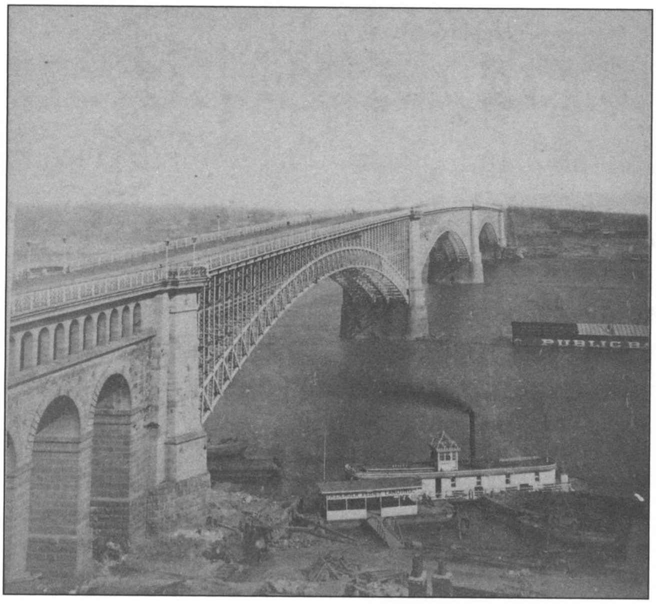

FIG. 1 The Eads Bridge in the 1880s. The steam ferry at a dock in the foreground finds ample business in competing directly against the bridge company. (Source: Author's collection.)

bridge—and that too is interesting. An issue contributing to this paradox is that the bridge has become a venerated icon, a status that hinders analysis.[2] Among historians, the bridge's technical attributes garner praise: the first structure (of any type) worldwide to rely upon structural steel, with spans of unprecedented length, its granite and limestone piers founded on bedrock far below the surface. In short, an old-fashioned Whiggish triumphalism, explicit or not, obstructs the questions that historians could ask. Behind these barriers, another issue blocks analysis. The massive reality of the Eads Bridge—in steel, iron, and stone—exerts such force in historians' narratives that they fail to see value in examining alternate designs. Yet benchmarks are essential to analyze the choices, shortcomings, and attributes embedded in this bridge or in any other technology.

The claim may appear surprising, so let it be clear: historians of technology seldom explore in any depth alternate design approaches or technologies that were conceived but not built—also known as *counterfactuals*. This *is* surprising because historical protagonists often weighed alternatives, and technological historians touch on these design trade-offs. Consider two examples from U.S. technological history: William Sellers's alterations of the Whitworth (British) screw threads to suit American conditions, and the merits of Boeing's Model 247 airliner versus the Douglas DC-1. In these sto-

2. For its iconic status, see David E. Nye, *American Technological Sublime*, 79–83.

ries, design accounts begin with the alternatives. However, technological historians usually construct narratives that are blind to alternate paths. Bruce Sinclair persuasively argues that the Sellers thread suited American needs, but widespread adoption of the British standards by U.S. machinery-makers could have produced positive results as well. While aviation historians invariably note the innovative 247, their accounts then focus on the DC-1 as the better plane—the apparent verdict of airplane buyers and airline customers. But in 1931, Boeing also developed a larger configuration for the 247 (larger than the design it chose to build), with more seating and more powerful engines. No historian explores this alternative in any detail—its rationale, potential service life, and ramifications for commercial aviation in the 1930s.[3] And if Boeing had found commercial success with its original 247, would it have chosen in 1934 to build its B-17 bomber prototype? As these examples suggest, counterfactual perspectives offer new analytic force in understanding the history of these technologies.

Nonetheless, technological historians have seldom explored the potential of asking "what if?" Contextual studies offer detailed tapestries, mostly highlighting elements that delineated the winner—the technology that succeeded on the historical stage, be it the caravel, the gasoline-powered automobile, the DC-3, the pressurized light-water reactor, or the digital computer.[4] Given their focus on technical-as-social, social constructionists mostly examine actually built technologies, from bicycles to fighter jets. For these analysts, social choices and contexts shape everything in the black box, even its most technical elements. This core methodological claim discourages interest in counterfactual technologies because there is no black box to unpack.[5] Some technological historians highlight contingencies by exploring technological failures while others delineate the historical evolution of ideas about alternative futures, but these rich genres offer different approaches and findings than do counterfactuals.[6] Whatever the preferred frame, the materiality of our subjects seems to overpower our capacity to

3. Bruce Sinclair, "At the Turn of a Screw." The larger version of Boeing's 247 is described in Ronald Fernandez, *Excess Profits*, 75. In *The Boeing 247*, F. Robert van der Linden details internal debates over early design studies (chap. 2) and asserts that Boeing's smaller plane was a mistake (68). But he offers little analysis of that choice.

4. The important exception (discussed below) is David Kirsch, *The Electric Vehicle and the Burden of History*.

5. In their desire to demonstrate that all technical attributes have social roots, SCOT analysts have little incentive to look at technological alternatives that were not built; see Wiebe E. Bijker, "How Is Technology Made?"

6. For a leading example, see John Law and Michel Callon, "Engineering and Sociology in a Military Aircraft Project." Notwithstanding the value in these studies, historians of technology remain largely blind to failure, as Eric Schatzberg notes in *Wings of Wood, Wings of Metal*, 5. The extensive literature on futuristic conceptions of technology includes Joseph J. Corn and Brian Horrigan, *Yesterday's Tomorrows*; and H. Bruce Franklin, *War Stars*. Studies of what the past once thought of the future differ fundamentally from the "what if" of counterfactuals.

reckon with the designs that, at a moment in the past, could have become alternative actors in history. In declining to explore counterfactuals we repeatedly hurry past key moments of contingency, disinclined to look at them very closely.[7] This omission is especially surprising for a field so adamantly opposed to the flip side of contingency—determinism.

Counterfactual History: Means and Ends

Standing astride the Mississippi today, the Eads Bridge is sui generis. In 1867–68, however, the promoters of six different ventures each sought public favor and private investors for plans to cross the river at St. Louis. At that moment, comparing these options preoccupied the entire city. By detailing the most developed alternative, this article takes us back to the moment of indeterminacy. Further, it provides a benchmark to promote understanding of the local and national forces that shaped any bridge project at this place and time; the logic of specific design and promotional decisions by the Eads group and by its chief rival, the Boomer/Post group; the crucial actions, alliances, and accidents that allowed Eads to best that rival; and the varied meanings of "success" in Eads's project—a venture that rivaled the Brooklyn Bridge in the unfolding technological iconography of the United States. Participants in Eads's venture offered conflicting verdicts on its success, and judgments shifted with time.

Counterfactual analysis offers three benefits for technological history. By exploring the alternatives that actors confronted or considered, we compensate for the hindsight bias that distorts historical vision. With the alternatives in view, we see again that rational choice explains little in history. Crucially, counterfactual study highlights the power of contingencies in shaping historical outcomes. Historians construct counterfactual scenarios by placing the actual record against a potential alternative—a history that did not happen, but conceivably could have. Examples demonstrate many approaches within the method. (The terms below are mine, except where noted.)

Contingent counterfactuals change one key event or actor, then trace the consequences unfolding over hours or decades. Military historians use this method to show the influence of individuals and contingencies. A famous example from the U.S. Civil War asks: If a small detachment of Union soldiers had not seized Little Round Top at Gettysburg, would the Confederates have prevailed in that battle and perhaps in the war? Coun-

7. Why we hurry readers past contingent moments raises fascinating questions about the nature of historical analysis and the power and structure of narrative. Counterfactuals are not entirely unknown in technological history, although the term does not appear in John M. Staudenmaier S.J., *Technology's Storytellers.* Footnotes 8 and 9 below cite recent anthologies of counterfactual studies; self-identified historians of technology wrote none of the sixty-four cases therein.

terfactuals aimed at popular audiences use this approach on a broader scale, portraying potential consequences if the Spanish Armada had won or the 1944 Allied invasion at Normandy had failed. The resulting scenarios are fun and fascinating, albeit speculative. In a somewhat different form, contingent studies have served purely analytic ends, providing fresh ground to examine such big issues as the rise of the West.[8]

Constrained counterfactuals are quite different. Niall Ferguson coined this term to describe close comparisons of "those alternatives . . . that contemporaries actually considered."[9] In comparing option X (which happened) with option Y (which did not), this method delineates the prime agents in historical choice and causation. Inspired by Ferguson and his coauthors, this article offers a constrained counterfactual.

Rewind time cases explore how history might have differed if an older paradigm had continued, rather than being replaced. Robert Fogel authored a well-known example, *Railroads and American Economic Growth.* To explore the real effect of railroads in shaping the U.S. economy, he constructed an alternate America, a nation of canals and roads in 1890, but no railroads. That work eventually landed a Nobel Prize in Economic Sciences for Fogel, but technological historians were unimpressed. A country laced by canals instead of railroads in 1890 simply seemed too far removed from reality.[10]

Anticipated outcomes appear in David Kirsch's history of the electric vehicle. In the first decade of automobility, unique technologies competed for investment capital and market share. Returning to this undetermined moment, Kirsch emphasizes that expectations about each choice—steam, gasoline, and electric—shaped both its own future and the evolution of competing paradigms.[11]

A path not taken appears in Richard White's revisionist account of transcontinental railroads in North America. He details the waste, fraud, and environmental abuses that resulted from the manic drive to lace the West with rails. To underscore that indictment, White closes with a counterfactual scenario, arguing that fewer lines built with more deliberation would have benefited all parties while limiting environmental wastage.[12] The insight is ultimately normative, not causal, although valuable nonetheless.

8. *Contingent counterfactuals* that aim for provocative narratives (humanistic history) dominate in Robert Cowley, ed., *The Collected What If?* Contingent counterfactuals to serve analytic ends (history as social science) appear in Philip E. Tetlock, Richard Ned Lebow, and Geoffrey Parker, eds., *Unmaking the West.*

9. Niall Ferguson, ed., *Virtual History*, 86.

10. *Technology and Culture* published a long, skeptical review of Fogel's book, arguing "instead of creating figments . . . we can compare what actually happened in two or more cases"; see Julius Rubin, "Review of *Railroads and American Economic Growth*," 233. Perhaps technological historians grew chary of counterfactuals because they disliked the speculative quality of two types: the big contingent cases, and Fogel's audacious rewinding of time.

11. Kirsch, *The Electric Vehicle and the Burden of History*, chap. 6.

12. Richard White, *Railroaded*, 516–17.

In passing considerations are the most common form for counterfactuals in technological history. In "How the Refrigerator Got Its Hum," Ruth Schwartz Cowan poses interesting questions about the capacities of firms making gas-powered refrigerators, factors hindering their ability to compete with manufacturers of electric machines. Henry Petroski wonders what might have happened if the *Titanic* had missed that iceberg.[13] Nearly all accounts of the Hiroshima and Nagasaki bombs note that World War II could have ended in other ways. Although provocative, the limited scope of these asides suggests that technological historians are wary about counterfactuals, or simply unaware of their potential.[14]

In exploring a *constrained counterfactual*, this article highlights the value of this analytic tool for historians of technology. Business historian Naomi Lamoreaux has underscored the utility of counterfactuals in two tasks that always confront historians: minimizing the distortions imposed by hindsight, and placing contingencies at the center of our accounts.[15] *Contingency* is a slippery idea. It begins with the notion that innumerable factors combined to shape protagonists' choices and historical outcomes—far too many for the actors involved to perceive fully, much less for historians long removed from events. Nonetheless, to write accurate and nuanced history, our work must begin by searching out those hidden influences, especially those that have faded from view. The constrained counterfactual is essential to that endeavor. Since engineers, entrepreneurs, and users *always* weighed alternatives and since they *had* to choose among undefined and uncertain options, historians of technology can find much analytic value in these constrained scenarios.

This article explores the potentials of the method by contrasting the Eads Bridge with an alternate proposed for St. Louis though never built, the Boomer/Post bridge. A largely conventional design, this multi-span truss bridge also originated in the summer of 1867. Most historical accounts do not take the Boomer/Post project seriously. After all, it lost. In August 1867, however, it was an entirely credible proposal advanced by men with more relevant credentials than Eads, who had never designed or built a bridge before. Useful sources describe the Boomer/Post proposal, including a hundred-page report by a board of accomplished engineers,

13. See Ruth Schwartz Cowan, "How the Refrigerator Got Its Hum"; and Henry Petroski, *To Forgive Design*. I mean no criticism of Cowan's marvelous essay, for her focus is on what *did* happen, not what *could have* happened. Although explicit counterfactuals are too rare, many historians use them implicitly or suggestively in structuring narratives. Whenever historians select one variable as a critical factor they have rejected alternative explanations.

14. By contrast, economic historians commonly test their hypotheses against counterfactual scenarios and calculations. For example, E. A. Wrigley, in *Energy and the English Industrial Revolution*, emphasizes the importance of coal in industrializing Britain by extrapolating London's demand for wood "in the absence of coal as an energy source" (39).

15. Naomi Lamoreaux, "Presidential Address."

that detailed the design and recommended its construction.[16] Furthermore, the proposed bridge shared design elements with three actual bridges completed during this era on the Missouri River. This counterfactual is built on facts.

This article explores three topics. First, it details the conventional narratives of each project. Although never fully delineated in accounts of the Eads venture, the Boomer/Post bridge usually appears as a foil to emphasize enduring narrative themes: Eads's design brilliance, the Chicago/St. Louis rivalry, and the aesthetic and innovative triumph of Eads's unique bridge. I show here how these narrative conventions have shaped what belongs, and what is omitted, in this history.

The second focus is a detailed survey of the Boomer/Post bridge. What did its designers propose and why? Crediting that venture as a serious alternative promotes our ability to understand how the Eads group won out. Moreover, in a few respects, the two ventures demonstrated similar design choices; these commonalities highlight the fundamental contexts that shaped the designs at this time and place.

The third topic is a counterfactual service life for the Boomer/Post bridge. Had it been built, what might have been the broader consequences? Authoritative answers are impossible, but reasoned conjectures are within reach. Answering these questions is no parlor game: the answers provide essential benchmarks to evaluate Eads's bridge and its roles in the unfolding histories of the city, the region, and the practice of civil engineering in America.

Conventional Narratives and Common Storylines

Eads and his bridge have not lacked for biographers. The starting point is *A History of the St. Louis Bridge*, published in 1881, by Calvin Woodward, an engineering professor at Washington University.[17] With hundreds of illustrations, Woodward provided a testament to Eads's accomplishment. Alongside detailed engineering descriptions, his narrative includes earlier attempts to span the river at St. Louis, the Boomer/Post crossing, the success of Eads's group in countering its competitors, finance, setbacks in digging the foundations and erecting the superstructure, disputes with contractors, and the grand public celebration at its opening. The book provided foundational material for later works, including those by Howard Miller and Quinta Scott (1979), John Kouwenhoven (1982), and Robert Jackson (2001), although each account significantly revises the history.[18] The bridge

16. *Proceedings and Report of the Board of Civil Engineers Convened at St. Louis.* This board is described in Simine Short, *Locomotive to Aeromotive*, 41–43.

17. Calvin M. Woodward, *A History of the St. Louis Bridge.* Louis How, *James B. Eads*, and Florence Dorsey, *Road to the Sea*, are unreliable, hagiographic biographies of Eads.

18. Howard Miller and Quinta Scott, *The Eads Bridge*; John A. Kouwenhoven, "The Designing of the Eads Bridge"; Robert W. Jackson, *Rails across the Mississippi.* Miller

also received extensive treatment in works by John Barry, David Billington, Arthur Morgan, David Nye, and Henry Petroski.[19]

These accounts cast Eads as a heroic iconoclast. Acknowledging his inexperience in any bridge project, his biographers nonetheless focus on talents that suited him for the task of bridging the river. All detail Eads's earlier career as a salvor when he literally walked the riverbed of the Mississippi under a diving bell of his own design, salvaging cargos from sunken steamboats. That experience provided a unique understanding of the river's powerful and shifting currents—knowledge vital to building a strong foundation. These facts obscure some nuances, however; for example, Eads adamantly asserted that his arches were both cheaper and better than the customary truss forms of railway bridges. None of the published accounts tests that proposition. His experiences under the Mississippi make such a powerful story that no one has explored whether Eads overplayed the role of currents as a design constraint.

The standard stories place his bridge within an overarching rivalry after 1865 between St. Louis and Chicago for supremacy among Midwestern cities. Ironically, Woodward's book clearly shows that Eads fostered newspaper stories casting his bridge as a local effort and the Boomer/Post alternative as a plot from Chicago that aimed (somehow) to hurt St. Louis.[20] Most subsequent authors overlook Eads's influence in this, focusing instead on the urban rivalry.[21] The competition makes a powerful narrative device, yet it obscures other truths. For example, by 1867, thoughtful observers in St. Louis knew that the city, located on the western bank of the Mississippi, faced inevitable decline if it failed to link up quickly with the railroad network of the East. Without a rail bridge, the city's real challenge would be survival and not supremacy over Chicago. The urban-rivalry narrative also obscures the immediate enemy of any bridge in St. Louis, the Wiggins Ferry Company. Founded in 1819, Wiggins owned much of the Illinois shorefront opposite St. Louis, and Illinois statutes gave it a monopoly on ferry services into the city.[22] Most railroads from the East

---

and Scott detail the metallurgy of Eads's steel bridge; Kouwenhoven delineates Eads's central role in its design; and Jackson focuses on the financing that propelled the project.

19. John M. Barry, *Rising Tide*, chaps. 4–5; David P. Billington, *The Innovators*, chap. 8; Arthur E. Morgan, *Dams and Other Disasters*, chap. 5; Nye, *American Technological Sublime*; Henry Petroski, *Engineers of Dreams*, chap. 2.

20. Woodward, *A History of the St. Louis Bridge*, 14–15, 19. Eads ensured that the publishers of three leading St. Louis dailies held stock in his company, thus guaranteeing a friendly local press, as Jackson astutely notes in *Rails across the Mississippi*, 36.

21. Miller and Scott believe that the Chicago threat compelled the people of St. Louis to push for a rail bridge during the winter of 1866–67. For Billington, the story of Eads and his bridge fits inside a chapter on "St. Louis versus Chicago and the Continental Railroads." Barry also casts the bridge as an outgrowth of this rivalry between the two cities. See Miller and Scott, *The Eads Bridge*, 79; Billington, *The Innovators*, 143; and Barry, *Rising Tide*, 56.

22. Jackson, *Rails across the Mississippi*, 8–10. To clarify the point, Illinois law gave

terminated in East St. Louis (Illinois), and transshipped their cargos via Wiggins's ferries into St. Louis (Missouri). These contracts armed Wiggins to fight any bridge, yet few authors have given it serious attention. Jackson alone offers a clear-eyed assessment of this powerful opponent.[23]

By the winter of 1866–67, business, political, and press leaders of St. Louis had bridge fever, as did the public, which resented the ferry monopoly throughout most of the year, then cursed the ice that blocked the ferries and isolated the city during hard winters. In the conventional accounts, a villain enters the story here, Lucius Boomer, a Chicagoan, as all authors reliably note. That winter, Boomer sought to secure a new charter in Illinois for a bridge-financing company that had originally formed in 1864 to build a crossing at St. Louis.[24] Effectively Boomer had muscled into that project, a fact that later authors interpret darkly. According to Kouwenhoven, rumors spread in St. Louis that Boomer's group was "about to sell out to people who did not want a bridge to be built." For Miller and Scott, "[i]t was never clear whether Boomer's real intent was to build a bridge or to prevent one."[25] Both Miller and Scott and Jackson go back to an 1855 incident when a new wooden-truss bridge, designed and built by Boomer's bridge-building firm, collapsed into the Gasconade River, killing forty-three business and political leaders, injuring many more, and shattering Missouri's hopes for its railroad to the Pacific.[26] The conventional narratives portray Boomer as venal and incompetent—a dramatic foil for the

---

the Wiggins company a monopoly on ferry services for St. Clair County, which, thanks to its location just opposite St. Louis, amounted to a near-monopoly on trans-river commerce there. East St. Louis was then a town inside St. Clair County. See Agnes Wallace, "The Wiggins Ferry Monopoly."

23. Woodward covers the ferry company in a single paragraph, as do Miller and Scott; see, respectively, *A History of the St. Louis Bridge*, 12; and *The Eads Bridge*, 77. Kouwenhoven, Billington, and Barry ignore Wiggins entirely, even as they play up Chicago's presumed antipathy. Jackson, *Rails across the Mississippi*, 7–9.

24. Two kinds of bridge companies figure in this article: a *bridge-financing company* secured charters, raised funds, contracted with others to build (and sometimes design) a bridge, contracted with railroads to run across it, charged tolls to pedestrians and others, maintained the span, and paid dividends to its stockholders (assuming that there were any profits). A *bridge-building company* might design such crossings as well, but it always made the superstructure components (and often the foundations and piers) and erected the bridge. Boomer headed a Chicago bridge-building firm, and he became an officer in a bridge-financing corporation that sought to build and operate the crossing at St. Louis.

25. Kouwenhoven, "The Designing of the Eads Bridge," 548; Miller and Scott, *The Eads Bridge*, 80. The best early source on these events, Woodward, had no doubt that the Boomer/Post project was an "entirely sincere" effort to build a St. Louis crossing (*A History of the St. Louis Bridge*, 19). By 2001, however, a publication of the National Park Service claimed that "Boomer had no intention of actually building a bridge. He just wanted to prevent anyone else from doing so, in order to assure St. Louis' demise"; see National Park Service, "James B. Eads and His Amazing Bridge," 2.

26. Jackson, *Rails across the Mississippi*, 19; Miller and Scott, *The Eads Bridge*, 81.

great Eads. Yet these accounts overlook notable facts. For example, by 1872 Boomer's American Bridge Company was the largest and most successful bridge-building firm in North America.[27] By 1876 that company had successfully bridged the Mississippi at seven places, while also constructing four crossings over the Missouri River.[28] All of these were rail bridges of considerable length, cost, and difficulty, facts suggesting that Boomer should be taken seriously.

Most histories of the Eads Bridge end soon after its completion. Woodward closes with the opening celebration in July 1874. Miller and Scott summarize a century of operational history in a single paragraph, asserting that "[t]he bridge never lived up to Eads's expectations. It did not generate anticipated tolls, nor did it revitalize the St. Louis economy." Jackson hails the bridge's aesthetic, but argues that "in economic terms, it never really worked very well."[29] All stories need an ending, but why this downbeat note? These authors appear flummoxed by the fact that Eads's bridge-financing company defaulted within a year of its opening. And these endings offer an anticlimax for the heroic trajectory of one narrative framework, as his bridge scarcely dented Chicago's preeminence over St. Louis.

These conventional narratives hold few surprises. The rivalry of Chicago and St. Louis frames every account of rail bridges across the Mississippi.[30] Casting Boomer as a dark conspirator builds up Eads as a savior of his city. Biographers cannot help but laud the star quality of Eads's innovative design and its pleasing aesthetics; a great man must have built a great bridge.[31] However, these narrative devices confirm assumptions rather than explaining the history. In particular, none of these accounts critically examines Eads's design choices.

27. "American Bridge Company," 288.

28. The best source for long-span bridges on the Mississippi and Missouri rivers during this era is Gouverneur K. Warren, *Report on Bridging the Mississippi River*, which also describes (167–83) the work of the 1867 engineering board that evaluated Boomer's proposed St. Louis crossing.

29. Miller and Scott, *The Eads Bridge*, 131 (see p. 134 for the bridge's operational history); Jackson, *Rails across the Mississippi*, 222–23.

30. The first rail bridge over the Mississippi, at Rock Island, Illinois (1856), exemplifies that contest in the historiography, with steamboat men versus rail advocates, a dramatic collision and fire sparked by a steamer, and a courtroom denouement featuring Abraham Lincoln. Boomer designed that "ill-fated and badly designed drawbridge," as Kouwenhoven could not fail to mention in "The Designing of the Eads Bridge," 542–43.

31. "Great man" history casts a long shadow across the St. Louis Bridge, known for over a century as the Eads Bridge. Unfortunately, this article may reinforce this distortion by referring to Eads's venture and to Boomer's company, names I use to avoid confusion. The proper name of the bridge-financing company in which Boomer played a leading role was the "Illinois and St. Louis Bridge Company," while the firm that Eads dominated in 1867 was the "St. Louis and Illinois Bridge Company."

Two Designs Compared

Eads unveiled his bridge plans in September 1867. Although the design's details later evolved considerably, its major elements were entirely Eads's conception and dated to that first version: three 500-foot-long shallow arches, with the main structural members in steel; a roadway deck carried above a dual-track railway; the weight of the arches, decks, and loads borne by two stone piers in the river. The design remains unique in North America.[32] Yet we can compare it against some enlightening contemporary benchmarks.

Comparing the Eads design to the plans of Boomer and Post takes us back to the choices confronting the civic leaders of St. Louis in September 1867, when the city had two well-sketched options on view. Each venture aimed its pitch particularly at the politicians, railroad managers, and potential investors needed to transform design into reality. And each design was more or less incomplete at that moment, with some matters undecided and others unknowable. The unknowns also deserve comparison.

Lucius Boomer was a busy man in 1867, working on deals for rail bridges on the Mississippi and Missouri rivers, while his firm supplied the Union Pacific Railroad with the spans (mostly wooden) to traverse countless rivers in its dash to the Rockies.[33] The St. Louis job was special, however, because success in this leading midwestern city would trumpet the talents of his company. Boomer collaborated with Simeon Post, a civil engineer who, in 1863, patented a "diagonal truss" for iron bridges. By 1871, Boomer's American Bridge Company would use Post trusses in three rail bridges over the Mississippi: at Hastings, Minnesota; Winona, Wisconsin; and Clinton, Illinois.

Environmental realities and legal requirements made the St. Louis crossing particularly challenging. The other rail crossings on the Mississippi were low bridges, with draw spans (a span that turned on a central pivot) to let river traffic pass. The 1866 federal law authorizing these interstate structures prohibited a drawbridge at St. Louis as an intolerable burden to steamboat traffic at that busy inland port. Instead, Congress required a fixed high bridge with at least fifty feet of vertical clearance for the unimpeded passage of shipping. Furthermore, the law required any St. Louis crossing to have at least two spans with clear openings of 350 feet between the piers, or a single span giving a 500-foot clearance.[34] Even the shorter mandate was challenging. At that time, the longest truss bridge in

32. Woodward's *A History of the St. Louis Bridge* provides a reliable engineering record, and this article uses it for design details.

33. Maury Klein, *Union Pacific*, 81, 138.

34. The Omnibus Bridge Bill of July 25, 1866, established these requirements for St. Louis within a larger authorization for eight bridges over the Mississippi as well as one Missouri River crossing at Kansas City. For the act, see Warren, *Report on Bridging the Mississippi River*, 197.

the country—the Steubenville, Ohio, crossing of the Ohio River—had a channel span of 320 feet. A few suspension bridges had longer spans, but Charles Ellet Jr.'s Wheeling Bridge in what is now West Virginia had collapsed in a severe storm, while John Roebling's Niagara Bridge undulated with every passing train—an experience that worried passengers, if not Roebling himself. For these reasons, Congress banned a suspension crossing at St. Louis, reflecting the common view among civil engineers that only truss bridges could safely bear the heavy dynamic loads that railroad trains imposed on long-span bridges.

Beyond the statutory requirements, the designers faced some environmental challenges: of the eight Mississippi River bridges authorized by Congress in 1866, the St. Louis crossing was the only one south of the confluence with the Missouri River. Although the site did not require a notably long bridge, the combined flow of the Mississippi and Missouri here resulted in faster currents, increased scouring of the sandy river bottom, greater variations in high and low water, and serious problems with winter ice floes.

Facing these constraints, Boomer and Post collaborated on a design for St. Louis that differed markedly from Eads's. Because Eads believed that strong currents and the associated scouring of the riverbed posed the main design challenges, he placed only two piers in the river, a choice that, in turn, required 500-foot spans to connect piers and abutments. For Boomer and Post, the main challenge was the required length of spans; they had less concern about currents or constructing secure piers. The Boomer/Post design called for:

- a span of 264 feet from downtown St. Louis to a pier on the St. Louis levee;
- two spans, each 368 feet long, to provide the required clearances for river traffic;
- four spans, each 264 feet long, to reach Bloody Island near the Illinois shore; and
- a span of 160 feet to the levee in East St. Louis, where an embankment would then lower the grade to the streets and railroads of that city.

This design put five piers into the river's flow, and two on the levees. Although the eight spans had varied lengths, they used identical components wherever possible[35] (fig. 2).

For each span, four parallel Post trusses supported a single deck. Along

35. *Proceedings and Report of the Board of Civil Engineers Convened at St. Louis*, 49, 82–83. All the spans would use the same elements for floor beams, top braces, and sidewalks. The two channel (longest) spans had a design height of 48 feet while the five 264-foot spans had a height of roughly 32 feet, and the 160-foot span was to be 22 feet high (estimate). Once built, these varied heights and lengths could only result in a cobbled, ungainly appearance.

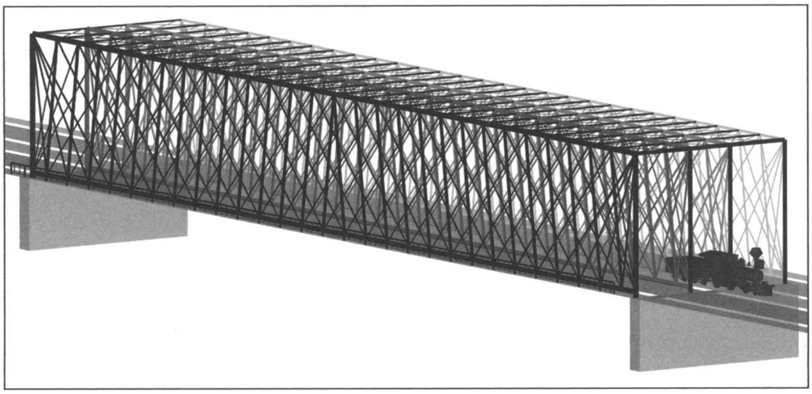

FIG. 2 This modern CAD drawing shows one of the two main channel spans (each 368 feet long) for the Boomer/Post bridge, with its unique configuration of four parallel trusses. Note the central right of way for trains and the two flanking roadways, with sidewalks outside of the trusses. For these longest spans Boomer and Post proposed a depth of forty-eight feet (the distance from the top chord, or beam, to the bottom chord), well beyond the norm for truss bridges of the day. Omitted from the drawing (for clarity's sake) are the wooden screens along the two central trusses, designed to prevent horses on the roadways from panicking when steam locomotives passed by. (Source: Drawing by Richard K. Anderson; author's collection.)

its centerline, a right of way with four rails accommodated the three gauges used by railroads converging on St. Louis; a Post truss flanked each side of the railway.[36] Outside of these trusses were two-lane roadways for horses and wagons, with inlaid tracks for horse-drawn street railway cars. The design placed another Post truss outside of the roadways on each side, with sidewalks outside of those trusses. In all, the deck width was seventy-five feet. Although the four parallel trusses in each span were unusual, the superstructure otherwise mirrored common practice in using standard iron truss forms.[37]

By contrast, Eads's superstructure was far more ambitious. He drew an unusual two-deck bridge, with a broad roadway above a railway deck with two standard-gauge railway lines. The fifty-foot-wide upper deck accommodated four lanes of traffic, with a street railway sharing that space, plus two sidewalks. The dual-track railway deck below provided double the service that Boomer and Post proposed. Eads planned to carry these decks and loads with shallow steel arches thoroughly braced together with exten-

36. To clarify this point: the single right of way could accommodate only one train at a time, but its four rails allowed trains of different gauges to cross.

37. In addition to the *Proceedings and Report of the Board of Civil Engineers Convened at St. Louis*, the Boomer/Post bridge is described and illustrated in "Bridge over the Mississippi River at St. Louis" and "Proposed Bridge across the Mississippi at St. Louis."

sive structural ironwork.[38] In 1867, steel had never been used in any structure in the world. The first U.S. Bessemer works opened in May 1867 to make steel rails. More broadly, iron was just beginning to displace wood as the dominant material for American railway bridges; steel was a radical choice.

Compared to Eads's design, the Boomer/Post proposal offered many advantages and few liabilities.[39] The Post truss was a proven success in long-span bridges for railway traffic, whereas Eads's shallow metal arches were unknown in the United States and rare in Europe. Engineers had confidence in the Post truss because they could easily compute its stresses using trigonometry. Computing the stresses in Eads's design was far more challenging, since each arched span passed axial loads (dead and live) into the piers and/or abutments on which it landed.[40] To model these forces, Eads's engineers employed "the calculus," apparently its first use in a U.S. bridge project.[41] In these calculations, the engineers drew on English tests of the tensile strengths of different steels by William Fairbairn. However, in September 1867 no steel works in the United States or Europe had come close to producing structural steel in the quantity and—more important—the uniform quality that Eads demanded. Its reliance upon iron gave the Boomer/Post design superstructure another practical advantage over Eads's design.[42]

Furthermore, Post's superstructure offered a real benefit to river men. Although Eads's 500-foot spans afforded easier passage for steamboat and

38. Woodward, *A History of the St. Louis Bridge*, 48. Eads drew his design inspiration and some of his engineering subordinates from an 1864 railway bridge built over the Rhine River in Coblenz. Designed for railway service only, its three shallow arches landed on two river piers and used wrought iron for its 317-foot spans.

39. This section compares the two projects as presented in 1867–68. The primary source for the Boomer/Post bridge is the *Proceedings and Report of the Board of Civil Engineers Convened at St. Louis*. For the Eads project we have James B. Eads's "Report to the President and Directors," his first full report (June 1868) as chief engineer. Both sources have similar content, combining engineering descriptions with St. Louis trade statistics, cost estimates, and anticipated revenues. As such, each was a prospectus to potential investors, balancing analysis with marketing and ignoring unknowable or difficult topics. For example, both omit any discussion of how to erect their superstructures.

40. Eads's arches passed both axial (lengthwise) loads into the piers and abutments, as well as vertical loads (downward thrust). Truss bridges did not present the complication of axial loads because each truss was structurally self-sufficient; their loads passed vertically onto the piers, which could be less massive as a result.

41. For calculus in French and British bridge design, see Eda Kranakis, *Constructing a Bridge*; see also Carl Condit, *American Building Art*, 190–93. In "The Designing of the Eads Bridge," Kouwenhoven argues that Eads made all the major design decisions while enjoying a collaborative relationship with his assistant engineers—men experienced in bridge design and construction, including Henry Flad and Charles Pfeifer (German émigrés trained in calculus) and Milnor Roberts and Theodore Cooper.

42. Boomer's board of engineers endorsed limited use of steel (as tension members in the trusses), but the Boomer/Post design did not depend on steel components; see *Proceedings and Report of the Board of Civil Engineers Convened at St. Louis*, 83–84. Eads needed steel to bear the compression loads in his arches.

barge traffic than did Post's design, the latter's spans gave fifty feet of vertical clearance at any point across the river. Eads provided that clearance only beneath the center of his arches, at just three places across the river. With their tall smokestacks, steamboat operators would surely prefer Post's design.

The two projects also demonstrated different design choices in their piers and abutments. U.S. bridge-builders had only begun to grapple with the challenges of securely placing piers for heavy rail bridges in the fast-flowing rivers of the West. Furthermore, the engineers on both projects lacked detailed knowledge on the lay of bedrock beneath the river's sandy bottom—information vitally important to constructing solid piers.[43] Both groups projected confidence, despite this uncertainty. In August 1867, as Boomer's engineering review board opened in St. Louis, Eads started his bridge with excavation work for the western abutment on the St. Louis levee, using a cofferdam to hold back the sand. Shallow bedrock depth there made that method feasible, while the start of construction at the city's figurative front door told every St. Louisian that Eads played to win. At that time, however, Eads had at best an untested plan for foundation work in the river itself. Meanwhile, Boomer's board of civil engineers endorsed iron pneumatic piles for the piers of his proposed bridge.

Three engineers at the meeting, Charles and William McAlpine (father and son respectively) and William Sooy Smith, were the leading U.S. authorities on pneumatic piles.[44] In 1861, the McAlpines used pneumatic foundations for a bridge over the Harlem River in New York City. For this job, the engineers ordered iron tubes six feet in diameter and nine feet long, with a wall thickness of two inches. By bolting the cylinders together (their inside diameters were flanged), they could assemble a piling of any desired length. The bottom section had a chamfered edge, a quarter-inch wide, to cut through sand. Such a piling was placed vertically at the location desired for a bridge pier, then driven into the riverbed by a conventional pile-driver. Atop that piling, the McAlpines placed another cylinder with an integral airlock; then they filled the bottom section with compressed air, and workers descended through the airlock to dig away at the riverbed. Periodically, the men and spoil returned to the surface. During these interludes, the engineers released the pressurized air in the piling, causing its full weight to bear down, and "the rapid inrush of water at the

43. *Proceedings and Report of the Board of Civil Engineers Convened at St. Louis*, 14–15. Early in the preceding winter, engineers employed by the City of St. Louis ventured out onto the frozen river to conduct test borings. Near the western shore, their boring bar hit sand at 23 feet below the low-water mark, and bedrock at a depth of 57 feet. Moving eastward, successive bores reached the sandy riverbed at 16 feet, while the bedrock below progressively deepened to 123 feet. During their last bore, the ice began to break up and the engineers had to flee, but the trend line suggested that the rock under the East St. Louis shore lay even deeper.

44. *A Biographical Dictionary of American Civil Engineers*, 85, 107.

bottom cause[d] a complete scouring of the material at and under the sharp rim of the column."[45] Such an air release could sink a piling twelve feet nearly instantaneously. As it descended, the engineers bolted additional cylinders to the top; upon reaching its desired depth the piling was filled with concrete. Two such pilings, braced together, formed each pier of a bridge. Because they supported the simple loadings imposed by trusses, such piers were far less massive than those that Eads needed, while the pneumatic method would sink them quickly.

Boomer's engineering board endorsed this method while leaving final decisions on some key points for determination in the field. Crucially, the board did not decide if all the pilings had to descend to the bedrock. Typically, engineers using pilings relied primarily upon friction along their length to prevent settling. The board agreed that the depth and power of scouring river currents would decide that question.[46] Nonetheless, it decided that iron pneumatic piles would provide a quick, economic, and safe method to build secure piers at St. Louis.

In September 1867, Eads could make no such claim for his own foundations. Nine months later, his first formal report as chief engineer proposed a complicated makeshift of cofferdams and caissons to place his piers on bedrock.[47] In April 1869, he would abandon those plans. Eads was caught in a bind between ends and means. His entire design originated with his view that the Mississippi currents posed the main challenge, and this belief directed all his other design choices. Massive stone piers placed on bedrock would resist the current. He could use just two river piers (versus the five in the Boomer/Post design) if he employed long spans. In turn, that choice led Eads to specify steel arches rather than iron trusses. Because the arches also exert an axial or thrust load (along their length), not just a vertical load (downward, onto their piers, as with trusses), Eads needed much larger piers than did Boomer and Post. When built their mass would become a virtue (by resisting current and scour), but devising construction methods was challenging. In September 1867, Eads and his team lacked full confidence in their own proposed method to build the piers, although their reservations remained hidden.

As presented in 1867–68, the two projects showed markedly different engineering choices. The Boomer/Post project reflected the state of the art, while Eads's design ventured repeatedly into unknowns. The basic capacities needed to build Eads's bridge simply did not exist in the United States. Moreover, the design he unveiled probably would have failed if attempted.[48]

45. *Proceedings and Report of the Board of Civil Engineers Convened at St. Louis*, 27.

46. Ibid., 81. The board envisioned that pilings to carry the heavy, 368-foot channel spans would all go down to the bedrock. From 1866 to 1878 thirteen bridges were built over the Mississippi between St. Paul and St. Louis; in only four did the builders carry all their piers down to the bedrock. See Warren, *Report on Bridging the Mississippi River*.

47. Eads, "Report to the President and Directors," 501–4.

48. From 1867 to 1870, Eads and his engineers nearly continuously altered the spec-

Beyond engineering differences, the two companies offered dramatically divergent cost estimates. In August 1867, Boomer's engineering board pegged an estimate of $6,564,000 for his bridge's foundations, superstructure, and approaches. Ten months later, Eads estimated that $4,878,000 would be needed for his bridge, its approaches, and the land beneath them.[49] If venture capitalists reviewed these numbers, Eads's estimate appeared enticing. Skeptics, however, might question how he proposed to build a double-track, double-deck bridge, using a novel material, at a price $1.6 million less than the more conventional Boomer/Post design.

With respect to legal powers and personnel, Boomer again held key advantages. His bridge-financing company had corporate charters from Illinois and Missouri, with Missouri granting the exclusive right to build a bridge at St. Louis. Moreover, the company had somehow secured a real prize: a right of way across land in East St. Louis owned by Wiggins Ferry.[50] Its chief engineer, Anda Anderson, had been superintendent of the U.S. military railroads during the Civil War, effectively the largest railroad in the country in 1865, and its president (from November 1867) was Daniel Garrison, a major figure in railroads radiating out of St. Louis to the east, west, and southwest.

Eads's interest in a St. Louis bridge had begun a year after Boomer's start, and he moved quickly to build strengths. By the summer of 1867, his engineers were committing plans to paper, and his bridge-financing company counted impressive names among its directors, including Tom Scott, who was vice president of the Pennsylvania Railroad, America's leading carrier. Eads made a bold play by starting excavations for his west abutment just as Boomer's engineering board convened in the city. The gambit reflected his ties to the political leadership of St. Louis, stewards of this city property. But the excavations proved difficult; for six months all Eads could show for the effort was a hole in the ground. Even as he projected towering confidence, the facts on the ground, in the law, and in engineering and technology stacked up against him.[51]

Overall, of the two firms' engineering, organizational, and legal capacities, Boomer had clear advantages. By the winter of 1867–68, his project was the rational choice, while Eads offered innovations piled onto risks

ifications for the arches, greatly increasing the quantity of steel in the bridge and modifying the spacing and dimensions of the steel chords in each arch. This extensive and expensive redesigning suggests some doubts about their original approach. Some of these changes are summarized in Miller and Scott, *The Eads Bridge*, 96. That Eads's 1867 design had basic flaws is not simply hindsight. In June 1867, Jacob Linville, a leading U.S. bridge designer, found the plans "entirely unsafe and impracticable" (qtd. in Woodward, *A History of the St. Louis Bridge*, 16).

49. *Proceedings and Report of the Board of Civil Engineers Convened at St. Louis*, 85; Eads, "Report to the President and Directors," 537.

50. Woodward, *A History of the St. Louis Bridge*, 12–28.

51. Ibid., 13, 15–16, 22, 25.

and unknowns. Why did the two ventures differ so radically? Petroski, the leading historian of U.S. bridge-building, notes that civil engineers of this period knew exactly where the great bridges were needed, long before the capital and organizations followed to build them.[52] Even as St. Louis debated the plans of Boomer and Eads, Roebling presented a hybrid suspension/truss design for the city. Design was comparatively easy. These professional engineers knew that the next steps to a completed bridge were far more challenging: forming a strong organization; raising capital; securing legal authorizations; and building piers and abutments, the superstructure, and approaches. Given his long experience in business, Boomer knew all this better than did the neophyte Eads. So Boomer offered a design that drew from the proven capacities of his Chicago bridge-building firm—a design that also promised speedy construction, welcomed railroads using three track gauges, and took few chances. Investors had every reason to come forward, until Eads stepped in the way.

Without experience in the bridge business, Eads had less reason to perceive legal, organizational, or capital needs as constraints at all. He would ensure that his firm had the requisite talent; he would obtain the necessary funding. Furthermore, Eads proposed a far more complex project than did Boomer. From the start, Eads envisioned the railway traffic on his paradigm-shattering bridge flowing down into an equally novel double-track tunnel under downtown St. Louis (fig. 3). Running for nearly a mile, this tunnel would debouch at a new union station, open to all lines converging on St. Louis.[53] This breathtaking vision probably helped Eads advance his project with the political leadership of the city.[54] It also helped himself. By late 1867, he and his business associates controlled the North Missouri Railroad.[55] Originating in St. Louis, this railroad aimed to reach Kansas City, with spurs pushing north into Iowa and connecting to the Union Pacific line at Council Bluffs. The railroad's backers sought to create a steam-powered alternative to the Missouri River, thus preserving for St. Louis its traditional hinterland trade. This line's prospect appeared golden once a bridge at St. Louis linked the city to the national rail network.

The complications of Eads's combined bridge, tunnel, and union sta-

52. Petroski, *Engineers of Dreams*, chap. 4.

53. Eads, "Report to the President and Directors," 485. Eads did not include cost estimates for the tunnel or station in his 1868 total for the bridge, discussed earlier. For the next four years, his company equivocated on how to finance and build those structures.

54. The city fathers could appreciate that Eads kept railway trains off of downtown streets, unlike the Boomer plan, which promised major disruptions to the business district (see *Proceedings and Report of the Board of Civil Engineers Convened at St. Louis*, 83). On the other hand, skeptics could fear actual loss of breath, even of life for passengers inside a 5,000-foot tunnel choked with locomotive smoke and steam.

55. Letter, James B. Eads to Gustavus Fox, 8 June 1867, in Gustavus Vasa Fox Collection, MS 439.17, New-York Historical Society; "St. Louis and the North Missouri Railroad." Both sources in Kouwenhoven Research Archive.

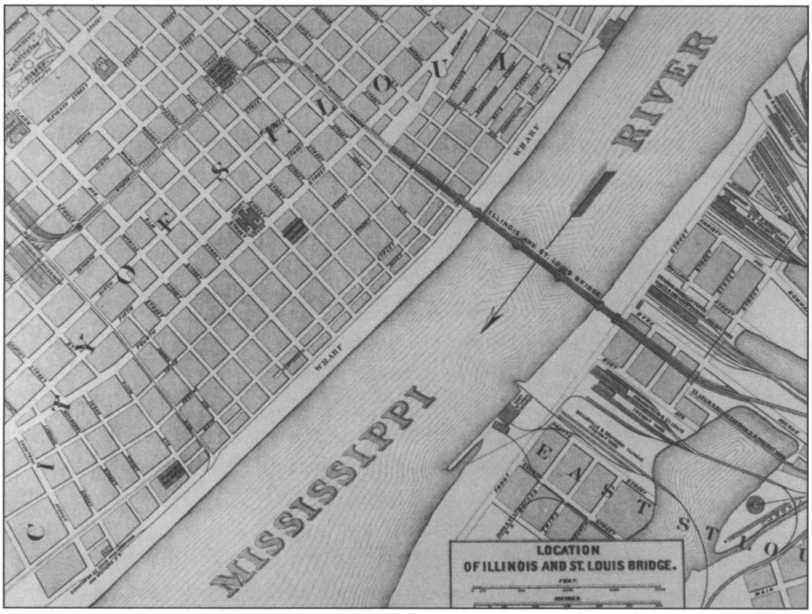

FIG. 3 Eads planned that trains arriving from the east would cross his bridge, descend below ground level, pass into a new tunnel beneath Washington Street (the commercial center of the city), then head south for a run of ten city blocks. After another turn to the west, passenger trains would arrive at a new union station (at the left edge of this image), with passenger service for all St. Louis carriers. He envisioned that freight terminals and yards would largely remain in East St. Louis, Illinois. (Source: Calvin M. Woodward, *A History of the St. Louis Bridge* [1881], plate X.)

tion made the project even more challenging.[56] If the city authorities of St. Louis had guided this process—soliciting proposals, reviewing their content, then selecting a finalist—it seems unlikely that Eads would have won. But U.S. cities themselves would not take the lead in shaping their own infrastructures until the Progressive Era. During the Gilded Age, these large bridge projects had to elicit private funds, making access to capital the real trump card. Eads would push past Boomer and through innumerable contingencies and challenges largely because he structured the venture to enlist self-interested allies and their capital over the next seven years.

During the winter of 1867–68, the two companies fought for public

56. Readers of Alfred Chandler and Thomas Hughes may perceive only advantages when individual railways became coordinated systems, but hindsight can deceive. While Eads saw benefits in systemic ties, railway officers of 1867 were skeptical, seeing other lines as competitors, not partners. Even while Eads espoused comity in town, his North Missouri Railroad sought territory to the west claimed by other St. Louis–based carriers, including the Pacific of Missouri (later absorbed into the Missouri Pacific), whose officers had allied with Boomer's bridge.

support, financial backing, and legal advantage in state courts and the U.S. Congress. By February 1868, the warring parties negotiated a truce, as neither could raise the necessary capital while the other remained alive. The two firms merged in March 1868.[57] Nothing in the merger terms specified the winner, although Boomer chose to withdraw. Perhaps Boomer and his colleagues still hoped to build their St. Louis bridge after Eads tripped over one of the many difficulties that clearly lay ahead. But in July 1868, Eads secured passage of a law in Congress requiring that any St. Louis bridge have a clear span of 500 feet. The statute convinced potential investors that Boomer's bridge was dead.[58] However, Eads had not won yet, as his project still faced towering challenges. Any failure would likely bring Boomer's bridge back to life, even if Congress had to repeal its 500-foot statute. Still, that gambit suggests Eads prevailed over Boomer partly through utter self-assurance.

Other personal issues shaped this outcome. Eads bested Boomer partly because he had so much at stake on winning. His design was a personal matter, and he sought to profit from an array of related investments, ranging from St. Louis real estate to the North Missouri Railroad. On the other hand, Boomer stepped away from the contest knowing that profitable bridge-building projects beckoned elsewhere on the Missouri and the Mississippi rivers—deals without well-connected opponents. Moreover, Eads had only secured the right to try. At that moment, Boomer had every reason to expect that his opponent would fail.

The turning points in constructing the Eads Bridge over the next five years offer further insights into why Eads succeeded against Boomer in many aspects of his design, although not all. For over a year, his engineers struggled to develop a safe and economical method to place the stone piers on bedrock. In April 1869, Eads returned from a European trip advocating a new French method for laying his foundations: using pneumatic caissons. His own engineering subordinates thought the approach was too risky, but Eads pressed ahead. Fourteen workmen died in building the foundations, all victims of the high atmospheric pressure inside the caissons. But they got the job done, and this method became common in U.S. engineering practice, although it was neither easy nor safe. In choosing to pioneer in caissons, Eads demonstrated again his fearless bent for innovating (fig. 4).

This same quality had led him to specify steel arches—a design choice requiring organizational strength to succeed. Lacking much formal education himself, Eads hired émigré engineering subordinates whose training

57. Woodward, *A History of the St. Louis Bridge*, 29.

58. The bill's sponsor, U.S. Representative William Pile of St. Louis, said on the House floor that "this bill is simply for the purpose of aiding this company in the money market" (*Congressional Globe*, 2974). After the two ventures merged, Eads took few ideas, plans, or personnel from Boomer's company; see Woodward, *A History of the St. Louis Bridge*, chap. 4.

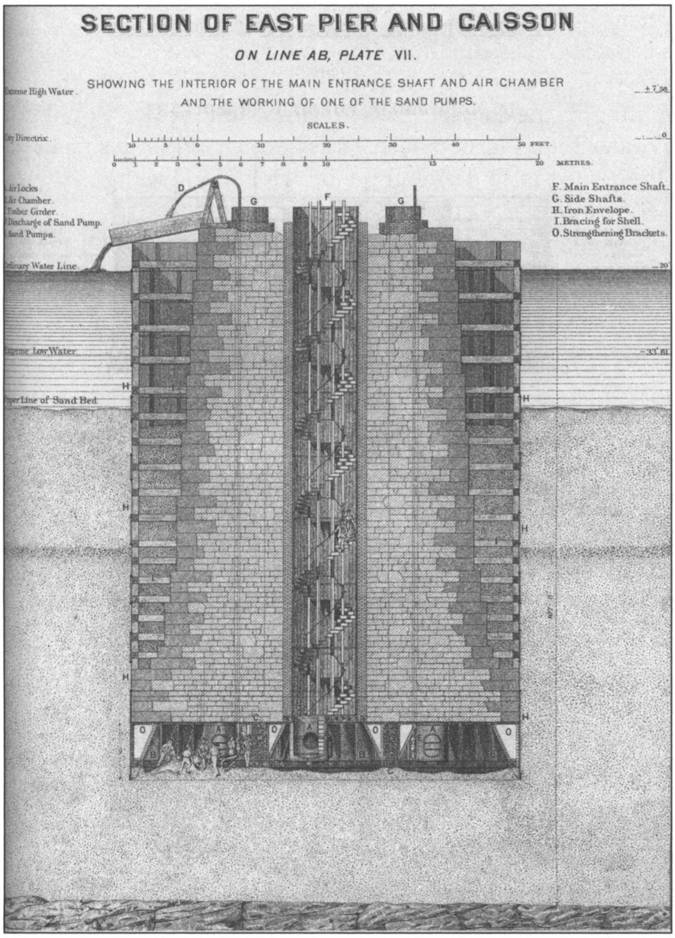

FIG. 4 A pneumatic caisson was a huge inverted box, open on its bottom side, with the dimensions of its top face equal to the footprint of the masonry pier—here, a hexagon measuring 55 by 75 feet. Constructed of heavy oak and reinforced in iron, the caisson was anchored securely in the river at the exact location desired for the pier. Masons then laid their cut stone on what amounted to a giant barge. With each new course of stone, the caisson progressively submerged into the river. The masons also installed an iron staircase and an airlock in the center of the masonry so that workers could eventually access the interior of the caisson. Once it reached the sand riverbed, they did just that. Working inside the pressurized caisson, they shoveled sand into ejectors while the masons continued their work laying stone courses on top of the pier, the added weight also forcing the caisson down. It would eventually land on bedrock—that is, if all went well—at which point the oak box was filled with concrete and permanently sealed. Here, the caisson for the east pier is still twenty feet from the bedrock. (Source: Calvin M. Woodward, *A History of the St. Louis Bridge* [1881], plate XIII.)

in Germany included mastery of calculus, which was essential in designing arches capable of handling the warring stresses and loads inherent in his design.[59] At the time, most U.S. engineers scorned higher math, as few had any training in the subject. Many of these authorities would condemn Eads's bridge both for the unusual stresses inherent in his arches and because they failed to understand the design and modeling methods of his engineering team.

In choosing steel, Eads effectively imposed a three-year delay on the project, as empirical steelmakers struggled to meet his specifications.[60] Throughout these difficulties, London investment banker Junius Morgan sustained the project. Before Morgan marketed the bonds, Eads and his associates raised $1.2 million in paid-in equity capital (stock), funds sufficient to build the west abutment and to raise the two piers above the river's surface by the summer of 1870.[61] Morgan then floated three tranches of mortgage bonds—a total of $9 million in debt funding—to finish the bridge.[62] Eads's 1868 cost estimate of $4.9 million had proven far from realistic. Overall, his creativity, organization, and persistence, floated by an ocean of British capital, combined to build the St. Louis Bridge.

To this point, this article has traced the design differences between the two proposals, and it has outlined the key challenges in constructing Eads's bridge. Note, however, that the two ventures shared some key elements. Compared to other bridges on the western rivers, these two proposed crossings were exceptional in accommodating five transport modes: railroads, wheeled private vehicles, mounted riders, pedestrians, and horse-drawn public trolleys.[63] That Eads and Boomer proposed multi-mode bridges that spanned the river at similar locations from East St. Louis into downtown reflected history and power. Those bridges *there* aimed to secure the railroad commerce terminating at East St. Louis while also directly challenging the dominance of Wiggins Ferry in St. Louis. With these similarities and differences in mind, we can now move the counterfactual forward by "building" Boomer's bridge (fig. 5).

59. Every day, the St. Louis Bridge undergoes major stress loadings that arise from variations in the ambient air temperature. Two design choices for the bridge aggravate these movements and stresses: the bracing between the steel arches, and the lack of hinges (or expansion joints) in the arches and in their connections to the piers and abutments. Woodward concedes the problem in *A History of the St. Louis Bridge*, chap. 26; all the accounts cited in footnotes 17–19 ignore the issue.

60. Miller and Scott, *The Eads Bridge*, 120.

61. Woodward, *A History of the St. Louis Bridge*, chap. 6.

62. Ruth Trask, "St. Louis Bridge Company," typescript (n.d.), 26–27, in Kouwenhoven Research Archive.

63. Warren, *Report on Bridging the Mississippi River*, describes the sixteen Mississippi River bridges built by 1878. Only four provided offered both road and rail service, and only two had separate rights of way for each.

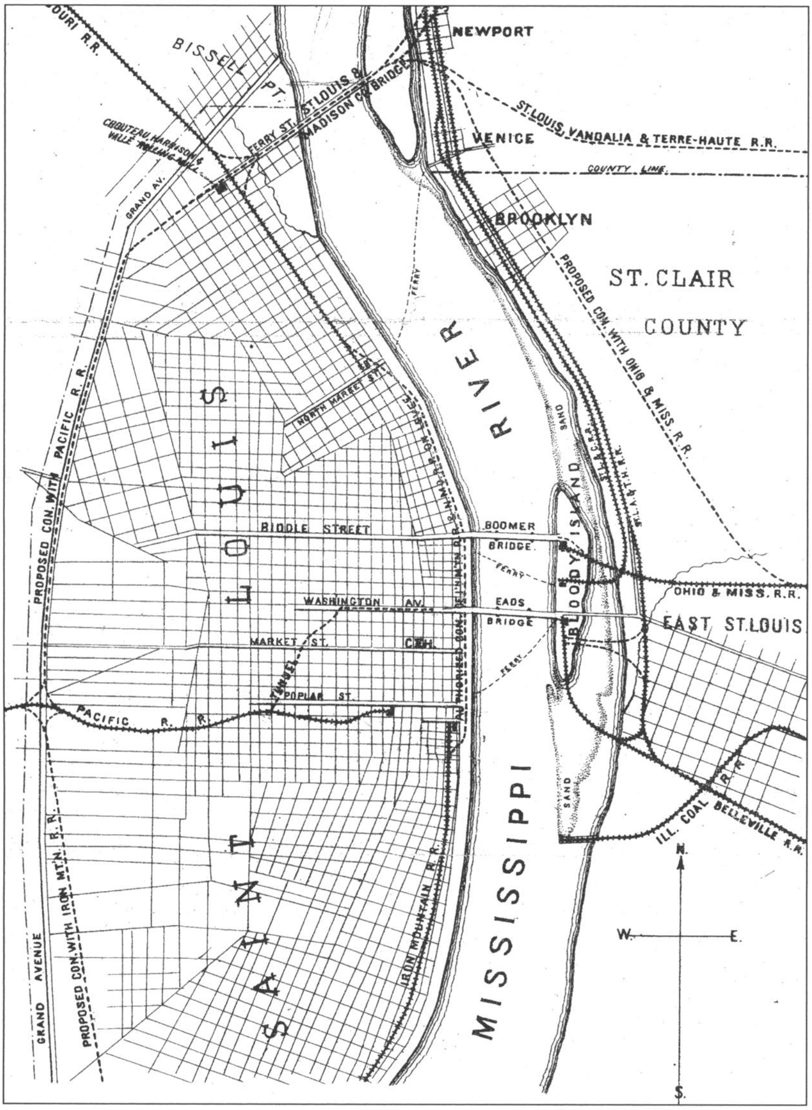

FIG. 5 This detail from an 1868 map shows the locations for both Eads's and Boomer's bridges. Eads proposed just two piers in the river, while Boomer envisioned five piers to support his shorter spans. The location given for Eads's proposed tunnel is somewhat inaccurate. This map was published by a third bridge company promoting another crossing about a mile upstream, which failed to interest investors. (Source: Map detail from a pamphlet titled "Alton & St. Charles County and the St. Louis and Madison County Bridge Companies Consolidated," n.p. [1868], in Kouwenhoven Research Archive.)

The Boomer/Post Bridge: Construction and Service Life through Counterfactual Analysis

How would the construction and operation of Boomer's bridge have played out? And how does that counterfactual history compare to the actual events and consequences surrounding the Eads Bridge? To make Boomer's structure real, we can look to three Missouri River bridges completed in these years: at St. Charles, Missouri; Leavenworth, Kansas; and Omaha, Nebraska. All were major links in the national railway map, especially the Omaha crossing, which provided the transcontinental Union Pacific Railroad with its eastern connection. All were high bridges (fifty-foot clearance) in standard truss forms. All combined cast- and wrought-iron components; none used steel. Their lack of dedicated roadways distinguished them from the St. Louis designs. With Post truss superstructures and iron pneumatic foundations (at Leavenworth and Omaha), these crossings bore close similarities to the Boomer/Post design for St. Louis[64] (fig. 6).

The similarities were no accident because Congress had mandated high spans for these locations to accommodate steamboat traffic, as it had for St. Louis; and the men who headed these projects maintained close professional ties. C. Shaler Smith designed the St. Charles Bridge, and Boomer erected it.[65] Boomer had the full contract for the Omaha Bridge, where Sooy Smith (a member of Boomer's engineering board) oversaw the foundation work, while Post designed the superstructure. Boomer also had the contract to design and build the Leavenworth crossing. Eads and his steel-arch bridge were outliers.

During the construction of their foundations, all of these Missouri River projects encountered problems with river scour: the fast currents shifted the sandy bottom and threatened foundations and piers during construction. The St. Charles project lost a timber caisson in this way. Although pneumatic pilings avoided those problems, they created others. In Omaha, one pneumatic pier took on an angle as it went down, proving very difficult to straighten. Once built, the piers there froze and cracked during cold weather. In Leavenworth, the piers went in well and quickly, but freezing and cracking problems also arose there.[66] Despite this, Sooy Smith's pneumatic piers supported the Leavenworth Bridge until its dem-

64. At St. Charles, each of the three channel spans was 318 feet long; the Leavenworth Bridge had three channel spans of 340 feet each; Omaha had a 300-foot channel span (plus ten spans of 250 feet each). The Leavenworth and Omaha bridges used Post trusses, while St. Charles had Warren and Fink trusses.

65. Just sixteen miles northwest of St. Louis, the St. Charles Bridge provided the North Missouri Railroad with a link to connect with the Union Pacific Railroad at Council Bluffs, Iowa. Eads's leading role in the North Missouri suggests that he had an effective working relationship with Boomer, rather than the enmity imputed in the standard accounts.

66. W. S. Smith, "Pneumatic Foundations."

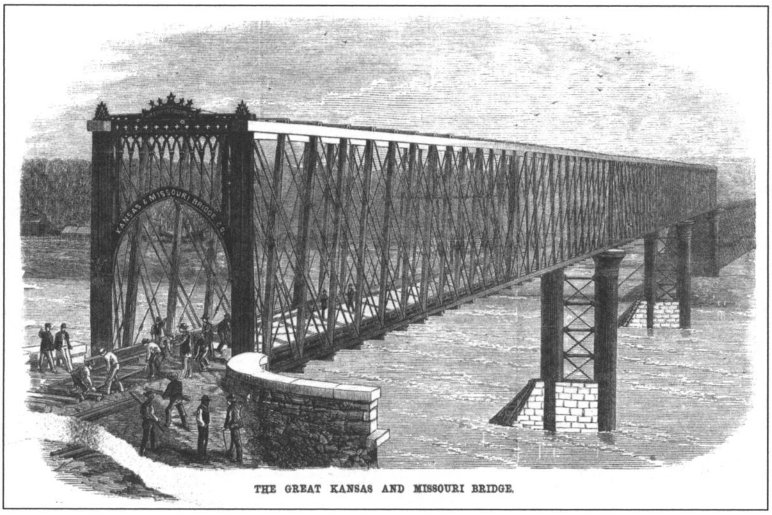

FIG. 6 The Leavenworth Bridge in 1873. Note the Post trusses and pneumatic tube foundations, reinforced with cut stone to protect against strong currents and ice floes. Common roadway traffic used this bridge when trains were not scheduled to cross. For St. Louis, Boomer and Post planned this basic configuration for the piers, but with two additional trusses in each span, allowing a full separation of roadway and rail traffic. (Source: Image, "Bridge over the Missouri River," *Scientific American*, 15 March 1873, 167, reprinted by Bridgehunter.com, available at http://www.bridgehunter.com/ks/leavenworth/fort-leavenworth/ [accessed 1 May 2012].)

olition in the 1950s, withstanding for eight decades the powerful flood currents, scour, and ice floes of the Missouri.

Turning from piers to superstructures, the Missouri bridges carried their planned loads, but the designs lacked resilience. In such bridges, the railway ties were typically laid on or were adjacent to the bottom chords of the trusses. If a train derailed, that accident could bring down the truss.[67] In 1879 and 1881, individual spans of the St. Charles Bridge failed in this way, dropping trains into the river[68] (fig. 7). High winds also threatened these truss superstructures. In 1877, a cyclone blew down two spans of the Omaha Bridge. Such incidents were not unusual in the operational histories of nineteenth-century bridges, partly because these histories were short by design. Like many technologies of the era, metal-truss bridges were gen-

67. Mark Aldrich, *Death Rode the Rails*, 140.

68. In retrospect, these collapses might appear to be prima facie evidence of inadequate design, especially in contrast to the endurance of Eads's bridge. At the time, few engineers or railway presidents would have agreed. As Aldrich notes, many engineers believed that such cases indicated an operational lapse (in the derailment itself), not a design flaw in the bridge (ibid., 149). Furthermore, three earlier derailments had not brought down the St. Charles Bridge; see "The St. Charles Bridge Disaster," 418.

FIG. 7 A lovely spot to picnic and to contemplate mortality. Image of the St. Charles Bridge after a derailment brought down one of its 318-foot-long Warren trusses. It is unclear whether this is the 1879 event when five men died and eighteen cars dropped into the river, or the 1881 collapse that resulted in the loss of thirty-one cattle and freight cars and the death of the locomotive engineer. In each case, the company simply rebuilt and carried on. (Source: "Wabash—First Missouri River Bridge" [photo 2], Bridgehunter.com, available at http://bridgehunter.com/mo/st-charles/first-wabash-rr/ [accessed 2 May 2012].)

erally built to be "good enough." Cash-poor railroads had other pressing uses for their capital, bridge-financing companies desired low initial costs and high returns on investment (a rare event), and bridge-construction companies needed to hold down costs simply to land the contracts.[69] Unlike Eads's creation, nearly every other railway bridge over the Mississippi or Missouri was replaced within decades of completion, as railway loadings outgrew the carrying capacities of the superstructures[70] (fig. 8).

69. This national bias for cheap initial construction is described in Eugene S. Ferguson, "The American-ness of American Technology." He notes that this reflected both the general scarcity of capital in the United States, and the self-fulfilling perception that rapid innovation would quickly render current designs obsolete.

70. The Leavenworth Bridge was a notable exception. Completed in 1872, it carried common road traffic and a single-track line of the Chicago, Rock Island and Pacific Railroad, both in the same right of way. Railway use ended in 1893, as traffic shifted to a stronger bridge nearby. The original Leavenworth crossing remained in service as a wagon, then an automobile, bridge until the early 1950s. Here, iron pneumatic pilings on bedrock proved an economical and long-lived design solution.

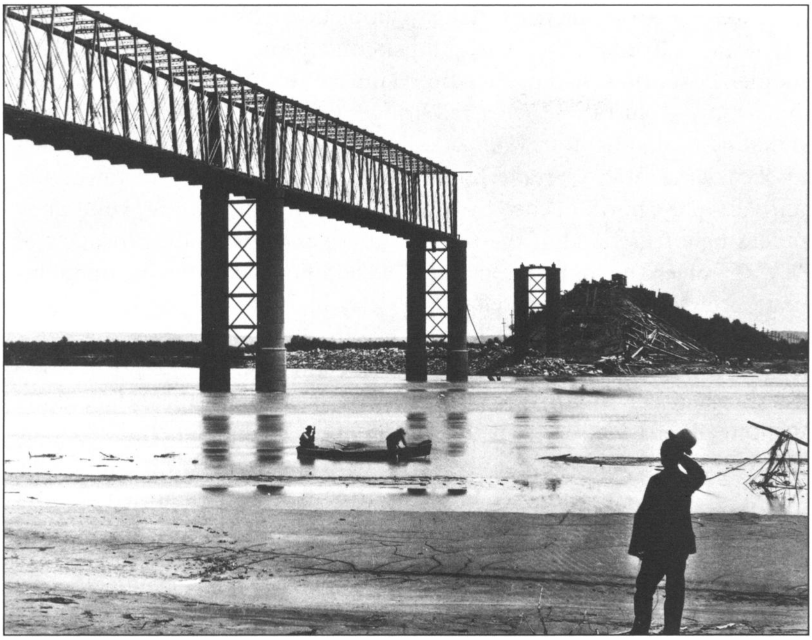

FIG. 8 The Union Pacific Railroad crossing of the Missouri River at Omaha had Post trusses on iron pneumatic piers. The bridge lost two spans to an 1877 tornado. Ferries provided a temporary and unsatisfactory substitute while the railroad replaced its errant spans—in just six weeks. In 1886–87, the Union Pacific built a new double-track Omaha bridge on new masonry piers. By 1916, it put up even stronger spans here to support heavier loadings. (Source: "Union Pacific's First Bridge," image BF14-236, Bostwick-Frohardt Historic Omaha Photo Collection, folio 14, negative 236, Durham Museum, Omaha, Nebraska, available at http://durhammuseum.contentdm.oclc.org/cdm/singleitem/collection/p15426coll1/id/1686/rec/1 [accessed 3 May 2012].)

The record of the Missouri River crossings suggests that the design choices of the Boomer/Post bridge were entirely feasible and justified. Its engineering simplicity would have kept down construction costs, making it attractive to investors, and the bridge would have been completed in about three years. It took seven years to build the Eads Bridge.[71] If completed by 1871, the Boomer/Post bridge would have done better financially than the Eads Bridge, which opened as the nation fell into recession. Beyond immediate profits, Boomer's venture would have carried far less debt, while his company had strong ties to the leading railroads that served the city.

71. Boomer's engineering board assumed completion by January 1871. Design and construction of the St. Charles, Leavenworth, and Omaha bridges required three years on average. All had two trusses in each span (rather than the four trusses in each of Boomer's St. Louis spans), but all were longer than the St. Louis crossings, requiring many more spans and piers.

A difference of four years in their completion dates had serious ramifications for railroads, merchants, shippers, and the people of St. Louis. If the Boomer/Post bridge had opened on 1 January 1871 it would have initially competed with just three other rail bridges over the Mississippi.[72] Thanks to that new crossing, the St. Louis railroads would have garnered a growing slice of the east/west trade, bolstering their finances. Instead, towns and railroads to the north opened their bridges every year, while St. Louis grew increasingly frustrated at the slow progress and uncertain prospects of Eads's gamble. The four-year lag imposed additional costs on anyone shipping, receiving, or buying goods. The delay had especially serious consequences for the managers of St. Louis's railroads, souring them on Eads's project and encouraging them to shift their traffic to crossings north of the city. Every other Mississippi bridge authorized under the 1866 statute (eight in all) entered service before the St. Louis Bridge (fig. 9).

Nonetheless, a rail bridge in service at St. Louis by 1871 would have scarcely affected the city's economic position relative to Chicago. By that year, Chicago had grown decisively larger than St. Louis, thanks to environmental endowments that favored the Illinois hub during the railway age.[73] Even Chicago's great fire of 1871 barely slowed its growth. Given that resilience, it seems unlikely that the Boomer/Post bridge would have retrieved midwestern urban supremacy for St. Louis.

The Missouri crossings suggest that the Boomer/Post bridge could have had a troubled service life, perhaps including problems in its piers, although outright failure seems improbable, despite Eads's concerns about currents.[74] But it might have lost spans in the powerful tornado that struck St. Louis in 1871. Delayed by his problems in securing reliable steel, Eads was still altering his superstructure design when that disaster hit the city. His engineers responded to the cyclone by designing, modeling, and installing a "wind truss" to protect the bridge from such abnormal loads. Here, Eads wrested an advantageous consequence from two problematic contingencies: his troubles with steel, and the tornado. Another devastating cyclone struck St. Louis on 27 May 1896, leveling the stonework of the bridge's eastern approaches and derailing a train nearby, but inflicting minimal damage to the steel arches. This 1896 twister killed 255 people and

72. These completion dates are from various sources, especially Warren's *Report on Bridging the Mississippi River.*

73. William Cronon, *Nature's Metropolis.*

74. Boomer's engineers probably would have modified some design choices during construction (as Eads's team did) after encountering actual conditions in the currents, sandy bottom, and bedrock beneath. If necessary, they could have taken all their iron pilings to bedrock, a straightforward process with pneumatic pilings in sand. And if scouring later proved problematic, they would have protected their piers with breakwaters of rough stone (riprap), a common practice on the river. See Warren, *Report on Bridging the Mississippi River,* 90–93.

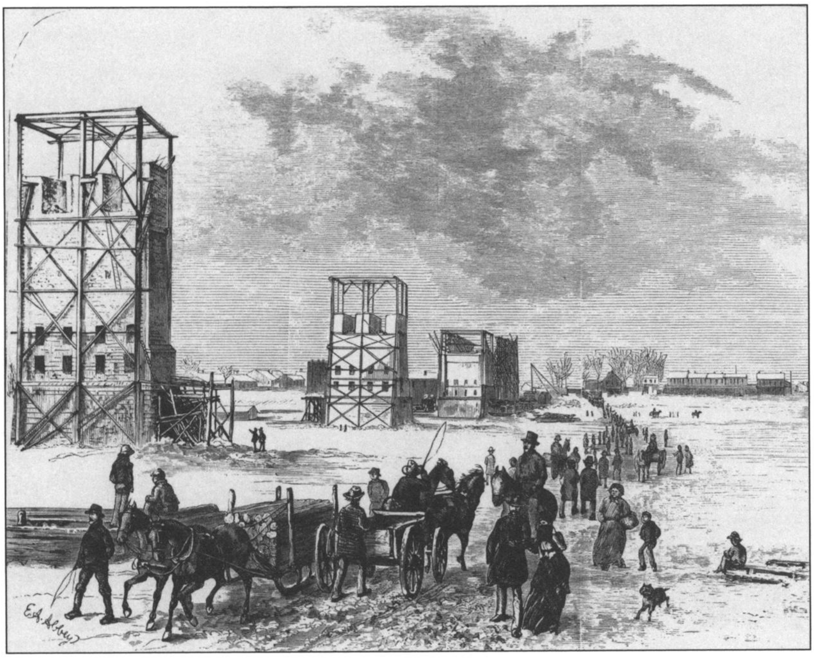

FIG. 9 In December 1872, the river at St. Louis froze hard enough to allow passage of teams and people—a common wintertime event. By this time, Eads and his men had been at work for five years. The piers and abutments all appear solid enough, but utterly useless. Some of these cold people are likely asking if this bridge will ever get built. (Source: Image, "Ice Bridge over the Mississippi at St. Louis," *Harper's Weekly*, 18 January 1873, 52, in Kouwenhoven Research Archive.)

would likely have obliterated at least two spans in the Boomer/Post bridge had it been built and still been in service[75] (fig. 10).

Long before then, though, the Boomer/Post bridge would surely have aroused the ire of river men, as did Eads's bridge.[76] Although legal under

75. The four trusses in each span of the Boomer/Post bridge offered no more strength against wind loadings—quite the reverse, as they presented more surface area to the wind, hence more vulnerability. Worse, the design required wooden screens along the full length of the two inside trusses to prevent horses on the roadways from panicking as trains passed. Unnecessary on Eads's double-deck design, these screens further increased the wind loadings on the counterfactual bridge. St. Louis got its second rail bridge over the Mississippi in 1890. If Boomer had prevailed during 1867–70, the city probably would have had a second rail bridge by the mid-1880s.

76. When Eads's company completed the first arch in September 1873, steamboat operators realized that a long-theoretical problem had become a real obstacle. Their vehement protests resulted in an inquiry by the U.S. Army Corps of Engineers, which found that the bridge impeded navigation (despite its compliance with the 1866 Omnibus Bridge Act). See Woodward, *A History of the St. Louis Bridge*, chap. 23.

FIG. 10 This westward-facing photograph (St. Louis is on the far shore) shows the remnants of the stone arcade that once supported the roadway deck shown at left in figure 1. As depicted here, the 1896 tornado blew off a section of the roadway, tumbling its supporting stonework across the bridge's railway deck. Eads's steel arches remained largely unscathed. (Source: Author's collection.)

the 1866 authorizing act, the Boomer/Post design placed five piers in the river at the heart of this busy inland port. Eads used only two piers. Minimal constraint to navigation was important for steamboats and would prove essential to the growing barge trade. Once Eads established the paradigm of two river piers, subsequent crossings at St. Louis above and below his bridge emulated this choice—a literal case of path dependence.

What to Make of "What If?"

This counterfactual history of the Boomer/Post crossing clearly indicates that there was not "one best way" to move trains, wagons, freight, and people across the river, or to make money doing it. Contingency and personality shaped Boomer's loss and Eads's win; the outcomes owed little to engineering choices. Judging both projects from their initial designs, Eads appears headed toward technical failure, while financial success seems more likely for Boomer. This suggests how headstrong Eads was in insisting on his approach, and in pulling it off. With hindsight directing our vision, Eads seems brilliant. With the Boomer/Post alternative in view, Eads's design appears improbable and risky, although bold.

Stepping away from these two projects, constrained counterfactuals highlight issues that are sometimes ignored or distorted by conventional historical narratives. They remind us that rational calculation alone seldom produces any event, design, product, or outcome, even when historical actors justify their actions as optimal.[77] Eads's success becomes more compelling once untied from a progression narrative and set instead amid the murky currents, unanticipated storms, and uncharted rocks of contingency.

Ultimately, constrained counterfactuals provide new grounds to wrestle with two challenging questions for technological historians: What is success for our subjects? and How do we reckon with it? The first question appears deceptively simple: Is the Eads Bridge a success? Conventional accounts are mostly positive, given the bridge's innovative qualities and long life, even as they struggle with its bankruptcy. But the St. Louis Bridge was sui generis then and now. Conversely, the Boomer/Post bridge represented a widely emulated paradigm for long-span railway bridges of the era. Considered in this light, its design and designers succeeded even though this particular crossing never was built.

Citing long usage as an indicator of "success" is somewhat problematic because this judgment is only possible in retrospect. Historians cannot escape hindsight, yet surely we should temper it by emphasizing the views of contemporaries and including design alternatives in narratives on technological change. "Survivor bias" casts a long shadow across our field.[78] But historians of technology often shy away from the thorny matter of evaluating "success"—a topic that can veer into perilous matters: loose talk about progress, an unreflective slide into determinism, or an uncomfortable shift into judgments.[79] Understanding these dangers, historians nonetheless should offer a detailed reckoning of our technological subjects. And constrained counterfactuals, rooted in time, provide a supple tool to evaluate success in all its complications.

Success was itself a historical phenomenon that evolved with time.[80] The

77. Lamoreaux makes just this point in her "Presidential Address," 650–51. Using counterfactual scenarios, Kirsch's fine study of the early decades of U.S. automobility, *The Electric Vehicle and the Burden of History*, focuses on this important topic of contingency versus rational choice.

78. The studies by Cowan ("How the Refrigerator Got Its Hum"), Kirsch (*The Electric Vehicle and the Burden of History*), and Schatzberg (*Wings of Wood, Wings of Metal*) speak to this problem.

79. Over forty years, historians of technology have developed a succession of analytic frames—including contextualism, the systems approach, social construction, and actor-network theory—focusing on the creation and use of technologies, and giving less attention to their consequences. The field is richer for these developments, yet it also needs nuanced *analytic* insight into how particular technological choices shaped history.

80. In *The Electric Vehicle and the Burden of History*, 201–3, Kirsch makes this point

Boomer/Post bridge would have been great for the St. Louis of 1871. At that moment, Eads's project appeared to be little more than unfinished piers and abutments. Throughout the 1870s, the counterfactual bridge would plausibly have served the city and its people and railroads better than Eads's crossing did. Waiting for serviceable steel delayed its opening until July 1874, miserable timing in light of the Panic of 1873. Less than a year after its debut, this $10 million venture sold at a bankruptcy auction for $2 million, erasing the equity investments of its once-optimistic backers.[81] That Eads succeeded technically should not obscure the high cost of his creation, roughly double that of a conventional crossing like the Boomer/Post bridge.[82]

By the 1880s, the Eads Bridge became increasingly successful both in fact and in comparison to the potential of the Boomer/Post crossing. In 1877, Junius Morgan's U.S. partner, John Pierpont Morgan, traveled to St. Louis to retrieve some value for the English bondholders of the bridge company. He crafted a pooling arrangement with Wiggins Ferry, allowing both companies to divide profits from the commerce of St. Louis rather than fighting over it. As national economic health revived around 1880, so also did the fortunes of the bridge and the region.[83] St. Louis grew much like Chicago did, by using railroads to harvest the agricultural wealth of its large hinterlands in the southeast and southwest of the United States. Gilded Age America had more than one "nature's metropolis."[84] By 1888, an average of 1,390 freight and passenger cars crossed over Eads's arched spans each day.[85] With its single track of mixed gauges, the Boomer/Post bridge would have been entirely inadequate to meet that demand, assuming that it remained in service at all, not obliterated by a tornado or replaced by a larger crossing. Furthermore, it seems implausible that St.

when comparing the evolving capabilities (success) of gas and electric automobiles in 1900 versus 1914.

81. In the end, Eads's bridge cost over $10 million, including finance charges, bonus payments, and other gravy to its backers and suppliers (Jackson, *Rails across the Mississippi*, 217). The tunnel and railway station piled up additional costs. After the bridge opened, Wiggins cut its ferry rates to retain business. The bridge company emulated the cuts but could scarcely afford the discounts, given its huge burdens in debt service. During its first full year in operation, an average of only sixty-four rail cars crossed the bridge every day.

82. Eads's 1868 "Report to the President and Directors" claimed that his arch design was the least expensive design paradigm compared to "every other system of bridging with long spans" (527).

83. By 1883, the reorganized bridge company earned a net annual profit of 9 percent of its gross revenues, a strong performance by contemporary standards; see St. Louis Bridge and Tunnel Railroad, *Annual Report for 1883*, 11.

84. This insight is not surprising, yet it is obscured by a conventional narrative framework in which authors and readers prefer their history to have winners and losers (I refer here to Cronon's *Nature's Metropolis*). Other Midwest urban centers that derived their wealth and growth from the harvest of nature included Kansas City, Omaha, Minneapolis, and the Quad Cities.

85. St. Louis Bridge and Tunnel Railroad, *Annual Report for 1888*, 5.

Louis's railroads and shippers would have generated such high demand for rail services if the city of the 1880s had to rely solely upon the Boomer/Post bridge. Eads's bridge, tunnel, and associated rail lines and terminals helped foster this commerce.[86]

The Eads Bridge also fostered the transformation of greater St. Louis. Throughout the 1880s and '90s, East St. Louis (across the river in Illinois) became a smoky, sprawling precinct of chemical plants, steel mills, tenements, glassworks, and the largest stockyard for horses and mules in the country, all interlaced by rail lines and yards. This grimy town was another engine of regional wealth derived from rail connections.[87] Without its bridge St. Louis would have withered, as did so many other river towns. With it the city prospered. In 1880, St. Louis ranked sixth in population among U.S. urban centers; a decade later it was fifth, and by 1900 it had moved up to the fourth position.[88]

This ending corrects earlier histories of the bridge, yet it aligns with an enduring narrative convention of technological history: namely, the great engineering feat ratified as a popular accomplishment and an engine of economic growth. But events soon departed from this familiar story. By 1889, the reorganized bridge company was part of a network of freight and passenger yards and terminals in the St. Louis region, all owned by the Terminal Railroad Association (TRRA). The association largely achieved Eads's vision of providing unified services for all carriers and customers, but to the press and public the TRRA became a vilified monopoly. St. Louis merchants and manufacturers protested, backing the new Merchants Bridge (1890), built three miles upstream from the Eads crossing. Within three years the TRRA took control of that would-be competitor.[89]

By the last decades of the twentieth century, the Eads Bridge had become a dilapidated white elephant, abandoned by rail traffic in 1974 and by cars and trucks in 1991.[90] Restored today for auto traffic and light-rail pas-

86. A key environmental factor contributed to the success of the St. Louis Bridge: the difficulty of bridging the Mississippi at points south of the city—all the way to the Gulf of Mexico. As late as 1928, only three rail bridges crossed the river south of St. Louis, while ferries for railcars operated at four locations. See *Handy Railroad Maps of the United States.*

87. For an excellent history, see Andrew J. Theising, *Made in USA.*

88. Data given in Campbell Gibson, *Population of the 100 Largest Cities and Other Urban Places in the United States.* Fixated on an imputed rivalry with Chicago, every historian of the Eads Bridge has overlooked its essential role in the hurtling economic growth of St. Louis between 1875 and 1890.

89. Theising, *Made in USA*, 64–65. Wiggins's ferries continued to carry significant freight and passenger traffic into the twentieth century, a fact unnoted by the conventional accounts and unsurprising to any reader of David Edgerton's *The Shock of the Old.* The TRRA finally bought out Wiggins for $5 million in 1902, evidence that its ongoing business (and its riverfront real estate) retained value despite the bridge; see Wallace, "The Wiggins Ferry Monopoly," 18. Ferry service continued until 1930.

90. "Built St. Louis: The Eads Bridge."

senger service, it is a kind of bridge to nowhere, as East St. Louis now epitomizes the country's postindustrial wastelands. Nonetheless, thanks to Eads's talents as a promoter, to his idiosyncratic mix of strengths and inexperience in civil engineering, and to historical contingencies, his bridge still has a role in shaping the ongoing history of the city and region.[91]

It also remains an enduring example of elegant engineering. From the start, Eads sought to create a grand public space on the river. With its utilitarian trusses, the Boomer/Post bridge never aspired to anything more than easy construction and immediate financial return. By contrast, Eads's structural arches supported the public roadway without obstructions. Since 1874, residents and visitors have enjoyed sweeping views of the city and river, views conveying the majesty that the natural environment and his arched spans give each other. Did the design elegance of his original proposal help in edging out the Boomer/Post project? It likely influenced the city's political leadership—an important constituency. Certainly, its bold simplicity and apparent functionalism have won favor from the day it opened. In these respects, Eads's bridge has proven timeless.

Constrained Counterfactuals in the History of Technology

Today, the Boomer/Post bridge is imaginary, but broadening our view to include that once-real alternative promotes understanding of what Eads and his team actually accomplished, allows critical assessment of the results, and highlights the many influences that shaped these outcomes. Crucially, this method encourages us to read history forward, unfolding amid the imperfect information available to its protagonists.[92] Constrained counterfactuals add both analytic force and nuanced understanding of causality to the historian's toolkit. Over the past half-century, historians of technology have developed new analytic frames and perspectives to counter the deterministic thinking and Whiggish susceptibilities common in popular views of technology and society. The constrained counterfactual simply provides another way to recover the complexity of the past. But how applicable is the method?

Certainly, this account grows out of a propitious historical moment: St. Louis's year of bridge fever in 1867, with its rich evidentiary record. Yet this analytic approach is broadly applicable. From the 1880s onward, the "request for proposals" became the primary method by which organizations specified their technological needs to external suppliers. Everything from highway bridges to military aircraft came out of design competitions

91. The bridge and Eads's 1874 tunnel under the city are now lynchpins of a new mass-transit system for the two-state region. Regional planners hope that this system will aid in a larger rebirth. Time will tell.

92. The value (and difficulty) in reading history forward is a key theme in Naomi Lamoreaux, Daniel M. G. Raff, and Peter Temin's "Against Whig History."

where innovators offered distinctive technical solutions in response to general performance and/or cost specifications. Historians of technology often take note of these "also rans," but seldom explore them in depth. Within many organizations, it was (and remains) common for engineers and managers to develop alternative designs for the same product or mechanism. These internal competitions seek a kind of Darwinian selection for new technologies.[93] Because we are not technological Darwinists, however, historians will find value in exploring this process of definition, design alternatives, social-shaping, and selection. For over a century, engineers, firms, investors, and agencies have used such contests to shape technological change, suggesting broad applicability for constrained counterfactuals.

Thorough documentation surely helps in constructing these cases, but the method is applicable to earlier technologies and eras, even to premodern topics. Ultimately, the constrained counterfactual broadens the record under examination to better understand historical choices and the contingencies that shaped them. Therefore it could prove particularly helpful in considering protagonists and choices for which less documentation survives. Lynn White Jr.'s effort to chart the diffusion of the medieval stirrup, for example, was a brilliant exercise in inductive logic, developed from archaeological finds, portrait painting, and telltale shifts in language. Because that record will always remain incomplete, hence conjectural, it seems both reasonable and fruitful to ask if a Charles Martel had or considered any other options to better seat his mounted fighters.[94]

Ultimately, the constrained counterfactual offers a new approach to an old goal: understanding what historical actors actually accomplished. The imaginary Boomer/Post bridge provides an essential benchmark in gauging the real work of Eads. When posed with care, counterfactuals allow a kind of controlled experimentation, as Niall Ferguson and John Lewis Gaddis both suggest.[95] With the Boomer/Post bridge as a guide, we can perceive and then isolate the choices and constraints influencing Eads and his team. We can identify which design decisions seemed debatable (for example, the imputed need for massive stone piers), which were problematic (the choice of steel), which were imaginative (the integrated bridge, tunnel, and terminal), and which were the contingent result of historical accidents, such as the wind truss that contributed to the bridge's longevity.[96] We can isolate why Eads succeeded instead of Boomer. And we can better understand how

93. This internal competition among technical alternatives provides much of the narrative drive in Tracy Kidder's *The Soul of a New Machine*, esp. chap. 6.

94. I cannot claim any answer here, suggesting only that White might have found value in the question; see his *Medieval Technology and Social Change*, chap. 2.

95. Ferguson, ed., *Virtual History*; John Lewis Gaddis, *The Landscape of History*, 100.

96. U.S. bridge-builders turned from iron to steel in the 1890s after the Siemens Martin process made steel available in low-cost structural shapes of reliable quality. Even then, truss forms dominated for railway loadings, not arches. See Henry Grattan Tyrrell, *History of Bridge Engineering*, 171.

that outcome shaped the landscapes of St. Louis. Moreover, this approach takes us back to the moments of indeterminacy: Boomer nearly triumphed, Eads very nearly failed—repeatedly. Contingencies loomed large at the time. Once we read these events as they unfolded, what appears overdetermined are the common narrative frameworks for Eads and his project. Those conventions constrain our understanding and analysis. Including the never-built alternative takes us back in time to see anew.

Bibliography

Archival Sources

Bostwick-Frohardt Historic Omaha Photo Collection, Durham Museum, Omaha, Nebraska

Kouwenhoven Research Archive (in the author's possession)[97]

Published Sources

Aldrich, Mark. *Death Rode the Rails: American Railroad Accidents and Safety, 1828–1965*. Baltimore: Johns Hopkins University Press, 2006.

"Alton & St. Charles County and the St. Louis and Madison County Bridge Companies Consolidated." N.p., n.d. (ca.1868) (Kouwenhoven Research Archive).

"American Bridge Company." *Railroad Gazette* 4 (6 July 1872): 288.

Barry, John M. *Rising Tide: The Great Mississippi Flood of 1927 and How It Changed America*. New York: Simon & Schuster, 1997.

Bijker, Wiebe E. "How Is Technology Made?—That Is the Question!" *Cambridge Journal of Economics* 34, no. 1 (2010): 63–76.

Billington, David P. *The Innovators: The Engineering Pioneers Who Made America Modern*. New York: Wiley, 1996.

A Biographical Dictionary of American Civil Engineers. New York: American Society of Civil Engineers, 1972.

"Bridge over the Mississippi River at St. Louis." *Engineering* (London) 6 (24 July 1868): 75, 82.

"Built St. Louis: The Eads Bridge." Available at http://www.builtstlouis.net/eads01.html (accessed 16 January 2013).

Condit, Carl. *American Building Art: The Nineteenth Century*. New York: Oxford University Press, 1960.

Congressional Globe. 42nd Cong., 2d sess. (9 June 1868).

Corn, Joseph J., and Brian Horrigan. *Yesterday's Tomorrows: Past Visions of the American Future*. Baltimore: Johns Hopkins University Press, 1996.

Cowan, Ruth Schwartz. "How the Refrigerator Got Its Hum." In *The Social*

97. John A. Kouwenhoven (1909–1990) amassed a research archive on the Eads Bridge between 1958 and 1982. His son gave it to the author after Kouwenhoven's death. Every source drawn from that archive to prepare this article is noted below.

Shaping of Technology, edited by Donald MacKenzie and Judy Wajcman, 202–18. Buckingham, UK: Open University Press, 1985.
Cowley, Robert, ed. *The Collected What If? Eminent Historians Imagine What Might Have Been*. New York: G. P. Putnam, 2001.
Cronon, William. *Nature's Metropolis: Chicago and the Great West*. New York: W. W. Norton, 1991.
Eads, James B. "Report to the President and Directors" (June 1868). In *Addresses and Papers of James B. Eads*, edited by Estill McHenry, 481–538. St. Louis: Slawson & Co., 1884 (Kouwenhoven Research Archive).
Edgerton, David. *The Shock of the Old: Technology and Global History since 1900*. New York: Oxford University Press, 2011.
Ferguson, Eugene S. "The American-ness of American Technology." *Technology and Culture* 20, no. 1 (1979): 3–24.
Ferguson, Niall, ed. *Virtual History: Alternatives and Counterfactuals*. New York: Basic Books, 1999.
Fernandez, Ronald. *Excess Profits: The Rise of United Technologies*. Reading, MA: Addison-Wesley, 1983.
Fogel, Robert William. *Railroads and American Economic Growth: Essays in Econometric History*. Baltimore: Johns Hopkins University Press, 1970.
Franklin, H. Bruce. *War Stars: The Superweapon and the American Imagination*. Amherst: University of Massachusetts Press, 2008.
Gaddis, John Lewis. *The Landscape of History: How Historians Map the Past*. New York: Oxford University Press, 2002.
Gibson, Campbell. *Population of the 100 Largest Cities and Other Urban Places in the United States: 1790 to 1990*. Population Division Working Paper no. 27. Population Division, U.S. Bureau of the Census, Washington, D.C. http://www.census.gov/population/www/documentation/twps0027/twps0027.html (accessed 13 April 2012).
Handy Railroad Maps of the United States. New York: Rand McNally, 1928.
"Ice Bridge over the Mississippi at St. Louis." *Harper's Weekly*, 18 January 1873, 52 (Kouwenhoven Research Archive).
Jackson, Robert W. *Rails across the Mississippi: A History of the St. Louis Bridge*. Urbana: University of Illinois Press, 2001.
Kidder, Tracy. *The Soul of a New Machine*. Boston: Little Brown, 1981.
Kirsch, David. *The Electric Vehicle and the Burden of History*. New Brunswick, NJ: Rutgers University Press, 2000.
Klein, Maury. *Union Pacific: The Birth of a Railroad, 1862–1893*. New York: Doubleday, 1987.
Kouwenhoven, John A. "The Designing of the Eads Bridge." *Technology and Culture* 23, no. 4 (1982): 535–68.
Kranakis, Eda. *Constructing a Bridge*. Cambridge, MA: MIT Press, 1997.
Lamoreaux, Naomi. "Presidential Address: Reframing the Past: Thoughts about Business Leadership and Decision Making under Uncertainty." *Enterprise and Society* 2, no. 4 (2001): 632–59.

_____, Daniel M. G. Raff, and Peter Temin. "Against Whig History." *Enterprise and Society* 5, no. 3 (2004): 376–85.

Law, John, and Michel Callon. "Engineering and Sociology in a Military Aircraft Project: A Network Analysis of Technological Change." *Social Problems* 25, no. 3 (1988): 284–97.

Miller, Howard, and Quinta Scott. *The Eads Bridge*. Columbia: University of Missouri Press, 1979.

Morgan, Arthur E. *Dams and Other Disasters: A Century of the Army Corps of Engineers in Civil Works*. Boston: Porter Sargent, 1971.

National Park Service. "James B. Eads and His Amazing Bridge." *The Museum Gazette*, January 2001, 2, available at http://www.nps.gov/jeff/historyculture/upload/eads.pdf (accessed 15 November 2013).

Nye, David E. *American Technological Sublime*. Cambridge, MA: MIT Press, 1994.

Petroski, Henry. *Engineers of Dreams: Great Bridge Builders and the Spanning of America*. New York: Knopf, 1995.

_____. *To Forgive Design: Understanding Failure*. Cambridge, MA: Harvard University Press, 2012.

Proceedings and Report of the Board of Civil Engineers Convened at St. Louis, in August 1867. St. Louis: George Knapp & Co., 1867.

"Proposed Bridge across the Mississippi at St. Louis." *Engineering* (London) 6 (7 August 1868): 116–17.

Rubin, Julius. "Review of *Railroads and American Economic Growth: Essays in Econometric History* by Robert William Fogel." *Technology and Culture* 8, no. 2 (1967): 228–34.

Schatzberg, Eric. *Wings of Wood, Wings of Metal: Culture and Technical Choice in American Airplane Materials*. Princeton, NJ: Princeton University Press, 1999.

Short, Simine. *Locomotive to Aeromotive: Octave Chanute and the Transportation Revolution*. Urbana: University of Illinois Press, 2011.

Sinclair, Bruce. "At the Turn of a Screw: William Sellers, the Franklin Institute, and a Standard American Thread." *Technology and Culture* 10, no. 1 (1969): 20–34.

Smith, W. S. "Pneumatic Foundations." *ASCE Transactions* 2 (1874): 417–26.

"The St. Charles Bridge Disaster." *Engineering News* 9 (27 December 1879): 418.

"St. Louis and the North Missouri Railroad." *The Railroad Gazette* 3 (11 November 1871): 330 (Kouwenhoven Research Archive).

St. Louis Bridge and Tunnel Railroad. *Annual Report for 1883*. St. Louis, 1883.

_____. *Annual Report for 1888*. St. Louis, 1888.

Staudenmaier, John M., S.J. *Technology's Storytellers: Reweaving the Human Fabric*. Cambridge, MA: MIT Press, 1985.

Tetlock, Philip E., Richard Ned Lebow, and Geoffrey Parker, eds. *Unmaking the West: "What-If" Scenarios That Rewrite World History*. Ann Arbor: University of Michigan Press, 2006.

Theising, Andrew J. *Made in USA: East St. Louis—the Rise and Fall of an Industrial River Town*. St. Louis: Virginia Publishing, 2003.

Trask, Ruth. "St. Louis Bridge Company" (financial history typescript, n.d.) (Kouwenhoven Research Archive).

Tyrrell, Henry Grattan. *History of Bridge Engineering*. Chicago: Author, 1911.

Van der Linden, F. Robert. *The Boeing 247: The First Modern Airliner*. Seattle: University of Washington Press, 1991.

Wallace, Agnes. "The Wiggins Ferry Monopoly." *Missouri Historical Review* 42, no. 1 (1947): 1–19.

Warren, Gouverneur K. *Report on Bridging the Mississippi River*. Washington, DC: USGPO, 1878.

White, Lynn, Jr. *Medieval Technology and Social Change*. New York: Oxford University Press, 1962.

White, Richard. *Railroaded: The Transcontinentals and the Making of Modern America*. New York: W. W. Norton, 2011.

Woodward, Calvin M. *A History of the St. Louis Bridge*. St. Louis: G. I. Jones, 1881.

Wrigley, E. A. *Energy and the English Industrial Revolution*. Cambridge: Cambridge University Press, 2010.