Regulating Railroad Innovation

Business, Technology, and Politics in America, 1840–1920

STEVEN W. USSELMAN
Georgia Institute of Technology

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Introduction

innovation (*n*): 1. the introduction of something new; 2. a new idea, method, or device: NOVELTY.

regulate (*vt*): 1. to govern or direct according to rule; 2. to bring order, method, or uniformity to; 3. to fix or adjust the time, amount, degree, or rate of.

– Webster's New Collegiate Dictionary

The subject of this book is, quite literally, a contradiction in terms. Genuine novelty knows no rules. We cannot reduce to routine what we do not yet know. Yet of course we cannot resist trying. For like death and taxes, technical innovation has proven to be an irresistible force in modern affairs. Its pervasive influence, its startling ability to transform lives and upset social norms, ineluctably draws our attention. For most of humanity, the encounter comes as a pragmatic response to concrete realities. For those historians, economists, and others who enjoy the luxury of observing technical change from a distance, the desire to tame innovation assumes a more abstract guise. Like theologians pondering the afterlife, they seek to decipher its mysteries, to identify patterns and governing principles, and thus to impose a measure of order and regularity upon this most beguiling of phenomena.

This book contributes to that effort by evaluating the prolonged attempt by Americans of a century ago to seize control over the most profound technological innovation of their lives: the railroad. The marriage of steam power and iron rail, conceived in Europe during the first quarter of the nineteenth century and mimicked across the Atlantic soon after, presented Americans with challenges and opportunities as profound as those posed by any new technology in their history. Capable of reshaping the contours of nature and dramatically compressing time and space, the railroad possessed enormous

potential to restructure social and economic affairs.[1] Nowhere was this so true as in the United States, with its abundance of land and expansive frontier. In this environment, railroads would not merely alter established patterns of trade and travel and draw people into larger orbits of commerce and culture; they would also give shape to an expanding nation whose course of development remained a matter of intense controversy. This prospect, at once exhilarating and unsettling, was all the more challenging because the new technology taxed the technical and economic capabilities of the young nation like virtually no other. If Americans wished to seize the potential inherent in the railroad innovation, they would have to acquire a broad array of new skills, and they would need to devise new methods of marshaling the economic resources necessary to support the railroad enterprise.

This initial encounter with the basic railroad innovation was no one-time event. In the rapidly expanding and politically decentralized United States, it occurred afresh in different locales under various political jurisdictions across the span of several decades during the mid-nineteenth century. Like a series of explosive charges detonating across the landscape, railroads spurted to life in fits and starts, each jolt shaking the immediate surroundings to their foundations while also sending tremors back through the established network to those places that had previously felt the transforming power of the railroad innovation. Only with the tumult of the Civil War would the rail network emerge on a continental scale and begin to assume the orderly form that Charles E. Perkins, president of the giant Chicago, Burlington and Quincy, aptly likened to a complex machine.[2]

Even after that network took shape, moreover, railroads remained in constant flux. Each component in the railroad ensemble – locomotives, cars, rails, and elements of the physical infrastructure such as bridges and stations – underwent virtually perpetual refinement. Much of this innovative effort, we see below, went toward bulking up the basic system. Cars, locomotives, and rails all increased dramatically in heft. Despite basic constraints on height and width imposed by initial choices of gauge and overpass clearances, the typical freight boxcar grew in capacity from around 30,000 pounds at mid-century to 100,000 by century's end. Rails grew proportionally, as did motive power. This rapid scaling up was no simple matter. Increasing the size of locomotives and rolling stock raised an array of complex

[1] For perceptive treatments of the transforming power of railroads, see Wolfgang Schivelbusch, *The Railway Journey: The Industrialization of Time and Space in the 19th Century* (Berkeley: University of California Press, 1986), and Daniel J. Boorstin, *The Americans: The National Experience* (New York: Random House, 1965) and *The Americans: The Democratic Experience* (New York: Random House, 1973). For a succinct statement regarding their economic significance, see Stanley Lebergott, *The Americans: An Economic Record* (New York: Norton, 1984), pp. 107–112.

[2] C. E. Perkins, "Organization of Railroads," ca. 1885, Papers of the Chicago, Burlington, and Quincy Railroad, Newberry Library, Chicago (hereafter, CBQ Papers), 3P6.36.

technical problems involving matters such as suspension, braking, and heat transfer. Mechanics continually redesigned parts or devised entirely new ones, often making use of new materials such as steel, alloys, and chemical lubricants. Even changing the size of the rail, seemingly the simplest of technologies, proved far from straightforward. For in altering the shape of the rail, railroads sparked a succession of changes in areas such as wheel design and track maintenance procedures. Perhaps more important, they disrupted established procedures among rail manufacturers. Scaling up the basic components of railroading thus involved a broad-based effort among numerous parties whose efforts needed to be integrated and coordinated in novel ways.

Besides steadily pursuing changes in scale, railroads also responded to pressures from various quarters encouraging them to alter the character of their services. Passengers sought to travel at faster speeds in luxurious cars outfitted with the latest amenities and equipped with novel devices promising to protect them from the dangers of transit. Though railroads often balked at introducing such complex novelties into their operations, enterprising innovators such as George Pullman and George Westinghouse forced their hands. Buttressed by strong patent protection and ultimately by legislation pertaining to railroad safety, these men compelled railroads to adopt popular technical novelties derived from unfamiliar technologies. Shippers of commodities such as livestock, dressed meat, fresh fruit, and a growing variety of expensive manufactured goods likewise demanded special services such as fast stock trains, refrigerated transit, and express delivery. Here, too, railroads often resisted. But over time, railroad services grew steadily more diverse and the array of railroad technologies more plentiful.

In addition to pressures generated by shifts in demand for railroad services, impetus for technical innovation came from changes in the supply of key factor inputs into the railroad industry. Born in a world of abundant land and wood and scarce capital, railroading matured in a far different environment. Once the first lines took shape and attracted commercial development, civil engineers and operating personnel faced continual challenges in trying to squeeze more traffic through increasingly congested locales. They accomplished a great deal by altering operating procedures. But in at least some cases, railroads resorted to using novel technologies such as automatic electric signals or electric traction. In choosing such radical alternatives, railroad executives confronted perhaps the most critically important factor input of all: their employees. Mobilized through strikes, unions, and an increasingly effective political movement, and aided by a labor market that rewarded the sorts of skilled personnel who worked in railroading, these employees exerted a steadily stronger influence that swayed thinking about new technology in complex ways.

At no point in its history, then, did American railroading reach some steady state in which pressures to innovate abated and technology stagnated. Though certainly constrained as they went along by previous choices

and commitments, railroads innovated continually. Change was always the order of the day. And though other technologies such as electric light and power and the telephone came along and captured the limelight, railroading remained on the frontiers of technical change well through the turn into the twentieth century. For even after the sheen of novelty faded and railroads acquired the patina of age, the task of sustaining technical innovation posed fresh challenges not previously encountered by any other industry. As railroading matured, it gave rise to a stream of novel techniques and methods of analysis aimed at managing technology and innovation in an orderly fashion. These efforts to render technical change more predictable and routine – in effect, to regulate innovation – themselves constituted one of the most significant technological developments of their day.

The dual challenge of regulating the basic railroad innovation while also regulating subsequent innovation in railroading was no mere matter of a few businessmen responding in logical fashion to a changing set of factor endowments. No simple calculus governed the choices of technologies and dictated their form; no inner logic inexorably gave shape to the system. Rather, railroading emerged and evolved under intensely combative circumstances through processes whose outcomes were highly contingent.[3] Commanding a vast share of the nation's resources and operating at the vanguard of change for nearly a century, railroading and railroad technology persistently posed novel challenges of such profound importance and apparently far-reaching implications they transcended the concerns of owners, operators, and customers. Time and again, these matters spilled into the domain of politics and government, ultimately engaging Congresses, courts, Presidents, public administrators, and the electorate at large. Decisions regarding railroad technology consequently occurred within a complex framework of public and private institutions encompassing a broad array of Americans in many capacities, and the course of technical change in railroading at once reflected and influenced issues residing at the very core of American politics and political ideology.

Far from taking us to a complacent and unchanging domain, railroading thus actually opens a uniquely revealing window into the dynamics not just

[3] For an interpretation of railroad history emphasizing the single-minded pursuit of efficient throughput, see the pioneering studies of Alfred D. Chandler, Jr., especially his *The Visible Hand: The Managerial Revolution in American Business* (Cambridge, Mass.: Belknap Press, 1977), pp. 81–205. While Professor Chandler's work brought a welcome corrective to portrayals depicting railroading strictly as a product of political and economic manipulation by powerful individuals, his treatment overlooks important elements of choice and contingency that shaped the course of railroading and railroad technology. For an explicit critique of Chandler, see Gerald Berk, *Alternative Tracks: The Constitution of American Industrial Order, 1865–1917* (Baltimore: Johns Hopkins University Press, 1994). Though I am not fully persuaded about the viability of the particular alternative Berk posits, I share his sense that railroading might have assumed a different form than it did.

of technical change but of American history. For while perhaps no technology of the nineteenth century generated more controversy than railroading, the complex interplay among business, technology, and politics that shaped railroad innovation was by no means confined to that industry. Efforts to create and to mold new technologies have been a central, recurrent feature of the American experience since at least the time of the Revolution, when individuals such as Thomas Jefferson grappled with the implications of steam engines and patent systems for the infant republic.[4] Many of the most tumultuous events in the nation's history have, at their core, involved disputes over the appropriateness and desirability of particular technologies. No significant transforming technology, including those of more recent times, has emerged untouched by such controversies. In unpacking and examining the choices made regarding railroad technology, this book seeks above all to bring this underappreciated dimension of American life to light and to develop some insight into the distinctive ways in which Americans have confronted the persistent challenges posed by new technology. For what, besides the past, do we have to guide us as we attempt to manage the unmanageable, to regulate the new?

How, then, did Americans go about trying to regulate railroad innovation? One thing seems apparent from the start. Unlike their counterparts in many other nations, Americans generally left responsibility for the immediate choices regarding technology in the hands of private individuals who had a direct personal stake in the matter. Though some informed parties embraced the idea of establishing a government board for railroad technology or even nationalizing the industry entirely, such proposals ultimately failed to take hold. Except for a brief experiment with legislation mandating the use of certain safety appliances, the specifics of railroad technology remained the province of individuals operating in the private sphere. At no point, however, did those individuals function entirely outside the influence of politics and public policy. Far from it. At virtually every turn, those directly responsible for railroad technology felt pressure from forces in the public arena. Rather than intervening directly in decisions pertaining to technology, those forces typically worked more circumspectly, serving instead to alter the incentives operating upon those immediately involved with railroad technology. In

[4] Hugo A. Meier, "Technology and Democracy," *Mississippi Valley Historical Review* 43 (1957): 618–640; Leo Marx, *The Machine in the Garden: Technology and the Pastoral Ideal in America* (New York: Oxford University Press, 1964); John F. Kasson, *Civilizing the Machine: Technology and Republican Values in America* (New York: Grossman, 1976), pp. 1–51; Merritt Roe Smith, *Harpers Ferry Armory and the New Technology: The Challenge of Change* (Ithaca: Cornell University Press, 1977), pp. 24–32; Eugene S. Ferguson, *Oliver Evans: Inventive Genius of the American Industrial Revolution* (Greenville, Del.: Hagley Museum, 1980); and John R. Nelson, Jr., *Liberty and Property: Political Economy and Policymaking in the New Nation, 1789–1812* (Baltimore: Johns Hopkins University Press, 1987).

some cases, as when the federal government embarked on controversial ventures to open Western lands rapidly for railroad construction or to set the rates railroads could charge for their services, this entailed actively shaping demand for railroad services in ways that ultimately influenced the course of technical change. In many others, as when Congress and the courts addressed the role of patents in railroading or shifted the liabilities for accidents from employees to the lines themselves, it involved manipulating the structures through which the incentives to innovate flowed.

These attempts to adjust the incentives to innovate, in large part by altering the structures through which those incentives operated, constitute the primary means through which Americans sought to regulate railroad innovation. Time and again in the history of American railroading, business managers and government officials alike attempted to gain a measure of control over the course of technical change in these ways. On many occasions this process involved negotiation or even open conflict between railroads and government. But the efforts to restructure incentives also occurred among railroads themselves, without direct involvement from government. At individual lines and through various interfirm arrangements such as engineering societies, trade associations, and inside agreements with suppliers and contractors, railroad management intervened to restructure the pathways of technical change. Frequently, government became involved only when these measures initiated by railroads sparked protests from some segment of the populace or appeared to conflict with established laws or ideals.

Regardless of who took the lead, the ongoing attempts to alter incentive structures worked to channel technical change toward certain areas and away from others at different moments in time. Often this channeling occurred as managers weighed the merits of known alternatives, as when they persisted in using hand brakes and manual semaphores rather than adopting automatic air brakes and electric signals. But more was involved than railroads acting as informed consumers, methodically selecting their preferences from an array of existing technical choices. The channeling of innovation also operated upon the realm of possibilities. Railroads chose at various moments in their history to pursue certain opportunities while neglecting or bypassing others. Lines attacked some problems vigorously while sidestepping or overlooking other matters that might justifiably have garnered their attention. In the process, railroads inevitably drew the creative efforts of their employees and of the broader technical community toward a few areas while diverting them away from other possible paths of technical change. In effect, railroads created pipelines of innovation, whose very effectiveness in focusing inventive efforts upon certain tasks served to impede or even to foreclose alternative developments of potentially far-reaching impact.[5] The frequent

[5] These ideas about the channeling of innovative activity along particular pathways or through certain pipelines draw upon the pioneering studies of Nathan Rosenberg.

public controversies regarding railroads often at root involved disputes over the suitability of these pipelines and the desirability of the innovations they would likely foster.

Efforts to channel technical change and reshape railroad innovation, while influenced always by various economic incentives, seldom boiled down simply to making rational choices grounded strictly in hard economic data. By its very nature, innovation involves uncertainty. Neither railroads nor their critics and overseers could escape that fundamental truth. Try as they might, they could not anticipate every eventuality and comprehend in advance the full effects of their choices regarding technologies. No one could say with absolute certainty that the selection of one technology over another or the decision to pursue some lines of innovation while neglecting others led to optimal or even preferred outcomes. This was especially true in railroading because the various components of the technical ensemble interacted to form an immensely complex system, one that included not only many coupled artifacts, but also numerous routines and bodies of acquired expertise. Changes in one area could easily wreak havoc in unanticipated places.[6]

In choosing to emphasize certain lines of innovation, railroads in effect sought out those paths that appeared least likely to cause disruptions. To some degree, of course, this search involved assessing anticipated costs and benefits and reading economic signals sent by the market. But the process also hinged upon key judgments exercised in the form of simplifying assumptions about how best to manage the system. Those axioms, essential for conducting business in a complex environment, on occasion ultimately acquired something approaching the authority of truth. For the very act of setting clear priorities and establishing broadly understood ground rules, whatever their merits, fostered a measure of consensus and bred a familiarity that enhanced the chances of implementing certain types of change without significant disruption. In this sense, the channeling of innovation was to a degree both arbitrary and self-reinforcing. Those approaches deemed best in advance generated the best results in practice, thus legitimizing the reasoning that privileged them in the first place.[7]

See especially his "The Direction of Technological Change: Inducement Mechanisms and Focusing Devices," in his *Perspectives on Technology* (Cambridge: Cambridge University Press, 1976), pp. 108–125.

6 On technical innovation in system-based industries, see Thomas P. Hughes, *Networks of Power: Electrification in Western Society* (Baltimore: Johns Hopkins University Press, 1983) and "The Evolution of Large Technological Systems," in Wiebe E. Bijker, Thomas P. Hughes, and Trevor J. Pinch, eds., *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology* (Cambridge, Mass.: MIT Press, 1987), pp. 51–82.

7 This phenomenon bears a strong resemblance to notions such as technological paradigms and trajectories. See Giovanni Dosi, "Technological Paradigms and Technological Trajectories," *Research Policy* 11 (1982): 147–162, and Edward W. Constant II, *The Origins of the Turbojet Revolution* (Baltimore: Johns Hopkins

In addition to remaining cognizant of these underlying assumptions and judgments, those wishing to comprehend technical change in railroading must also account for the deep emotions felt by many Americans who encountered the railroad and its many technical accouterments. Railroads had the power, as Lewis Mumford noted of electric light and many other technical novelties of the day, to "stir the minds and spark the senses."[8] Long after they had become common features on the American scene, railroads remained technological marvels. Trains equipped with an array of technical novelties moved across the landscape at startling speeds, along routes shaped by stunning feats of civil engineering, governed in orderly fashion by sophisticated methods and, in some cases, automatic devices that appeared to promise fail-safe protection. Such technical virtuosity was alluring. It could dazzle even the staunchest of critics, and for many Americans, it held out the promise of seemingly endless possibilities. Even the act of subjecting the complex railroad system to engineering study and rendering innovation more routine could generate enormous enthusiasm among the public. At the 1904 World's Fair in St. Louis, visitors flocked to see a team of engineering professionals operate a plant built by the Pennsylvania Railroad for testing locomotives.

This ability to evoke such intense emotion, together with the obvious significance railroads held for social and economic relations and the uncertainties inherent to innovation, insured that the disputes through which railroading took shape went well beyond the matter of how best to provide efficient transport. Railroad technology, like so many other innovations, emerged and evolved amidst great hype, in a climate where hope and imagination could matter more than cold economic calculus. This was obviously true at the start, when promoters competed avidly to attract investors and political favors in support of their proposed lines. But even long after this initial frenzy of oft-fanciful enthusiasm had subsided, Americans still saw enormous potential and possibilities in railroads and railroad technology. Though sometimes troubled by changes railroads had wrought, they looked optimistically toward further triumphs of inventiveness and engineering in railroading. The recurrent concern with restructuring the incentives to innovate betrayed this persistent feature of the public psyche. New marvels, Americans seemed convinced, were always just around the corner. They need only find ways to unleash them.

University Press, 1980). It might also be seen as a variant of path dependency. See Paul David, "Clio and the Economics of QWERTY," *American Economic Review* 75 (1985): 332–336; W. B. Arthur, "Competing Technologies, Increasing Returns, and Lock-In by Historical Events," *Economic Journal* 99 (1989): 116–131; and Michael L. Katz and Carl Shapiro, "Systems Competition and Network Effects," *Journal of Economic Perspectives* 8 (1994): 93–115.

[8] Lewis Mumford, *The Brown Decades: A Study of the Arts in America, 1865–1895* (New York: Harcourt, Brace, 1931), p. 35.

The maturing railroad industry of the late nineteenth century put this persistent optimism to the test. As the system took hold and railroads grew seemingly ever more effective at channeling innovation down particular paths, Americans grappled with a dilemma they would encounter time and again as they embraced the transforming technologies of the twentieth century. How, they wondered, might they encourage pursuit of cost-reducing refinement and routine without stifling the flow of technical novelties? How could they reap the benefits of order and system while leaving the door open for continued inventiveness that might take them to new possibilities? How, in regulating the railroad innovation, might they keep from regulating innovation out of railroading?

In tracing the experiences through which Americans arrived at this essential tension between efficiency and innovation, this book follows the lead of Charles Perkins, the railroad president who in a lengthy memorandum written to his corporate staff sometime around 1880 likened the sprawling railroad they supervised to a complex machine.[9] In running this machine, Perkins noted, he and other managers turned increasingly toward an array of technical experts trained in the "exact sciences" of engineering. Able to identify opportunities for increased economy and efficiency that would yield significant savings when applied throughout the entire system, this engineering force conducted a sustained effort at refinement. The seasoned executive contrasted this advanced stage of railroad development with the more chaotic conditions prevailing during his managerial apprenticeship, when he supervised construction of the Burlington's lines across the sparsely settled territory of Nebraska. Under those circumstances the railroad operated with considerably less exactitude. Managers paid more attention to tasks such as recruiting customers and acquiring the basic equipment, rather than to making sure trains ran at peak efficiency or rails provided longer service for less cost.

Part I of this book examines railroading during its long adolescence, before the machine paradigm took hold. This extended stage of development began during the 1820s and 1830s, when the pioneering synthesis of a self-propelled engine linked to a train of carriages mounted on a fixed track of low resistance first appeared. This stage persisted for nearly five decades, as Americans repeatedly sought to exploit the spectacular potential inherent in the marriage of railroad technology and virgin land. As entrepreneurs embarked on a set of modest concurrent experiments organized at the state or local level, debate swirled through American politics over how government might encourage such activities and direct them toward serving particular purposes. Some parties desired to build extensive, integrated facilities aimed at promoting through shipments of commodities to be sold in an international market.

[9] Perkins, "Organization of Railroads."

Others looked upon the railroad primarily as a tool for promoting diverse local economic activity. Disputes between these groups occupied a central place in American politics from the Age of Jackson through the Civil War, as various parties struggled to devise inducements that would serve their interests. By the conclusion of the war, the new technology had become the indispensable tool of an emerging empire built on continental proportions.

Throughout this tumultuous formative period, application of the basic technical assembly to new locales remained the paramount objective. Managers sought above all to bring the technology of railroading to new areas and to foster economic development in the process. Choices of technologies often reflected particular local circumstances, including investment opportunities of managers who in many cases had received charters from government based on their ability to promote growth. Efforts to innovate often exuded an idiosyncratic and speculative character, with great wealth flowing to those who turned inside knowledge to their advantage. Managers often obtained key technologies from firms in which they themselves had invested. Patent rights and personal relations loomed large during this period, as insiders looked to capitalize upon the opportunities opened by massive public subsidies of enterprises based on the most complex technical assemblies of the day. At the same time, railroads often flaunted the rights of patent holders who stood outside the inner circles. This cavalier approach left them exposed to significant liabilities, as they belatedly discovered during a well-publicized series of costly lawsuits after midcentury.

Troubles such as these helped usher in the second stage of American railroading. As the expansive building boom at last subsided during the 1870s, managers such as Perkins turned to the daunting task of evaluating and routinizing the sprawling networks they had created. Like parents belatedly discovering a precocious but troubled child, they threw themselves with abandon into what Perkins termed "running the machine." Curtailing the rampant experiment and insider dealing of an earlier day, managers placed responsibility for technology in the hands of technicians and administrators who imposed rigorous technical standards and channeled innovative energies toward particular objectives. To facilitate these efforts, railroads turned increasingly to the ranks of college-trained engineers who had mastered the methodical, systematic techniques of scientific analysis. They founded pioneering laboratories grounded in a common methodology of testing and materials analysis. Knowledge of railroad technology came increasingly to reside in published studies readily accessible to a community of expert professionals.

This shift toward professional engineering brought fundamental changes in the organizational arrangements structuring technological change. Believing the market-based patent system actually interfered with the flow of those technical improvements they most desired, railroads pressed Congress and the courts to revise the patent laws or at least alter fundamental doctrines

pertaining to them. Ultimately, railroads would circumvent the patent system by entering into trade associations and by devising other cooperative arrangements that created alternative pathways of innovation. Working through a growing network of trade associations and engineering societies, experts from the railroads and from their suppliers developed procedures for setting technical standards that effectively provided a basis for negotiating the course of technical change. In this way railroads effectively substituted industry-wide agreements for the more chaotic and uncertain exchanges of the open market. Their efforts prompted Americans to assess how the rise of a corporate economy changed the ways in which incentives to innovate worked their way through the economy and fundamentally altered the pathways of technical change.

Imposing a degree of routine and order virtually unprecedented in any other industry, managers tamed the basic railroad innovation while sustaining a more predictable flow of less radical innovations that helped railroads substantially enhance their productivity. This impressive performance, documented in Part II, persuaded virtually everyone connected with the industry to adopt the machine analogy. By the turn into the twentieth century, politicians and the public as well as executives and investors had come to see railroading as a well-honed conveyor belt for transporting goods and people in highly routinized fashion. Many influential figures now approached the industry as something like a grand engineering problem susceptible to the analytical methods and quantitative measures of technical experts. Engineering standards became the accepted language of the day, providing a source of hope and even enthusiasm not just among the business community but among the mounting ranks of reformers and the broader public as well. Governments asserted a new role as potential stewards of the industry, in which they might draw upon engineering methods to dictate operating procedures and to set appropriate rates.

Yet just as the engineering approach became enshrined in railroad finance and in public policy, American railroads reached a juncture that revealed the inherent limitations of the engineering methods Perkins espoused. Faced with mounting demand from increasingly diverse customers, railroads discovered that continued pursuit of improvements along the established trajectories of greater bulk and increased power no longer yielded the productivity gains they desired. Newly purchased cars and locomotives sat idle in congested yards. Steel rails of unprecedented heft broke with alarming frequency. The situation, as discussed in Part III, called for a shift to a new paradigm built upon a new set of underlying assumptions that Perkins and most others connected with the industry had not anticipated. Searching for remedies to the pressing problems and responding to renewed pressure from government for improved safety, lines reluctantly found themselves considering radical new departures in technology such as automatic brakes and signals and electric traction. These techniques posed challenges and concerns of a sort railroads

had successfully evaded for much of the late nineteenth century. Lines needed to develop competence in electrical technology and in other technical domains outside the narrow expertise of their established engineering forces. In an effort to meet the specialized needs of particular customers, railroads experimented with new operating procedures intended to build greater flexibility into train movements, disrupting established measures of performance in the process. At virtually every turn, moreover, managers found themselves confronting an increasingly powerful labor force. For while the technological trajectories of the late nineteenth century had largely served to help railroads sidestep labor conflict, the innovations of the early twentieth brought managers and workers face-to-face over problems they could not easily resolve.

The mounting friction in the railroad machine reached the breaking point with the arguments over rate increases and federal control that occupied the industry from 1906 through the end of World War I. While railroads found their faith in engineering methods waning, the public and the regulatory community grew increasingly enamored with the potential of engineering expertise to provide ordered stewardship of the vast railroad enterprise. During the famous Eastern Rate Case of 1911, railroads stood immobilized as Louis Brandeis, evoking the virtues of Frederick Winslow Taylor and his methods of scientific management, defeated their attempt to win a rate increase. Trapped by the rhetoric and methods they had done so much to promote, railroads could not during the subsequent decade turn their industry down a more innovative path. Wartime demands distorted traffic patterns, creating circumstances that resembled those of the late nineteenth century while masking the trends toward specialized service that had seemed to herald the future of railroading. At war's end, government and the railroads ultimately settled into an uneasy regulatory arrangement that would prove more of an impediment than an inducement to innovation. Railroading slipped into a long, steady decline during which it acquired the trappings of a technical backwater.

Such a fate could only have astounded an observer from a century before, when the nascent technology of railroading opened the door to an uncertain future brimming with challenges and opportunities. In tracing the shifting paradigms of railroad innovation, we turn first to this world of expectancy and anxiety and examine how Americans of the mid-nineteenth century struggled over the course of many decades to assemble railroad machines in forms that would serve their diverse aspirations and objectives.