Technological Change and Work



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Short Abstract

This doctoral thesis examines the impact of innovation on jobs using the first historical index of job quality and international comparative case studies of sectors in Great Britain and the United States. It makes four principal contributions. First, it constructs a new indicator of living standards that measures work-related wellbeing in the past. Second, it shows that macroinventions increased the division of labor and thereby raised the inequality of work-related wellbeing. Third, it demonstrates that firms' push to reduce unit labor costs produced a race between job quality and productivity. Managers adopted microinventions that could have reduced work intensity or improved safety, but to raise productivity they demanded higher effort levels and increased throughput, which mitigated improvements to safety and conditions. Fourth, it shows that some instances of technological change produced widespread unemployment and provided opportunities to reorganize the workforce. Higher-status workers used the dislocation of innovation to claim or retain the best jobs. These findings contribute to historical scholarship on the development of living standards and provide perspective for debates about job polarization and the future of work.

Long Abstract

This doctoral thesis examines the impact of technological change on jobs using three sectoral case studies from Great Britain and the United States between 1750 and 1910. It analyzes changes in work-related wellbeing in spinning and interurban transportation by constructing and applying the first historical index of good jobs. To measure access to employment and the distribution of work opportunities, it uses primary source evidence from government and company records. The job quality analysis is based on more than 14,000 observations of wages and working time from manuscript payrolls, account books, and vouchers, including the first payment datasets for American hand spinners and road maintenance workers, and for canal laborers before the Erie Canal. The thesis also makes extensive use of qualitative evidence about employment, including workers' letters, diaries, and memoirs, contemporary doctors' reports, corporate records of activities, discipline, and accidents, factory inspectors' reports, and trade handbooks. The evidence from these sources is used to describe job tasks, work locations, and components of job-related wellbeing such as intensity, safety, and control.

The impact of the British and American Industrial Revolutions is one of the most studied topics in economic history. To capture the development of living standards, scholars have used income (Williamson 1985, Margo & Villaflor 1987, Feinstein 1998), consumption (Mokyr 1988, Logan 2006), outcome measures including anthropometrics (Floud et al 1990, Komlos 1993, Komlos & A'Hearn 2019), and capability measures such as the Human Development Index (Crafts 1997). Composite indicators have become increasingly common for measuring wellbeing (Prados de la

Escosura 2015, Gallardo Albarrán 2019). This thesis contributes a new tool for measuring historical wellbeing, the Historical Occupational Quality Index (HOQI), and conducts the first systematic analysis of work-related wellbeing in the past.

A work-based approach to wellbeing is also motivated by two important modern issues: job polarization and automation. Since the 1970s, information and communications technology has been a key cause of the declining number of good middle-class jobs in rich countries (Autor et al 2006, Goos & Manning 2007). Partly because of this process of job polarization or 'hollowing out', the UN has established 'decent work' for all as one of the Sustainable Development Goals, and job quality is part of the EU's Pillar of Social Rights. Moreover, automation is likely to be one of the most important developments of the coming decades, with job displacement and shifts in work organization on the horizon. Recent studies have suggested that nearly half of jobs in the United States are at high risk of automation, and surviving occupations will be very different from current jobs (Frey & Osborne 2017, Manyika et al 2017, Baldwin 2019). Evidence from historical examples of technological change aids researchers aiming to predict the effects of future innovation and suggests approaches to maintain or improve work-related wellbeing.

The thesis uses a three-part methodology to capture changes in work-related wellbeing and access to good jobs. It constructs the first index of historical job quality using evidence of historical workers' preferences about what constituted 'good jobs' (Chapter 2). The index has eight parts: wages, working time, stability of earnings, accident risk, industrial disease risk, control, intensity, and repetitiveness. The codebook (Appendix 1) outlines the steps used to score the qualitative measures and

combine the eight components into an occupational quality score. This approach makes extensive use of qualitative evidence, and the thesis provides detailed descriptions of occupations, covering tasks, hierarchies and organization, work locations, and health risks.

The thesis incorporates changing access to good jobs by presenting evidence on the number of jobs available in a sector (occupational availability) and the demographics of the workforce (occupational distribution). These dimensions account for job destruction or growth in employment, and shifts in the characteristics of the workforce. Neither Britain nor America enumerated occupations in their censuses until the mid-19th century, so employment estimates before this period are based on material throughput, spinning machinery in use, the number of transportation companies and their mileage, and contemporary claims. The thesis uses employers' records, census data, and contemporary reports to show the age, gender, and racial composition of the workforce, where jobs were located, and how these attributes changed. This three-dimensional approach of job quality, availability, and distribution captures the changes in occupations and employment opportunities as well as the diversity of effects across different types of workers and attributes of jobs.

The first case study (Chapters 3 & 4) analyzes the dramatic changes in work in the spinning section of the British textile industry from the Industrial Revolution up to the First World War. Yarn production using spinning wheels was a widespread, low-paid, high-control, safe occupation for women in the 18th century, and there had been relatively little technological change for most of the early modern period. From the 1760s, the spinning jenny, water frame, and spinning mule radically changed

work-related wellbeing, altered the organization of work, rapidly raised productivity, and caused significant unemployment. After a brief interval in which workers used hand-powered machines in their homes, operatives became concentrated in factories where they earned higher wages at the cost of long hours, increased occupational risks, higher work intensity, and less control over their work. The job quality analysis is based on extensive primary source evidence, including more than 5000 observations of wages and working time in early factories from manuscript account books. The dislocation of innovation allowed adult men to claim the best factory jobs as mule spinning operatives and overseers. These two groups earned the highest wages and had more control over their work than the women and children whom they supervised.

Factory production expanded the range of tasks, and firms responded by increasing the number of occupations in spinning. Instead of a single worker spinning yarn and delivering it to a merchant for onward sale or to a weaver for further production, factories employed workers to tend machines, clean the spinning rooms, oversee the operatives, maintain the steam engine or water wheel, and manage the factory's operation. While the number of occupations increased, the workforce shrank by the early 19th century. High factory productivity left former hand spinners—who were overwhelmingly women—without work. Chapter 3 uses evidence of hand spinners' productivity, archival accounts of the number of factories constructed, and estimates of machine output to produce the first estimate of technological unemployment in the late 19th century. The destruction of women's jobs and the fact that men took the best factory occupations meant that technological change in spinning was male-biased.

Following the 'macroinventions' phase of the First Industrial Revolution, further technological developments, regulation, and unionism shaped work-related wellbeing for spinners from the 1830s up to 1910. Managers hoped that a new technology, the automatic or 'self-acting' mule, would allow them to replace the highly-paid and militant mule operatives. However, the early self-actors were only able to spin coarse yarn and required substantial adjustment by a trained worker, so firms could not dispense with mule spinners. These lead workers, now known as self-actor minders, were unionized from the first third of the 19th century and retained relatively high wages and control of the shopfloor. This high level of control included hiring assistants and training them to become minders, which allowed minders to maintain male dominance in British spinning. The first factory regulations were enacted in the early 19th century to protect children and then women, but regulation was generally ineffective until the 1830s. After the 1833 Factory Act, the main impact of regulation was to reduce working hours. Safety and ventilation were rarely addressed despite frequent worker injuries from machinery and mounting evidence that inhaling textile fibers caused serious respiratory ailments. Firms' efforts to lower costs by economizing on raw materials in the late 19th century and running machinery faster pushed more work onto employees, especially the young assistants of the self-actor minders.

The second case study (Chapters 5 & 6) considers the parallel development of factory spinning in the Northeastern United States. It presents the first dataset of American hand spinners' earnings, assembled from farmers', dyers', and weavers' account books. The scattered sources for American hand spinning earnings are the

result of an inchoate market for yarn in which many families produced clothing for themselves or purchased imported fabrics. This setting meant that most American hand spinners worked occasionally, with spinning a relatively minor occupation. Mechanization in the United States primarily used the water frame and successor continuous spinning technologies, unlike Britain, which predominantly used intermittent spinning machines. Continuous machines were better suited to American conditions, as they could spin coarse yarn for standardized fabrics and required fewer expensive male workers.

In the first decades of the 19th century, three models of factory production developed in the United States: a corporate, paternalistic system in Massachusetts that produced long runs of standardized cloth in large mills, a competitive model with many small firms and more heterogenous outputs around Philadelphia, and a family labor system with a mixture of continuous and intermittent spinning machines in Rhode Island. Chapter 5 measures job quality in each model of factory production using more than 2000 new observations of wages and working time from the early 19th century, as well as descriptive evidence. All three systems shared features with British mills: higher occupational risks, lower worker control, longer hours, and greater intensity. However, the paternalism of the Massachusetts mills, which aimed to prevent the creation of an industrial proletariat in America by paying higher wages and imposing less discipline, provided slightly higher work-related wellbeing than the other systems. All three models also included male-biased technological change as men claimed the best jobs when new technology expanded the task range and firms increased the division of labor. One mitigation was that the small number of dedicated hand spinners in America meant that there was little technological unemployment.

From the 1840s, American spinning became somewhat more concentrated in Massachusetts and the differences in regional models ebbed. The main technological development up to 1910 was the introduction of new continuous spinning machines, called ring frames. The widespread adoption of ring spinning was followed by increases in work intensity during the 1840s in the form of the 'speedup' and 'stretch-out', which required workers to monitor more machines operating at higher speeds. Increased effort levels, alongside higher capital-per-worker, raised productivity, but wages were stagnant until the 1860s. Rising work intensity and static wages caused native-born workers to leave yarn production. By the mid-19th century, most spinning workers were immigrants, first from Ireland, and then Southern and Eastern Europe. The US Constitution left regulation of working conditions to the states, and there were no effective limits on hours or rules about conditions until the late 19th century. States began to establish factory inspectorates from the 1880s, which finally enforced restrictions on hours and children's labor, although occupational safety remained poorly regulated. The improved productivity of ring frames combined with increasing numbers of machines assigned to each worker meant that spinning employment grew more slowly than textile production up to 1910. Rising wages, especially after 1900, and falling hours as a result of regulation were the main causes of improvements in work-related wellbeing.

The third case study (Chapters 7–9) analyzes interurban transport in the Northeastern United States. Most research on transport innovation in America has focused on its macroeconomic impacts (e.g. Taylor 1951, Fogel 1964). However, there have been fewer studies of work for the new transport enterprises (Smith 1963, Licht

1983, Aldrich 2006), and no comparisons of work on roads, canals, and railroads. Chapters 7 and 8 analyze the 'macroinventions' period of change, when American transport shifted from rudimentary, narrow dirt roads to turnpikes, canals, and finally railroads. Technological changes vastly increased the task range and firms responded by creating many new jobs, such as firemen to fuel steam locomotives, machinists to repair rolling stock, signalmen and flagmen to control trains, and white-collar roles to monitor expenditure, set timetables, and handle capital acquisitions. Modern management (Chandler 1977) was the result of the expanded range and repetition of tasks and the greater geographical extent of railroads. This new division of labor encompassed a wide spectrum of work-related wellbeing: track laborers toiled in exhausting conditions for modest pay and brakemen risked their lives on every journey, while railroad managers enjoyed very high pay and safe conditions.

After the railroad was firmly established as the dominant mode of interurban transport by the 1860s, a variety of improvements to rail infrastructure, rolling stock, and train control technology continued to change work into the 20th century. Many of these microinventions, such as replacing iron with steel in rails and locomotive boilers, could have improved safety. However, firms' drive to increase productivity mitigated their accident-reducing potential through intensive use. More powerful locomotives pulling heavier loads at higher speeds meant that occupational safety hardly improved for many railroaders. Federal regulation eventually mandated railroads adopt some safety-improving technology, but the effects were limited. Railroad pay was relatively high for many occupations, although it stagnated from c. 1870–1890, and work-related wellbeing remained unequal.

The case studies show that large technological changes, or macroinventions, expanded the task range of work, which led firms to increase the division of labor. This more specialized workforce experienced greater inequality of work-related wellbeing, which the thesis describes as 'job stratification'. The transformative capacity of macroinventions sometimes outstripped increases in demand for cheaper products and services, which caused substantial job destruction. Cases in which macroinventions were adopted to produce substitutes for imported goods, or in which sectors grew in a symbiotic relationship with the broader economy, saw little or no technological unemployment. After firms adopted macroinventions, their continuing search for productivity growth frequently led them to increase the intensity of work while adopting smaller technological changes, or microinventions. These innovations could have enabled lower effort or improved safety, but managers' push to reduce unit labor costs led them to raise throughput, which limited or negated the effort-saving or safety-increasing potential of microinventions. The race between productivity and good jobs meant rising wages and regulations that imposed shorter hours were the primary drivers of improved work-related wellbeing in the late 19th and early 20th century. Technological changes also produced opportunities to reorganize the gender division of labor, generally to the benefit of previously high-status workers. In the spinning case studies, men invariably claimed and usually retained the best jobs after mechanization. White men restricted entry to railroad jobs and retained the most desirable occupations into the 20th century.

This thesis constructs a new measure of historical wellbeing and applies it to three case studies of transformative technological change. Using hundreds of

previously unexplored archival sources, published material from government reports, and census data, it shows how major technological changes can increase the inequality of wellbeing while creating new occupations. It demonstrates that competitive pressures encourage firms to raise work intensity, thereby mitigating the effort-saving or safety-improving potential of smaller inventions. Finally, it shows that innovation can destroy large numbers of jobs and cause reorganization of the workforce. These findings contribute to research on historical living standards, contemporary discussions of job polarization, and debates about the future of work.

Chapter 1
Introduction

Chapter Abstract

Work is fundamental to quality of life, but it has been missing from historical accounts of wellbeing. This dissertation provides the first systematic analysis of how innovation has impacted work-related wellbeing in the past. Research on the relationship between technology and jobs provides insights into the development of living standards, contributes to debates about job polarization, and speaks to possibilities and pitfalls for the future of work. To illuminate these three areas, the thesis constructs the first index of historical job quality. It then applies this index, using a descriptive and quantitative approach, to three case studies of technological change in the past. The analysis shows that major technological changes can broaden the range of tasks, which encourages firms to increase the division of labor, creating new jobs and higher inequality of work-related wellbeing. Major inventions may produce large-scale unemployment, depending on the technology and the context in which it is adopted. After firms reap the gains of a major technological change, efforts to improve output per worker place job quality in a race against productivity. Technology also offers opportunities to reorganize the workforce, which has generally benefitted higher-status workers.

Work is an essential part of life. Except for a fortunate few, everyone must toil to secure their material survival. While work has been a constant component of human society, who works, what workers do, and where they work has varied over time. Geography, natural resources, conflict, and cultural expectations have shaped the organization of work, workplaces, and the demographics of the workforce. This thesis focuses on one cause of changes in work: technology. It explores how innovations have changed the task composition of occupations, the experience of work, the locations of toil, the amount of employment, and the distribution of jobs over the workforce. Examining the effects of past instances of technological change contributes to research on historical wellbeing, to current discussions about the disappearance of middle-income jobs, and to debates about the future of work.

To analyze the impact of work on wellbeing, the thesis constructs the first historical measure of good jobs, the Historical Occupational Quality Index, and applies it to three sector case studies of technological change from 1750–1910. Using quantitative and qualitative evidence, it shows that major innovations like the railroad increased the range of tasks, which led to a greater division of labor and stratified work-related wellbeing. The worst jobs improved little or declined in quality, but the division of labor produced new jobs, some of which were higher quality. Innovation bred inequality and opportunity. Once a macroinvention was well-established, managers adopted technical refinements and labor practices to increase productivity that raised work intensity, reduced employees' control of their work, and increased occupational risks or mitigated the effects of safety-improving technology. The competition between firms' demands for higher output and workers' desire for good jobs was closely fought. Regulation in the late 19th and early 20th century reduced

working hours and improved conditions in some cases. Further innovation did not necessarily improve work-related wellbeing and the gains from productivity improvements continued to be unequally distributed.

Work, Wellbeing, and History

This thesis analyzes work as an aspect of quality of life because employment is nearly ubiquitous and it impacts many areas of objective wellbeing.[1] Workers spend a large amount of time at work, and jobs are a source of mental and physical illness.[2] Employment is an important part of self-reported wellbeing, which economists and other social scientists have increasingly studied since the 1990s.[3] Reported wellbeing-at-work may also be positively related to productivity.[4] Moreover, as Chapter 2 demonstrates, historical workers also showed an interest in their work-related wellbeing.

This study of the relationship between technology and occupations in the past has three more specific motivations: historical, contemporary, and forward-looking. Debates about the effects of industrialization on living standards are seminal in

[1] Francis Green, *Demanding Work: The Paradox of Job Quality in the Affluent Economy* (Princeton Oxford: Princeton University Press, 2006); Iftikhar Ahmed, "Decent Work and Human Development," *International Labour Review* 142, no. 2 (2003). Sandrine Cazes, Alexander Hijzen, and Anne Saint-Martin, "Measuring and Assessing Job Quality," *OECD Social, Employment and Migration Working Papers* No. 174 (2015).
[2] Elena Cottini and Claudio Lucifora, "Mental Health and Working Conditions in Europe," *ILR Review* 66, no. 4 (2013).
[3] Andrew E. Clark, "Work, Jobs, and Well-Being across the Millennium," in *International Differences in Well-Being*, ed. Ed Diener, Daniel Kahneman, and John Helliwell (Oxford: Oxford University Press, 2010).
[4] Petri Böckerman and Pekka Ilmakunnas, "The Job Satisfaction-Productivity Nexus: A Study Using Matched Survey and Register Data," *ILR Review* 65, no. 2 (2012).

economic and social history.[5] One view holds that the technologies of the British Industrial Revolution raised wages, which improved living standards for the working class. Another asserts that the combination of urban crowding, disease, long working hours, rural unemployment, and other 'disamenities' offset higher wages, leading to either immiseration following a halcyon pre-industrial period, or at least an 'Engels' Pause' in which capitalists profited but workers gained little.[6] This thesis is the first project to describe and quantify job quality in the past, and it uses this novel approach to examine how innovations during the Industrial Revolution affected work-related wellbeing and employment opportunities.

The thesis also contributes to national economic histories and related fields of historical social science. American economic historians have been primarily interested in the macroeconomic effects of innovation, particularly railroads, and specifically whether the construction costs and public subsidies expended on rail transport were justified by the social savings and dynamic benefits they generated.[7] Historians of technology have studied the process of railroad innovation extensively, and its effect

[5] Among others: T. S. Ashton, "The Standard of Life of the Workers in England, 1790–1830," *The Journal of Economic History* 9 (1949); E. J. Hobsbawm, "The British Standard of Living 1790–1850," *The Economic History Review* 10, no. 1 (1957); R. M. Hartwell, "The Rising Standard of Living in England, 1800–1850," *The Economic History Review* 13, no. 3 (1961); Jeffrey G. Williamson, *Did British Capitalism Breed Inequality?* (Boston: Allen & Unwin, 1985); Charles Feinstein, "The Rise and Fall of the Williamson Curve," review of Did British Capitalism Breed Inequality?, Jeffrey G. Williamson, *The Journal of Economic History* 48, no. 3 (1988).
[6] Robert C. Allen, "Engels' Pause: Technical Change, Capital Accumulation, and Inequality in the British Industrial Revolution," *Explorations in Economic History* 46, no. 4 (2009).
[7] Robert William Fogel, *Railroads and American Economic Growth: Essays in Econometric History* (Baltimore: Johns Hopkins University Press, 1964); Albert Fishlow, *American Railroads and the Transformation of the Antebellum Economy* (Cambridge: Harvard University Press, 1966). Paul A. David, "Transport Innovation and Economic Growth: Professor Fogel on and Off the Rails," *The Economic History Review* 22, no. 3 (1969).

on jobs has primarily been considered in terms of occupational safety.[8] This study contributes to American economic history and the history of technology by synthesizing the detailed descriptions of engineering developments with evidence of their effects on workers, and evaluating whether the productivity-enhancing benefits of technology improved jobs. Business historians have examined the development of large firms and hierarchies, and this project adds systematic and granular analyses of tasks that can provide insights into changes in the organization of work.[9]

Labor history has focused on the development of class consciousness, unions, and class politics. In the United States, the histories of the Knights of Labor and the American Federation of Labor have received significant attention, as have artisans and other skilled workers.[10] Scholars have written about specific aspects of work or discussed individual instances of industrial action and their role in the development

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[8] John H. White, *American Locomotives: An Engineering History, 1830–1880* (Baltimore: Johns Hopkins University Press, 1997); *The American Railroad Freight Car: From the Wood-Car Era to the Coming of Steel* (Baltimore: Johns Hopkins University Press, 1993); *The American Railroad Passenger Car* (Baltimore: Johns Hopkins University Press, 1978); Mark Aldrich, *Death Rode the Rails: American Railroad Accidents and Safety, 1828–1965* (Baltimore: Johns Hopkins University Press, 2006); William D. Middleton, *When the Steam Railroads Electrified* (Milwaukee: Kalmbach Books, 1974); Steven W. Usselman, *Regulating Railroad Innovation: Business, Technology, and Politics in America, 1840–1920* (Cambridge: Cambridge University Press, 2002).

[9] Alfred D. Chandler, *The Railroads: The Nation's First Big Business* (New York: Harcourt, Brace & World, 1965); *The Visible Hand: The Managerial Revolution in American Business* (Cambridge: Belknap Press of Harvard University Press, 1977).

[10] E. P. Thompson, *The Making of the English Working Class* (London: Victor Gollancz, 1963); John Foster, *Class Struggle and the Industrial Revolution: Early Industrial Capitalism in Three English Towns* (London: Methuen, 1977). Keith Burgess, *The Origins of British Industrial Relations: The Nineteenth Century Experience* (London: Croom Helm, 1975). Sean Wilentz, *Chants Democratic: New York City & the Rise of the American Working Class, 1788–1850* (Oxford: Oxford University Press, 1984). Daniel J. Walkowitz, *Worker City, Company Town: Iron and Cotton-Worker Protest in Troy and Cohoes, New York, 1855–84* (Urbana: University of Illinois Press, 1978). Bruce Laurie, *Artisans into Workers: Labor in Nineteenth-Century America* (New York: Hill and Wang, 1989). Mary H. Blewett, *Men, Women, and Work: Class, Gender, and Protest in the New England Shoe Industry, 1780–1910* (Urbana: University of Illinois Press, 1988). Philip Sheldon Foner, *History of the Labor Movement in the United States* (New York: International Publishers, 1947).

of unions.[11] However, labor historians have not systematically evaluated the effects of technological change on the quality of jobs. This research contributes to labor history by drawing attention back to work itself, and uses a transparent framework to assess work-related wellbeing.

In recent decades, the information and communications technology revolution (also called the Third Industrial Revolution) has been a major factor in the polarization of rich country labor markets. Academics, commentators, and politicians have increasingly discussed this growing problem and its economic, social, and political impacts.[12] Some recent studies have given job polarization or 'hollowing out' since the 1970s a causal role in the rise of right-populism during the 2010s.[13] Analyzing earlier instances of transformative innovation reveals that stratification of occupation-related wellbeing is not new, and it may be the result of an increased task range that expands the division of labor. A longer-term historical perspective on job quality puts recent

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[11] Janet Greenlees, *When the Air Became Important: A Social History of the New England and Lancashire Textile Industries* (New Brunswick: Rutgers University Press, 2019). Norman Ware, *The Industrial Worker, 1840–1860: The Reaction of American Industrial Society to the Advance of the Industrial Revolution* (Boston: Houghton Mifflin, 1924).

[12] David H. Autor, Lawrence F. Katz, and Melissa S. Kearney, "The Polarization of the U.S. Labor Market," *American Economic Review* 96, no. 2 (2006); Maarten Goos and Alan Manning, "Lousy and Lovely Jobs: The Rising Polarization of Work in Britain," *The Review of Economics and Statistics* 89, no. 1 (2007). A more holistic perspective is Green, *Demanding Work*. See also Timothy J. Bartik and Susan N. Houseman, *A Future of Good Jobs? America's Challenge in the Global Economy* (Kalamazoo, Michigan: W.E. Upjohn Institute for Employment Research, 2008). Arne L. Kalleberg, *Good Jobs, Bad Jobs: The Rise of Polarized and Precarious Employment Systems in the United States, 1970s to 2000s* (New York: Russell Sage Foundation, 2011). 'Hollowing out' was described earlier (in a different form) by Frank Levy and Richard J. Murnane, *The New Division of Labor: How Computers Are Creating the Next Job Market* (New York: Princeton University Press, 2004), 11–15. These (largely) technologically-driven explanations differ from 20th century descriptions of dual labor markets such as David M. Gordon, Richard Edwards, and Michael Reich, *Segmented Work, Divided Workers: The Historical Transformation of Labor in the United States* (Cambridge: Cambridge University Press, 1982).

[13] Italo Colantone and Piero Stanig, "Global Competition and Brexit," *American Political Science Review* 112, no. 2 (2018). David Autor et al., "Importing Political Polarization? The Electoral Consequences of Rising Trade Exposure," *American Economic Review* 110, no. 10 (2020).

debates in context by providing more examples of the effects of technological changes and their causes, and it suggests potential solutions to the job quality problem. Most researchers have only considered the decline in job quality since the 1970s and used cross-country comparisons to investigate policy solutions.[14] This historical and comparative study analyzes the sources of changing job quality and availability across varying legal, economic, and political contexts over a much longer period.

In addition to 'hollowing out', a growing body of popular and scholarly writing suggests that automation and artificial intelligence could transform life and work again in the 21st century.[15] Many authors highlight the potential improvements to living standards that new technologies may produce, although they also discuss the possible downsides of transformative innovation.[16] However, few studies include long-run analysis or consider past technological change beyond brief and simplistic histories of the British Industrial Revolution.[17] These cursory narratives almost invariably present industrial technology as a short- or medium-term disruption for some workers, but provide no granular analysis of work-related wellbeing or potential lessons from past Industrial Revolutions beyond the trite claim that disruptions have always been resolved, and human wellbeing has risen.[18] Such broad claims ignore the

[14] In addition to note 12, see Françoise J. Carré and Chris Tilly, *Where Bad Jobs Are Better: Retail Jobs across Countries and Companies* (New York: Russell Sage Foundation, 2017).
[15] Richard E. Baldwin, *The Globotics Upheaval: Globalisation, Robotics and the Future of Work* (London: W&N, 2019). Daniel Susskind, *A World without Work: Technology, Automation and How We Should Respond* (London: Allen Lane, 2020).
[16] Erik Brynjolfsson and Andrew McAfee, *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*, New ed. (New York: W.W. Norton & Company, 2016), 9–10.
[17] The notable exception is Carl Benedikt Frey, *The Technology Trap: Capital, Labor, and Power in the Age of Automation* (Princeton: Princeton University Press, 2019).
[18] An egregious example is R. P. Bootle, *The A.I. Economy: Work, Wealth and Welfare in the Robot Age* (London: Nicholas Brealey Publishing, 2019).

details of why and on what dimensions wellbeing eventually improved, as well as the durable negative impacts of technology. Present-day workers are no more likely to quietly accept the downsides of technological change than their predecessors were in the 18th century, and assuming that a rising tide of innovation will lift all boats—or lift them equally—may prevent future generations from enjoying better jobs.

The Task-Based Approach and the Impacts of Technology

Tasks are key to understanding the reasons for technological substitution and the organization of employment. This thesis takes inspiration from recent studies that have used task composition to estimate future technological unemployment.[19] However, it constructs an account of tasks and work in the case study sectors from primary and secondary sources rather than using occupational definition data from sources such as O*NET for the task composition of present-day jobs. The detailed descriptions of work demonstrate how tasks and conditions changed with technology and highlight subtle changes as well as technological unemployment.

All work is composed of tasks and occupations are bundles of tasks. An employer could pay different workers to complete each task in a productive process but would incur high search costs. Instead, employers bundle tasks into jobs that require repetition of the same task or additional tasks, and employers determine the composition of bundles based on practical and social factors. Jobs usually combine related abilities: reading and writing, perhaps; probably not carpentry and riveting.

[19] Carl Benedikt Frey and Michael A. Osborne, "The Future of Employment: How Susceptible Are Jobs to Computerisation?," *Technological Forecasting and Social Change* 114 (2017). Cf. Alan S. Blinder, "How Many U.S. Jobs Might Be Offshorable?," *World Economics* 10, no. 2 (2009).

Most bundles minimize a worker's time spent switching between tasks (changing tools, moving from one workspace to another).

Workers can be augmented by technology (tools, machines, IT) that makes task completion easier, but technology may also add new tasks (e.g. maintenance). In some cases, technology eliminates occupations entirely. The technological improvements discussed in the following case studies fall into two broad, loosely-defined groups: macroinventions and microinventions. Macroinventions entail major changes in capital equipment and work organization. They may also have important macroeconomic effects and can incorporate product (or service) as well as process innovation.[20] Microinventions are changes to macroinventions, such as more durable materials, superior engineering for higher speeds, mechanisms that reduce the risk of accidents, or more precise calibration that reduces the need for human adjustment. In the case studies, macroinventions increased the range of tasks needed to provide a service or produce a good, and encouraged employers to reorganize bundles. As a result, macroinventions increased the division of labor and added new occupational titles. Increased task depth (repetition of tasks) also stimulated division of labor by incentivizing firms to hire workers who specialized in completing repeated tasks instead of retaining more heterogenous task bundles. Some macroinventions produced technological unemployment because they raised productivity more quickly than demand increased, even though the task range expanded.

[20] This approach follows Ralf Meisenzahl and Joel Mokyr, "The Rate and Direction of Invention in the British Industrial Revolution: Incentives and Institutions," in *The Rate and Direction of Inventive Activity Revisited*, ed. Josh Lerner and Scott Stern (Chicago: University of Chicago Press, 2012), note 8.

After firms adopted macroinventions, competition pushed managers to seek out new sources of cost saving. These included technical improvements that raised output per worker and new labor management strategies. Changes to management practices included demanding a higher intensity of work and asserting more control of the shopfloor. In general, microinventions enabled higher productivity but did not eliminate existing jobs, although some, like railroad electrification, could allow firms to reduce their workforce.

Overview

The next chapter outlines the methodology used in the thesis. First, it argues that measuring work-related wellbeing is important for a comprehensive understanding of historical living standards. It then explains in greater detail why present-day researchers have become interested in job quality, and provides evidence from past workers for the components of the Historical Occupational Quality Index. It presents the analytical narrative approach to describing jobs and job quality, sets out how the index is calculated and scored, and suggests sources that researchers can use to capture job quality. More technical detail, including the scoring rubrics for qualitative components, are provided in Appendix 1. Chapter 2 also outlines the second and third legs of the methodology, which quantify and describe the change in employment in a sector over the period of technological change (occupational availability) and shifts in the demographic composition and location of the workforce (occupational distribution).

The following seven chapters present detailed descriptions of changes in work from the three case studies of technological change from 1750 to 1910. The case studies

analyze two sectors that featured technological dynamism with both macro- and microinventions in varying settings. The international comparative dimension in Chapters 3–6 shows the effects of technology when firms faced different factor endowments that had implications for technical choice. There were also similarities and differences in institutions: the trajectory of factory regulation was similar in the United States and Britain, although it proceeded at different speeds. Unionization influenced work organization and conditions in Lancashire but was much less important in New England. Chapters 7–9 provide evidence from a transformational sector that underwent a series of major technological changes and was exposed to extensive microinventive activity up to 1910. This mixture of common and disparate elements enables analysis of the causes of changes in work-related wellbeing and access to good jobs, underlining distinct outcomes and common results.

The first case study analyzes how work changed in a major part of the textile industry of Great Britain, spinning. Chapter 3 considers the period of mechanization, from 1750 to 1830, using a new dataset of more than 5000 observations of wages and working time from the early factory system and descriptive primary and secondary sources. It demonstrates that factory production dramatically changed the components of work quality in this sector, caused large-scale technological unemployment, and transformed the gender composition of the workforce. Chapter 4 continues the British spinning case study up to 1910, focusing on cotton spinning in Lancashire. It demonstrates the limitations of partial automation technology and the effects of managers' cost-cutting strategies, regulation, and exclusionary union practices.

The next two chapters explore the transformation of spinning in the Northeastern United States, in which a barter-based, frontier economy adopted a variety of industrial models in the early factory era.[21] Chapter 5 presents the first dataset of earnings by American hand spinners and contrasts their working conditions with factory systems in Rhode Island, the Lowell mills, and Philadelphia. These three approaches to industrialization demanded more effort and hours from workers, but the Lowell system provided greater security and higher wages in the early decades. The qualitative analysis of factory work is underpinned by more than 2000 wage and working time observations from the archival records of New England factories. Chapter 6 describes how managers aimed to secure higher productivity from the 1840s by demanding more effort from workers after firms installed high-speed machinery. Rising intensity and stagnant wages in the mid-19th century drove most native-born workers from the spinning rooms of textile factories, and they were replaced by immigrants from Ireland and then Southern and Eastern Europe who had fewer alternative opportunities. The mule spinning operative, who remained a highly-paid worker in Britain with extensive control on the shopfloor, was stripped of many of his responsibilities in the United States and increasingly replaced by alternative technology. Chapter 6 also outlines the extended and fitful process of attempting to regulate American textile mills, which eventually reduced hours and child labor, although it made little impact on occupational safety.

Chapters 7–9 discuss the dramatic technological changes of the Transportation Revolution in the Northeastern United States. Chapter 7 considers the period up to

[21] For Chapters 5–9, the Northeast is Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, and Delaware.

1830, and includes the first wage and working time data for American road repairs, pre-canal transportation services, and canal repairs before the Erie Canal. These datasets comprise more than 3000 observations of wages and working time from a highly dispersed set of manuscript sources. In the mid-18th century, interurban transportation employed few workers and provided a patchwork of services. From the late 18th century up to 1830, Americans built privatized roads and then canals, which moderately expanded the task range of work, increased the scale of operations, and began to stratify work-related wellbeing.

Chapter 8 outlines how the railroad accelerated these developments from 1830: its geographical scale and wide range of technical and organizational challenges increased the task range much further, which led to a commensurate increase in specialization. This new division of labor further stratified job quality. The job-related wellbeing of many on-train personnel, who worked long hours and had high occupational risks, was much lower than the high earnings, extensive work control, and safe conditions of railroad managers. The occupational quality analysis in Chapters 8 and 9 is based in part on more than 5000 observations of Northeastern railroaders' income and working time from 1840 to 1889, drawn from manuscript railroad payrolls and pay slips. The final case study section (Chapter 9) surveys the wide array of technical improvements to railroads, including new safety devices, developed from 1860 to 1910. While some innovations could have saved hands, limbs, and lives, many railroads were slow to adopt them. Moreover, managers' pressure to carry more goods in longer trains limited the safety-enhancing effects of new technology, and kept the race between productivity and safety a close contest.

The final chapter recapitulates the key findings of the thesis, places them in the context of research on historical living standards and technological change, and suggests implications of this study for job polarization and the future of work. Macroinventions may create a variety of new, good jobs, but they can also lead to greater inequality, and do not prevent stagnation of work-related wellbeing for workers at the bottom. Policies that enhance worker bargaining power may help to make future technologically-induced productivity improvements politically acceptable. Further, broad standards for working conditions can mitigate the downsides of the race between productivity and good jobs by limiting firms' reliance on labor intensification to extract higher output-per-worker.

Chapter 2
Good Jobs and Bad Jobs in History

Chapter Abstract

This chapter argues that the quality of employment—whether workers are employed in 'good jobs'—is an important aspect of wellbeing, and constructs an index to measure historical occupational quality. The chapter begins by explaining why work quality should be included as a measure of living standards. It describes the literature on present-day job quality and uses historical workers' perspectives about the aspects of jobs they valued to derive components of job quality in the past. It then outlines how to measure the components and combine them in a Historical Occupational Quality Index, suggests sources that provide information about the components, and sets out the analytical narrative approach to describe work-related wellbeing that underpins quantification. Finally, it describes the second and third elements of the thesis methodology, changes in the number of jobs in a sector (occupational availability) and the characteristics of workers employed in a sector (occupational distribution).

Introduction

There is a diversity of metrics to analyze human wellbeing in the past. Income, consumption, outcome measures including anthropometrics and vital statistics, and capability measures such as the Human Development Index contribute to a rounded view.[1] This chapter argues that the quality of occupations is an important aspect of historical living standards and constructs the first index to measure this part of quality of life. Measures of wellbeing are explicitly or implicitly based on preferences. Evidence of workers' expressed interests from union organizing, strikes, political

[1] Selected contributions, particularly to the classic British debate, include, on income: Peter H. Lindert and Jeffrey G. Williamson, "English Workers' Living Standards During the Industrial Revolution: A New Look," *The Economic History Review* 36, no. 1 (1983). Jeffrey G. Williamson, *Did British Capitalism Breed Inequality?* (Boston: Allen & Unwin, 1985). Charles Feinstein, "The Rise and Fall of the Williamson Curve," review of Did British Capitalism Breed Inequality?, Jeffrey G. Williamson, *The Journal of Economic History* 48, no. 3 (1988). "Pessimism Perpetuated: Real Wages and the Standard of Living in Britain During and after the Industrial Revolution," *The Journal of Economic History* 58, no. 3 (1998). Consumption: Joel Mokyr, "Is There Still Life in the Pessimist Case? Consumption During the Industrial Revolution, 1790–1850," ibid.48, no. 1 (1988). Sara Horrell and Deborah Oxley, "Bringing Home the Bacon? Regional Nutrition, Stature, and Gender in the Industrial Revolution," *The Economic History Review* 65, no. 4 (2012). Ian Gazeley and Sara Horrell, "Nutrition in the English Agricultural Labourer's Household over the Course of the Long Nineteenth Century," ibid.66, no. 3 (2013). Anthropometrics: Roderick Floud, Kenneth W. Wachter, and Annabel Gregory, *Height, Health and History: Nutritional Status in the United Kingdom, 1750–1980* (Cambridge: Cambridge University Press, 1990). John Komlos, "The Secular Trend in the Biological Standard of Living in the United Kingdom, 1730–1860," *The Economic History Review* 46, no. 1 (1993). Stephen Nicholas and Deborah Oxley, "The Living Standards of Women During the Industrial Revolution, 1795–1820," ibid., no. 4. Vital statistics: Thomas McKeown and R. G. Record, "Reasons for the Decline of Mortality in England and Wales During the Nineteenth Century," *Population Studies* 16, no. 2 (1962). Kirsty McNay, Jane Humphries, and Stephan Klasen, "Excess Female Mortality in Nineteenth-Century England and Wales: A Regional Analysis," *Social Science History* 29, no. 4 (2005). Using the Human Development Index: Partha Dasgupta and Martin Weale, "On Measuring the Quality of Life," *World Development* 20, no. 1 (1992). N. F. R. Crafts, "Some Dimensions of the 'Quality of Life' During the British Industrial Revolution," *The Economic History Review* 50, no. 4 (1997); "The Human Development Index and Changes in Standards of Living: Some Historical Comparisons," *European Review of Economic History* 1, no. 3 (1997). Subjective indicators of wellbeing have been explored much less by historians but play an increasing role in contemporary discussions. One example is Gross National Happiness, measured in the World Happiness Report produced by the UN Sustainable Development Solutions Network. Also see contemporary studies of subjective work-related wellbeing discussed in the Introduction.

advocacy, wage premia, and demands for insurance suggests that they have been concerned with occupational quality. Using this evidence, the chapter sets out components of good work in history. Historical sources can be used to analyze job quality based on these components, and the chapter presents an approach to measure the eight components and combine them in an index of good jobs in the past.

Analysis of job quality brings a new dimension to historical social science on wellbeing. Economic historians have discussed how technology, *inter alia*, has impacted some aspects of occupations in the past, but work-related wellbeing has not been described or measured systematically. By contrast, as noted in Chapter 1 above, there has been substantial research on the quality of present-day jobs.[2] Measurement of occupational quality in contemporary research is based on survey data that captures job satisfaction or aggregate statistics for aspects of jobs such as pay and working hours. Representative survey data is not available to historians and present-day objective measures focus on the aspects of work that are easiest to quantify, which limits researchers' view of the attributes of a good job.[3] Survey data are also vulnerable to changes caused by peer effects and adaptive expectations. The index of job quality constructed below is composed of eight aspects of work that can be quantified or

[2] In addition to studies cited in the Introduction, contemporary approaches include (among many): Iftikhar Ahmed, "Decent Work and Human Development," *International Labour Review* 142, no. 2 (2003). Dharam Ghai, "Decent Work: Concept and Indicators," ibid.; Janine Leschke and Andrew Watt, "Job Quality in Europe," *ETUI-REHS Working Papers* (2008). Sandrine Cazes, Alexander Hijzen, and Anne Saint-Martin, "Measuring and Assessing Job Quality," *OECD Social, Employment and Migration Working Papers* No. 174 (2015). Sally Wright et al., "Indicators of Job Quality," in *CIPD Research Reports* (2018). Earlier literature on this topic is collected in James C. Taylor, *The Quality of Working Life: An Annotated Bibliography* (1973).

[3] One example is the very narrow US Private Sector Job Quality Index, which compares the share of high-wage, high-hour jobs and low-wage, low-hour jobs. Daniel Alpert et al., "The U.S. Private Sector Job Quality Index," (Cornell Law School, 2019).

scored to produce a composite historical measure of occupational quality. This index allows researchers to compare the quality of jobs across time and space.

The following section justifies including occupational quality as a measure of wellbeing. It then provides historical evidence for the aspects of jobs that workers valued and uses this evidence to outline the components of an occupational quality index. The next section describes potential sources of information for the index, the analytic narrative approach used in this thesis to describe work-related wellbeing before quantifying job attributes, and summarizes the scales for converting qualitative evidence into numerical values.[4] The penultimate section discusses the second and third elements of the impact of technological change on work—the availability of work and its distribution. The conclusion recapitulates the evidence presented for measuring work-related wellbeing and notes further uses for historical job quality measurement.

Approaches to Measurement and Work-Related Wellbeing

Economic historians generally construct measures of past economies using at least one of two motivations: deductive approaches, which examine quantifiable aspects of history that present-day scholars think had a meaningful impact on the past and perhaps the present; and inductive approaches, which use quantifiable elements of the past that contemporaries said were important to them. Deductive measures may include social savings or national income, which few contemporaries discussed but

[4] Complete scoring rubrics are provided in Appendix 1.

the importance of which are now obvious to researchers. Inductive measures may include earnings, share valuations, interest rates, and demographic figures.

Metrics for human wellbeing are based on an inductive approach: we measure what people thought was important to their quality of life. We use wages and diets because we know that people cared about their income and consumption; we use anthropometrics because there is evidence that people preferred to be healthier; we examine vital statistics because humans wanted to live long lives in the company of family and friends with similar longevity. Historical social science aims to analyze the past to better understand the period of study and to inform the present and future. To achieve either of these goals, measurement of historical wellbeing must be based on the expressed preferences of people in the past.

Using an inductive approach that looks to past attitudes shows that work is central to quality of life. As long as labor earnings have been required to satisfy needs and wants, the availability of work has been essential. People have known they must work and have feared unemployment.[5] And as long as people have needed employment, they have demonstrated concern and interest in their inputs (in time and effort), their work experience (control and conditions), and the outcomes of their work (in wages and health), as will be described in more detail below. Measures of wellbeing aim to determine how living conditions have changed over time. Workers

[5] James Vernon, *Hunger: A Modern History* (Cambridge: Belknap, 2007), 239; Matt Perry, *The Jarrow Crusade: Protest and Legend* (Sunderland: University of Sunderland Press, 2005); Roy Rosenzweig and Paul Buhle, "Organizing the Unemployed: The Early Years of the Great Depression, 1929–1933," in *Workers' Struggles, Past and Present*, ed. James Green (Temple University Press, 1983). For a present-day view, see Andrew E. Clark, "Work, Jobs, and Well-Being across the Millennium," in *International Differences in Well-Being*, ed. Ed Diener, Daniel Kahneman, and John Helliwell (Oxford: Oxford University Press, 2010), 439–40.

in the past cared about the quality of their jobs, and researchers analyzing their quality of life should be interested in it as well.[6]

While economic history has not examined work-related wellbeing independently or systematically, there is a large body of research that attempts to measure job quality in the present. This has been motivated in part by falling numbers of good middle-class jobs in rich countries, a process described as job polarization or 'hollowing out'.[7] Scholars have shown this phenomenon is a result of technological change and import competition, and linked the declining number of manufacturing jobs that required modest formal education to the rise of economic populism in the late 2010s.[8] These findings suggest that measuring changes in the availability of good jobs can contribute to political history as well as research on the development of wellbeing.

In part as a result of job polarization and the broader movement towards measuring multidimensional wellbeing, the International Labour Organization has promoted the concept of 'decent work', which has been included in Sustainable Development Goal 8. The SDGs are globally-agreed benchmarks for improving lives, ensuring equality, and protecting the planet for the 2015–2030 period. SDG 8 combines the aspiration of economic growth with the availability of 'full and productive

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[6] An alternative justification for present-day job quality measurement is Rafael Muñoz de Bustillo et al., "E Pluribus Unum? A Critical Survey of Job Quality Indicators," *Socio-Economic Review* 9, no. 3 (2011).

[7] David H. Autor, Lawrence F. Katz, and Melissa S. Kearney, "The Polarization of the U.S. Labor Market," *American Economic Review* 96, no. 2 (2006). Maarten Goos and Alan Manning, "Lousy and Lovely Jobs: The Rising Polarization of Work in Britain," *The Review of Economics and Statistics* 89, no. 1 (2007).

[8] Italo Colantone and Piero Stanig, "Global Competition and Brexit," *American Political Science Review* 112, no. 2 (2018). David Autor et al., "Importing Political Polarization? The Electoral Consequences of Rising Trade Exposure," *American Economic Review* 110, no. 10 (2020).

employment' and 'decent work for all'.[9] In addition, the European Union has committed to 'more and better jobs' in its European Pillar of Social Rights Action Plan.[10] Interest in 'decent work' has stimulated a plethora of contemporary studies, many produced by NGOs or government agencies, that attempt to construct measures of 'decent work' or occupational quality.[11] Academic research has also explored measures of work quality and emphasized the importance of aspects that can be more difficult to quantify than wages and work hours, such as work stress, as well as heterogeneity across sectors.[12]

The composition of present-day indices varies, with some providing a theoretical justification for their components and others using survey data to derive them. Variation in the composition and sources of different indices have made international comparisons difficult.[13] A historical index of job quality needs to be usable in a wide variety of contexts, with flexibility to adapt to local conditions, like

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[9] United Nations Department of Economic and Social Affairs, "Goal 8," https://sdgs.un.org/goals/goal8.

[10] European Commission, "European Commission's Priorities," https://ec.europa.eu/info/strategy/priorities-2019-2024_en.

[11] In addition to references above, see David Bescond, Anne Châtaignier, and Farhad Mehran, "Seven Indicators to Measure Decent Work: An International Comparison," *International Labour Review* 142, no. 2 (2003). Florence Bonnet, José B. Figueiredo, and Guy Standing, "A Family of Decent Work Indexes," ibid.; ibid. Francis Green and Tarek Mostafa, "Job Quality Indices for Europe," (LLAKES Centre, Institute of Education, London). Janine Leschke, Andrew Watt, and Mairead Finn, "Putting a Number on Job Quality? Constructing a European Job Quality Index," *ETUI-REHS Working Papers* (2008). Rafael Muñoz de Bustillo et al., "Indicators of Job Quality in the European Union," (EU Directorate General for Internal Policies Policy Department A: Economic and Scientific Policy, 2009).

[12] Andrew E. Clark, "Your Money or Your Life: Changing Job Quality in OECD Countries," *British Journal of Industrial Relations* 43, no. 3 (2005); Nádia Simões, Nuno Crespo, and José Castro Pinto, "Determinants of Job Quality — Evidence for European Country Groups," *Acta Oeconomica* 65, no. 2 (2015). Greg Kaplan and Sam Schulhofer-Wohl, "The Changing (Dis-)Utility of Work," *Journal of Economic Perspectives* 32, no. 3 (2018). There is an earlier literature on good jobs from the 1970s, including James O'Toole, *Work and the Quality of Life: Resource Papers for Work in America* (Cambridge: MIT Press, 1973).

[13] Cazes, Hijzen, and Saint-Martin, "Measuring and Assessing Job Quality," 12.

refinements to Robert Allen's welfare ratio methodology.[14] To construct an index of work-related wellbeing in the past, this thesis derives components from evidence of historical workers' views. Just as economic historians base many of our measures of living standards on the expressed preferences of people in the past (albeit usually without a discussion of choices about what to measure), the elements of occupations that mattered to workers can also be determined inductively. This approach requires evidence on what workers have desired in occupations or demanded from their employers. Strikes, petitions, labor organizing, political advocacy, and insurance purchases indicate the aspects of jobs that were important to workers, and this method parallels the survey-based approach of some contemporary studies.[15]

Strikes were a direct expression of discontent, and their precipitating causes expressed workers' preferences. Studies of the causes of strikes have produced extensive evidence about workers' motivations.[16] Petitions to employers or political bodies directly demonstrated workers' preferences in their own words. Wage premia also provide insights: if workers were offered additional compensation for some

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[14] Kathryn E. Gary and Mats Olsson, "Men at Work: Wages and Industriousness in Southern Sweden, 1500–1850," *Scandinavian Economic History Review* 68, no. 2 (2020); Mauro Rota and Jacob Weisdorf, "Italy and the Little Divergence in Wages and Prices: New Data, New Results," *The Journal of Economic History* 80, no. 4 (2020).

[15] Richard Anker et al., "Measuring Decent Work with Statistical Indicators," *International Labour Review* 142, no. 2 (2003)., 150. The recent CIPD index has used survey data on workers' priorities, "UK Working Lives: Survey Report," in *CIPD Research Reports* (2018).

[16] A detailed enumeration of the causes of late 19th century American strikes, which includes many of the concerns in this section, is *Tenth Annual Report of the Commissioner of Labor: Strikes and Lockouts, Volumes I & II* (Washington, 1896). There is a cautionary note in Isaac Cohen, *American Management and British Labor: A Comparative Study of the Cotton Spinning Industry* (New York: Greenwood, 1990), 154–55. Other compilations include Massachusetts Bureau of Statistics, *Thirty-Ninth Annual Report on the Statistics of Labor* (Boston, 1909), F. Peterson, "Strikes in the United States, 1880–1936", *Bureau of Labor Statistics Bulletin* No. 651 (1938). A description of 'non-economic' strike causes on American railroads is provided in Shelton Stromquist, *A Generation of Boomers: The Pattern of Railroad Labor Conflict in Nineteenth-Century America* (Urbana: University of Illinois Press, 1987), 31–40.

occupations, this suggests that they disliked attributes of such jobs. When workers organized or demanded government programs to ameliorate occupational risks, we can see their preferences to avoid dangerous or precarious conditions. We can also observe workers' preferences when they have demanded compensation, through political advocacy or the legal system, for enduring working conditions they considered harmful or unacceptable.

Workers have consistently expressed an interest in their wages and many strikes have had earnings as their proximate cause. Working time has been a recurrent point of contention, and there have been many campaigns for shorter working hours. Stable and secure employment and earnings have also been a concern of employees. Workers who were not employed and paid consistently had difficulty securing sufficient income and smoothing their consumption. Summary dismissals, short-time working, and irregular paychecks have been causes for labor unrest. Another consideration is the health impacts of work. Toiling in an occupation that had a high risk of injury or death from accidents was undesirable and workers organized for improved safety measures at firms that put employees in danger. When work produced industrial disease such as respiratory illness or cancers stemming from chemical exposure, workers demanded compensation, and in some cases set up self-help organizations to insure themselves against accidents and injuries.[17]

[17] See the previous note and, on the stability of earnings, Sara Horrell and Deborah Oxley, "Work and Prudence: Household Responses to Income Variation in Nineteenth-Century Britain," *European Review of Economic History* 4, no. 1 (2000). On accidents, P. W. J. Bartrip and Sandra Burman, *The Wounded Soldiers of Industry: Industrial Compensation Policy, 1833–1897* (Oxford: Clarendon Press, 1983), 14–19.

Control over the work process and supervision are common points of contention in descriptive sources about occupational disputes. Control encompasses how workers were supervised, who determined the location, organization, and pace of work, and if there was harsh discipline. Workers have shown resistance to authoritarian management structures and to violent punishments for contravening company rules; some employers have raised wages to ensure that labor accepts reduced control.[18] The intensity of work also had a clear impact on wellbeing. Frequent physical exhaustion or work that was mentally taxing usually required a wage premium, and workers have demonstrated resistance to high-effort labor. Intensity could also negatively affect other aspects of wellbeing such as physical and mental health.[19] Finally, there is evidence that highly repetitive work was undesirable. Wage premia for very routine work in car manufacturing indicates that monotony reduced job quality.[20]

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[18] Many examples and a description of the contest between employee control and scientific management are provided in David Montgomery, *Workers' Control in America: Studies in the History of Work, Technology, and Labor Struggles* (Cambridge: Cambridge University Press, 1979). Cf. James R. Green, *The World of the Worker: Labor in Twentieth-Century America* (New York: Hill and Wang, 1980). Control has also been discussed in the literature on labor process, including Craig R. Littler, *The Development of the Labour Process in Capitalist Societies: A Comparative Study of the Transformation of Work Organization in Britain, Japan, and the USA* (London: Heinemann Educational, 1982). For more examples, see Wayne Lewchuk, *American Technology and the British Vehicle Industry* (Cambridge: Cambridge University Press, 1987), 64–65. Cohen, *American Management and British Labor*. Richard White, *Railroaded: The Transcontinentals and the Making of Modern America* (New York: W.W. Norton & Co., 2011), 236–37, 422.

[19] Green and Mostafa, "Job Quality Indices for Europe," 9. Intensity was also discussed by historical observers of occupational health, such as J. T. Arlidge, *The Hygiene, Diseases and Mortality of Occupations* (London: Percival & co., 1892), 13–17. Night working contributed to intensity and workers expressed a preference for day work and complained about the exhaustion of night shifts and the difficulty of work in poor light. *Reports of the Society for Bettering the Condition and Increasing the Comforts of the Poor*, vol. IV (London: W. Bulmer and Co., 1805), Appendix 1, 17–18.

[20] James Foreman-Peck, Sue Bowden, and Alan McKinlay, *The British Motor Industry* (Manchester: Manchester University Press, 1995), 169–70. Steven Tolliday, "Management and

Capturing Work-Related Wellbeing in History

The inductive evidence presented above produces an eight-component Historical Occupational Quality Index (HOQI). Some components are quantifiable, but measuring others requires converting descriptive evidence into a numerical value.

Components of the Historical Occupational Quality Index

1. Real Compensation (*w*)
2. Working Time (*t*)
3. Stability/Security of Employment and Earnings (*s*)
4. Immediate Health Risks (*a*) (e.g. from accidents)
5. Long-Term Health Risks (*d*) (e.g. from industrial disease)
6. Supervision & Control (*c*)
7. Work Intensity (*i*)
8. Repetitiveness/Monotony (*r*)

As discussed above, contemporary job quality measures vary between countries, making international comparisons difficult. Historical wellbeing research requires metrics that can be used across space and time. Comparability enables researchers to assess relative performance and clearly identify the causes of improvements or declines in wellbeing. Therefore, evidence for most components of the HOQI can be derived from a variety of sources, and the index can be scaled down to the level of a single worker's observations (with detailed evidence in personal diaries and accounts) or calculated using national-level evidence for an occupation.

Evidence to measure earnings and working time can be found in account books, time books, bills, receipts, vouchers, and ledgers. Some narrative sources also provide evidence about standard working hours and the frequency of dismissals and payment. Precisely measuring historical working time is difficult: many sources only

Labour in Britain 1896–1939," in *The Automobile Industry and Its Workers: Between Fordism and Flexibility*, ed. Steven Tolliday and Jonathan Zeitlin (Cambridge: Polity, 1986), 30–31.

provide numbers of days worked but not hours. Measuring working time is even more challenging for piece rate occupations, but it is possible to use descriptive evidence of schedules or standard hours in other occupations to estimate hours of employment. From the 19th century sources such as reports from government labor bureaus or boards provide evidence about hours worked, although scheduled hours were not necessarily the same as actual hours worked.[21]

Components three to eight are more difficult to measure. They are scored based on qualitative evidence to maintain consistency when comparing across periods with varying source availability. Employment security is impossible to precisely quantify before regular employee-level record keeping began at some firms in the late 19th century. However, there is descriptive evidence of stability, and some firms kept reports of dismissals and departures. Payment dates in account books also indicate the (in)frequency of earnings. Before the advent of rigorous labor regulation and widespread insurance for work accidents, there are few sources to quantify health risks. Accident books only survive from the end of the 19th century and their coverage remains patchy in industrialized countries before the interwar period. From the late 19th century, some regulators collected accident reports, although their thoroughness is disputed.[22] To estimate occupational risks for earlier periods, researchers must rely on descriptive information such as compilations of injuries or common diseases by managers or doctors. Later studies of industrial disease for the same or similar occupations may also provide insight. Control over the work process can be

[21] For a recent firm-level study, see Joyce Burnette, "Missing Work: Absenteeism at Pepperell Manufacturing Co. In 1883," *Cliometrica* (2020).
[22] E.g. Bartrip and Burman, *Wounded Soldiers of Industry*, 11–15, 37–38.

determined using qualitative evidence from firms' rules for their employees, discipline records, and workers' diaries and autobiographies. Work intensity can be gauged from similar sources, as well as government reports from labor bureaus and factory inspectors. Handbooks of trades and machinery provide detailed descriptions of tasks that allow the reconstruction of task composition necessary to gauge repetitiveness, and workers' own writings can also be useful.

Measurement of job quality in this thesis relies on extensive analytical description. A detailed picture of the occupations under consideration, focusing on tools, tasks, and workplaces, is essential to assign accurate values for the scored components. As the thesis is primarily concerned with the effects of technology, it places the tools and machines that workers used in the foreground, paired with comprehensive descriptions of tasks. Tasks are the core of occupations and analysis of job-related wellbeing must focus on workers' activities. Work locations shape job quality through their effects on occupational safety, control, and intensity. In Chapters 3–6 and 9 work tasks, work locations, and the components of job quality are analyzed in turn. In Chapters 7 and 8 thematic sections describe elements of work and work-related wellbeing that were common across the workforce, and occupation-specific sections outline variations in job quality between groups of workers.

The HOQI components are similar to components of several present-day indices that use large-scale survey data to measure job quality. However, the HOQI is an indicator of objective rather than subjective wellbeing, as the scored components do not rely on information about job satisfaction.[23] Benefits of an objective approach

[23] Wright et al., "Indicators of Job Quality."

include that it is less vulnerable to adaptive expectations and peer effects. If workers' expectations about their outside options change, such as during a business cycle downturn, this can alter their job satisfaction without any shift in the occupation itself.[24] Satisfaction may also reflect comparisons of compensation or supervision with colleagues and friends rather than a consistent baseline, and jobs may improve absolutely but decline in relative terms.[25] Measures of occupational quality based on expressed satisfaction can be misleading because poor (or good) matching between workers and jobs can produce a lower (or higher) quality score. Job satisfaction is important, but it should be used alongside other indicators.[26] Moreover, measuring subjective wellbeing in the past is difficult, and representative studies are impossible.

Quantifying the first two components (wages and working time) draws on established work in economic history and the study of wellbeing, and the qualitative measures (3–8) use scoring rubrics. Some economic history research has employed scoring systems, and other social sciences have used this method extensively.[27]

The two quantitative components are w and t. Calculating w requires computing the welfare ratio (WR) for a typical worker, using earnings for a week of

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[24] A. E. Clark, "Worker Well-Being in Booms and Busts," in *The Labour Market in Winter*, ed. Jonathan Wadsworth and Paul Gregg (Oxford: Oxford University Press, 2011).

[25] For evidence of peer effects, see David Card et al., "Inequality at Work: The Effect of Peer Salaries on Job Satisfaction," *American Economic Review* 102, no. 6 (2012). Another exposition of jobs as positional goods is Robert H. Frank, *Choosing the Right Pond: Human Behavior and the Quest for Status* (New York: Oxford University Press, 1985), 8, 45–48.

[26] Survey questions and settings can affect subjective wellbeing measurement, see Gabriella Conti and Stephen Pudney, "Survey Design and the Analysis of Satisfaction," *The Review of Economics and Statistics* 93, no. 3 (2011).

[27] Crafts, "Quality of Life." Within economic history, more papers with scoring systems have used binary constructions, e.g. J. Bradford De Long and Andrei Shleifer, "Princes and Merchants: European City Growth before the Industrial Revolution," *The Journal of Law & Economics* 36, no. 2 (1993). There are many examples of scoring qualitative information in political science, including the Polity Index.

work and a consumption basket.[28] The HOQI uses a week as the standard unit of quantifiable work as many historical workers switched jobs on a seasonal basis.[29] However, the *s* component criteria incorporate a penalty for irregular work. The cost of the basket is scaled based on the estimated consumption needs of the modal type of person (e.g. adult woman, child, etc.) employed in an occupation.[30] The items in the basket (e.g. types of food, quantity of fuel and clothing) may be adjusted to suit the location under consideration. To incorporate the diminishing marginal returns to wellbeing, the index uses a quadratic function, as shown in equation [1] below, with the lowest possible value for an occupation (in which work is performed for no compensation) set at 1 to correspond with the lowest values in components 3–8.[31] Regional or inter-firm wage and price variations can be used to compare work quality in different locations or establishments.

$$[1] \qquad w = \sqrt{WR} + 1$$

[28] See Appendix 1 for further details.

[29] Judy Z. Stephenson, "Working Days in a London Construction Team in the Eighteenth Century: Evidence from St Paul's Cathedral," *The Economic History Review* 73, no. 2 (2020). For an earlier period, see John Hatcher, "Unreal Wages: Long-Run Living Standards and the 'Golden Age' of the Fifteenth Century," in *Commercial Activity, Markets and Entrepreneurs in the Middle Ages: Essays in Honour of Richard Britnell*, ed. Ben Dodds and Christian D. Liddy (Boydell & Brewer, 2011).

[30] Based on Humphries' revision of Allen, adult men's consumption baskets are set at 100% of the total cost, adult women at 85%, and children at 60%. Jane Humphries, "The Lure of Aggregates and the Pitfalls of the Patriarchal Perspective: A Critique of the High Wage Economy Interpretation of the British Industrial Revolution," *The Economic History Review* 66, no. 3 (2013). Cf. Robert C. Allen, "The High Wage Economy and the Industrial Revolution: A Restatement," ibid.68, no. 1 (2015).

[31] The method does not use logarithms (which are used for GNI per capita in the HDI) because they would produce negative values when a welfare ratio was less than one. The quadratic also results in less sharply diminishing returns to income. Contra criticisms of the HDI, the HOQI maintains concavity for income. For one brief discussion, see Miles B. Cahill, "Diminishing Returns to GDP and the Human Development Index," *Applied Economics Letters* 9, no. 13 (2002). The extent of diminishing returns to income in subjective measures of well-being varies, see Richard A. Easterlin, "Diminishing Marginal Utility of Income? Caveat Emptor," *Social Indicators Research* 70, no. 3 (2005).

The working time component is scaled to match the scoring rubrics for the qualitative components, the values for which are from 1 (the lowest possible value) to 5. Scaling for working time is based on the HDI, which sets minimum and maximum values for a component and then scales those values to 0 and 1, respectively. The maximum value for Average Hours (AH) is 84 per week (which corresponds to a *t* value of 1) and the minimum is 20 (a *t* value of 5). The equation for scaling is simplified and presented in [2] below.

[2] $$t = 6.25 - \frac{\mathrm{AH}}{16}$$

Scoring for the qualitative components is based on criteria that are explained fully in Appendix 1; a short summary is provided here. As noted above, better jobs will receive higher scores on the 1–5 scale. Stability of earnings (*s*) is scaled from 1 (unpredictable employment with inconsistent payment times or incomplete payment) to 5 (high job security with regular payments). Immediate health risks (*a*) range from a very high probability of serious injury or death at work—perhaps in an occupation such as logging—to very safe occupations that have low risks of minor injuries—most white-collar jobs. Long-term health impacts (*d*) vary from high risk of industrial disease in an occupation such as coal mining to low-risk modern office occupations.[32]

The scale for control and supervision (*c*) runs from, on the low-quality end, total employer control over the location, manner, and order of task completion, to, on

[32] Separating the two health components allows researchers to assess risks independently. This is useful for jobs with a high probability of injury or death that may not have had long-term health effects for those who survive their term of employment. It also allows for future improvements to component weights based on evidence of changing time discounting with increasing longevity. For example, there is evidence that the value of life rose in the 20th century. Dora L. Costa and Matthew E. Kahn, "Changes in the Value of Life, 1940–1980," *Journal of Risk and Uncertainty* 29, no. 2 (2004).

the high-quality end, worker discretion over the location and conduct of their work. The physical and psychological effects of violent supervision are incorporated in the *a* and *d* components. For work intensity (*i*) a job scored as 1 was maximally physically or mentally exhausting—day labor in construction or working as an emergency room nurse are examples, while jobs with minimal exertion would receive higher scores.[33] Occupations that require working hours that disrupt normal patterns of rest, such as night shifts, will also score lower on this component. The repetitiveness or monotony of work (*r*) is scored based on the variety of tasks involved in an occupation. Jobs that consist of the same task or handful of tasks for the entire working day scored as 1, and occupations that contain a variety of tasks should receive higher scores.

The remaining challenge is weighting, perhaps the greatest problem for composite indicators of well-being. There are two common approaches: 1) a 'naïve' set of weights, which usually assign equal weight to all components, as in the HDI; 2) attempts to assign empirical weights.[34] However, the economic history literature rarely engages with the point made at the beginning of the previous section: *the choice of components should be based on evidence of preferences*. Several recent works have used a more empirical approach to weighting a given set of components but provide little

[33] The scoring of this component draws on the Work Intensity Index in Green and Mostafa, "Job Quality Indices for Europe," 9, 19.

[34] For method 1, see Leandro Prados de la Escosura, "World Human Development: 1870–2007," *Review of Income and Wealth* 61, no. 2 (2015); "Human Development in the Age of Globalisation," *European Historical Economics Society Working Papers* No. 157 (2019). The HDI similarly lacks an empirical basis for its components or for its weights. Dasgupta and Weale, "On Measuring the Quality of Life." See also Partha Dasgupta, "Well-Being and the Extent of Its Realisation in Poor Countries," *The Economic Journal* 100, no. 400 (1990). For method 2, see Daniel Gallardo-Albarrán and Herman de Jong, "Optimism or Pessimism? A Composite View on English Living Standards During the Industrial Revolution," *European Review of Economic History* 25, no. 1 (2020).

or no evidence for the choice of components.[35] By contrast, the HOQI components are based on historical evidence of workers' preferences. The index combines them using a naïve, HDI-style set of weights, as shown in equation [4] below.

Beyond questions of weighting, there is a more serious criticism of composite indices: that they contain the implicit preferences of researchers and their aggregation obscures more than it reveals.[36] Blithe acceptance of data from composite indices can be misleading. However, as described above, the HOQI is not a purely quantitative tool and stands on two empirical foundations. First, it is constructed from the expressed preferences of historical workers about what aspects of jobs were important. Second, quantification is based on an extensive analytical narrative that describes work and its positive and negative attributes in detail. Moreover, without a composite indicator it is not possible to make any consistent claims about improvement or declines in multidimensional job quality across long periods or between locations. Researchers simply return to the century-old living standards debate: a dispute between quantitative and qualitative evidence or between countervailing movements in different qualitative elements of wellbeing. The HOQI provides a consistent yardstick for measuring work-related wellbeing, and the criteria for the scored components can be useful for research that takes a purely descriptive approach to job quality. Future improvements to the naïve weighting system can further enhance our understanding of historical wellbeing.

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[35] E.g. "English Living Standards."

[36] Nicola Amendola and Giacomo Gabbuti, "Human Development," in *Measuring Wellbeing: A History of Italian Living Standards*, ed. Giovanni Vecchi (New York: Oxford University Press, 2016). Nicola Amendola, Giacomo Gabbuti, and Giovanni Vecchi, "On the Use of Composite Indices in Economic History: Lessons from Italy, 1861–2017," *HHB Working Papers Series* No. 11 (2018).

Finally, there is the issue of compensating differentials. If dangerous work was compensated by high wages, what is the value in a composite index? There are at least two answers to this point: first, many dangerous jobs were also poorly-paid, particularly when the long-term health risks were not known.[37] Nonetheless, those poorly-understood health risks did impact workers' quality of life. Second, a composite index allows researchers the opportunity to analyze the size of compensating differentials, how they changed over time, how non-wage aspects of jobs can also compensate for downsides, and to explore how preferences varied across space and time.

To compute composite job quality, the index takes the geometric mean of the six components that are scored using qualitative information (*s*, *a*, *d*, *c*, *i*, *r*) in equation [3] and then the geometric mean of this composite qualitative (*q*) component and the two quantitative components, *w* and *t*, in equation [4].[38]

[3] $$q = \sqrt[6]{s \bullet a \bullet d \bullet c \bullet i \bullet r}$$

[4] $$\text{HOQI} = \sqrt[3]{w \bullet t \bullet q}$$

This composite measure is the first platform for measuring occupational quality in history. The ordinal ranking of occupations is the main object of investigation: the index can show, given the components and weights used, whether the same jobs improved over time and if some jobs were better or worse than others.

[37] P. W. J. Bartrip, *The Home Office and the Dangerous Trades: Regulating Occupational Disease in Victorian and Edwardian Britain* (Amsterdam: Rodopi, 2002), 6.

[38] A geometric mean is also used in other indices of contemporary and historical wellbeing, including the HDI and Prados de la Escosura's Augmented HDI. Leandro Prados de la Escosura, "Augmented Human Development in the Age of Globalization," *The Economic History Review* 74, no. 4 (2021).

Building a universe of historical occupations from many locations and periods will allow for comparisons between jobs based on their cardinal values.

Occupational Availability & Distribution

The Historical Occupational Quality Index provides a multifaceted approach to describe and measure the work-related wellbeing of people employed in the past. Accounting for the impact of technological change on jobs must consider two further facets: the quantity of work available (occupational availability), and who was employed (occupational distribution). Occupational availability is simply the number of people employed in an occupation or sector, which is important to consider as improvements in occupational quality may be offset by technological unemployment.[39] Occupational distribution is the demographics and locations of the workforce. The principal characteristics considered in the case studies are age, gender, location, and race or national origin. This strand of the analysis accounts for the distributional consequences of changes in labor demand that affect different types of workers differently. Shifts in the composition of the labor force may have been the result of technological changes that pushed employers to hire more trained workers or smaller (younger) operatives, but the case studies show that occupational distribution was shaped by social as well as economic and technological factors.

[39] Ghai, "Decent Work: Concept and Indicators," 115–21.

Summary

This chapter has argued that job quality is an important element of historical living standards. It has presented evidence for the aspects of an occupation that workers valued, outlined how to measure these components, and shown how to combine them into a yardstick for work-related wellbeing. The HOQI is an analytical framework and a metric for quality of life that can illuminate and clarify important aspects of historical changes in wellbeing. The component-based approach enables analysis of tradeoffs between occupations and inequalities of work-related wellbeing, and the composite calculation enables long-term comparisons of the availability of decent work.

An occupational quality approach has value beyond analysis of technological change. For historical social science that attempts to measure life in the past to understand a specific context, and for research that analyzes history to produce policy-relevant findings for the present, understanding work-related wellbeing adds to our knowledge about quality of life. For example, job quality analysis can shed light on the past impacts of regulation, the effects of unionization, and differences in wellbeing between firms, cities, or countries. Further, historical evidence about how and why the quality of jobs changed in the past can help policymakers and employers design better work and labor institutions.

Economic historians should investigate the quality of work for the same reason that we measure other aspects of past wellbeing: because we have evidence that people cared about it. That evidence enables us to systematically analyze work quality in history, and primary sources provide the data and qualitative information to measure

and score components of occupational quality. Using this multifaceted perspective and a mixed-methods approach more fully incorporates workers' experiences into our understanding of wellbeing in the past.

The next seven chapters use the HOQI, with occupational availability and job distribution analysis, to assess how innovation has changed work and access to jobs in three historical case studies. The chapters describe how technology has produced unemployment, created new jobs while increasing the inequality of wellbeing, led to competition between rising productivity and job quality, and shifted the demographic composition of workplaces.

Chapter 3
Spinning in the British Industrial Revolution, 1750–1830

Chapter Abstract

This chapter describes the transformation of work in spinning during the British Industrial Revolution. It uses the methodology outlined in Chapter 2, a new dataset of more than 5000 observations of factory wages and working time, and qualitative evidence from manuscript and printed sources to outline how jobs changed in this dynamic sector. Before industrialization, a spinning wheel was operated by a single hand spinner, but factory machines increased the task range and firms responded by dividing the new tasks into several occupations subject to labor discipline. This division of labor produced inequality of work-related wellbeing. Most spinning jobs changed from low-pay, high-control, low-risk work to higher-paid but low-control and more dangerous occupations. There were some jobs, such as overseer and mule operative, with very high pay and high control. The initial phase of industrialization in spinning included male-biased technological change, as men claimed the best jobs and many women hand spinners were left without employment.

Introduction

Clothing production was the second-largest sector of the preindustrial British economy after agriculture, employing hundreds of thousands of hand spinners in the mid-18th century.[1] After centuries with little technological change, three inventions in the 1760s and 1770s made textiles one of the most dynamic sectors of the First Industrial Revolution. Machine spinning began in the 1760s and factories largely replaced hand spinning by the early 19th century. Technological change shifted workers into new premises, expanded the task range, and changed the age and gender composition of the workforce. The expanded task range led to a greater division of labor, created new jobs, and increased inequality of wellbeing. Men secured the best factory occupations while many women who had spun using spinning wheels suffered technological unemployment.

The first sections of this chapter describe hand spinning work and job quality. The next sections outline the three machines of the Industrial Revolution and the tasks of workers who used them, before moving to an analysis of job quality in the factory, encompassing work premises, pay, and conditions. The chapter concludes by synthesizing the dimensions of job quality and estimating technological unemployment in cotton spinning. The focus of the job quality analysis follows the course of employment in this sector, shifting from hand spinning of wool and linen to factory spinning of cotton.

[1] S. N. Broadberry et al., *British Economic Growth, 1270–1870* (Cambridge: Cambridge University Press, 2015); Craig Muldrew, "'Th'ancient Distaff' and 'Whirling Spindle': Measuring the Contribution of Spinning to Household Earnings and the National Economy in England, 1550–1770," *The Economic History Review* 65, no. 2 (2012).

Hand Spinning

For hundreds of years before industrialization spinners produced yarn using spinning wheels or the spindle and distaff. [2] The main fibers used in British textile production were wool, which was divided into woollen and worsted, flax, cotton, hemp, and silk. Woollen production used shorter-staple wool to make fluffier, heavier fabrics, while worsted cloth was made from longer-staple wool.[3] The regions with concentrated preindustrial textile production primarily produced woollen and worsted; linen production was more diffuse. Cotton entered the British market in the early modern period and was primarily used for weft in cloths with a linen warp.[4] All fibers required preparation before spinning. Flax required the most extensive preparation: it had to be wetted to dissolve its internal connective substances, then dried, broken up, and combed ('hackled') to remove woody pieces and align the fibers.[5] All fibers were cleaned and carded or combed (drawn between two parallel

[2] By the 18th century, the spindle and distaff were used for fine spinning or in peripheral areas. The distaff was a short pole that held unspun fiber; spinners usually propped it under one arm. The spinner held the narrow cylindrical spindle in the opposite hand, drew out fiber from the distaff, and used a weighted 'drop' spindle that rotated to twist the fiber.
[3] Silk spinning ('throwing') was mechanized in Italy during the late Middle Ages. It is excluded on account of its earlier technological change. D. C. Coleman, *Courtaulds: An Economic and Social History*, vol. 1 (Oxford: Clarendon Press, 1969), 12–16. Anthony Calladine, "Lombe's Mill: An Exercise in Reconstruction," *Industrial Archaeology Review* 16, no. 1 (1993): 82–84. While some hand and machine spinners used jute and nettle, and animal fibers including llama, alpaca, and dog, these were a minor share of output. Patricia Baines, *Spinning Wheels, Spinners and Spinning* (London: Batsford, 1977), 17.
[4] 'Warp' refers to the generally stronger yarns placed lengthwise on a loom; 'weft' is usually softer, and sent widthwise by the shuttle between the taut warp yarns. Alfred Powell Wadsworth and Julia de Lacy Mann, *The Cotton Trade and Industrial Lancashire, 1600–1780* (Manchester: Manchester University Press, 1931), 12–17.
[5] Baines, *Spinning Wheels*, 18–25. *Linen: Hand Spinning and Weaving* (London: Batsford, 1989), 14–16.

wooden surfaces with fine wire hooks). This process formed proto-threads, called rovings, for spinning.[6]

Spinning shaped and stored fiber with three processes: pulling the roving out along its length to reduce its width (imparting draft), using the rotating spindle to twist the fibers together (friction between tightly-twisted fibers gave the yarn strength), and winding the yarn into a cylindrical package or 'cop', past the tip of the spindle.[7] A wheel spinner held a length of roving in one hand while the other end of the roving was wrapped around the spindle. To spin, she slowly released roving while rotating the wheel with her free hand. The rotating wheel turned the spindle via a cord or belt. A wheel spinner controlled the draft as fiber passed through her fingers and regulated twist using the rotational speed of the wheel. Once she produced a thread of suitable strength, length, and fineness between the tip of the spindle and the hand she used to hold the roving, she wound the yarn onto the cop.[8]

Spinning wheel maintenance or repair was simple, rapid, and inexpensive: the only moving parts were the wheel, the spindle, and the band that transmitted rotation from the former to the latter. Wheels, normally 60–100 cm in diameter, and the apparatus on which they rested were made of wood, with bearings sometimes made

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[6] *Spindle Spinning Cotton: An Introduction to the Technique*, Rev. ed. (Farnham: P. Baines, 1994), 2–3.

[7] Worsted spinners drafted and twisted in separate motions. Flax spinners generally wetted their fingertips to soften the fibers, which improved yarn quality. *Linen*, 26–27, 50. For finer points, see D. T. Jenkins and Kenneth G. Ponting, *The British Wool Textile Industry: 1770–1914* (London: Heinemann, 1982), 18–21. Muldrew, "'Th'ancient Distaff'," 501–04. Also Harold Catling, *The Spinning Mule* (Newton Abbot: David & Charles, 1970), 14–16.

[8] Beginning in the 16th century the 'flyer' wheel allowed spinners to twist and wind in a continuous motion, which sped up their work. The flyer was a U-shaped piece of wood with several metal hooks along its arms. Yarn was drafted, twisted off the spindle, and then routed through one of the hooks and onto the rotating bobbin for winding. *Spinning Mule*, 16.

from leather. The spindle, usually 13–25 cm in length, was made from metal or wood.[9] The largest wheels were used for wool spinning and required spinners to walk backwards and forwards to draw out fiber and then wind on to the cop, covering up to 10 kilometers per day. Cotton spinning wheels were smaller, around 75 cm.[10] Unless they were standing to spin on a 'great' wheel, spinners generally sat on a wooden chair or stool next to the wheel.[11] Most spinners turned the wheel by hand, but foot pedals became increasingly popular during the early modern period.[12]

Hand Spinning: Organization and Quality of Work

The two main systems for hand spinning were household labor and 'putting-out'. In the former, a family or household unit carded fiber, spun it into yarn, wove fabric, and sold it. The latter system, which was more common, divided production steps across households: a woman received yarn, spun it, and turned it over to a merchant who arranged weaving.[13] The second model took its name from the fact that work was given or 'put out' to spinners. In both systems, most hand spinners worked at home, where they had almost total control over the work process. Merchants could only supervise a spinner's activities by reducing her payment or cutting her off from further employment. When this occurred it was usually punishment for poor quality

[9] Baines, *Spinning Wheels*, 42, 48–58.
[10] *Spinning Wheels*, 60–62.
[11] *Spinning Wheels*, 104.
[12] Abbott Payson Usher, *A History of Mechanical Inventions* (Cambridge, Mass.: Harvard University Press, 1954), 295.
[13] Pat Hudson, "From Manor to Mill: The West Riding in Transition," in *Manufacture in Town and Country before the Factory*, ed. Maxine Berg, Pat Hudson, and Michael Sonenscher (Cambridge: Cambridge University Press, 1983), 124–25. Jenkins and Ponting, *The British Wool Textile Industry*, 8–11.

yarn, slow delivery, or fiber embezzlement.[14] Some hand spinning occurred in spinning schools and workhouses that received raw fiber from a merchant. An instructor or overseer monitored work, which added some labor discipline.[15]

Spinning was a seasonal and cyclical employment. Spinners frequently stopped for the harvest or worked more during the winter.[16] Irregular work could be reinforced by seasonal changes in remuneration, deadlines for cloth output to reach exporting ships, and cyclical fluctuations in demand.[17] Therefore, earnings in spinning could be inconsistent, both by choice and because of factors beyond a worker's control. There is no evidence of serious accidents in court records, although indoor work may have included a small risk of injury from fire. The physical and mental exertion was modest, although producing finer yarns required more focus and skill. All hand spinning was very repetitive. A large majority of spinners were women and girls, though some sources show that boys spun and assisted female spinners.[18]

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[14] T. W. Hanson, "Jonathan Akroyd's Account Books," *Transactions of the Halifax Antiquarian Society* (1939): 142. Sidney Pollard, *The Genesis of Modern Management: A Study of the Industrial Revolution in Great Britain* (London: E. Arnold, 1965), 33–34. John Styles, "Spinners and the Law: Regulating Yarn Standards in the English Worsted Industries, 1550–1800," *Textile History* 44, no. 2 (2013).

[15] Barnsley Archives & Local Studies, EM/985. Almira Vickers Gray, *Papers and Diaries of a York Family 1764–1839* (London: Sheldon Press, 1927), 56.

[16] Examples include Warwickshire County Record Office, DR(B) 100/89; Kent History and Library Centre, P308/12/16.

[17] Jane Humphries and Benjamin Schneider, "Spinning the Industrial Revolution," *The Economic History Review* 72, no. 1 (2019): note 30. Wadsworth and Mann, *Cotton Trade*, 404.

[18] Francis A. West, *Memoir of Jonathan Saville of Halifax* (New York: G. Lane & C. B. Tippett, 1845), 7–11. "Notes on the Life of Joseph Ricketts, Written by Himself, c. 1858," *Wiltshire Archaeological and Natural History Magazine* 60 (1965): 121–22. Timothy Claxton, *Hints to Mechanics, on Self-Education and Mutual Instruction* (London: Taylor and Walton, 1839), 5.

Hand Spinning: Earnings

Spinners' wages have become part of debates about incentives for industrial innovation. Using figures from Muldrew and Feinstein, Allen claimed that spinners' wages rose precipitously to 12d per day in the 1770s, leading to the invention of the spinning jenny and water frame.[19] Humphries and Schneider found a much lower average level of wages from direct evidence of earnings.[20] While there was a range of possible wage levels, with variation primarily driven by yarn quality, most women and children probably earned about one consumption basket per day, and occasionally only slightly more. After a possible spike in pay during the early 18th century, average spinning earnings were roughly 4d per day from 1740 to the end of the century, which was lower than wages for other male and female workers.[21]

Hand Spinning: Working Time

There is no direct evidence of hours worked for putting-out spinners. In his criticism of Humphries and Schneider, Allen asserts that they observed low daily earnings because spinners were only working part-time.[22] Contra Allen, Humphries and Schneider claim that piece rates for impoverished workers incentivized diligence

[19] Robert C. Allen, "London Prices & Wages Dataset," https://www.nuffield.ox.ac.uk/media/2139/london.xls. Allen has omitted the 12d per day observation from "Spinning Their Wheels: A Reply to Jane Humphries and Benjamin Schneider," *The Economic History Review* 73, no. 4 (2020): Figure 1. Muldrew, "'Th'ancient Distaff'." Charles Feinstein, "Wage-Earnings in Great Britain During the Industrial Revolution," in *Applied Economics and Public Policy*, ed. Iain Begg and S. G. B. Henry (Cambridge: Cambridge University Press, 1998).
[20] Humphries and Schneider, "Spinning the Industrial Revolution," esp. Figures 7–9, online appendix S1. Allen has disputed these findings in Allen, "Spinning Their Wheels."
[21] Humphries and Schneider, "Spinning the Industrial Revolution," Figure 9 and online appendix S1.
[22] Allen, "Spinning Their Wheels."

when work was available. Any part-time work was part-time on a yearly basis (spinning consistently and then not spinning for several months) rather than a weekly basis.[23] Evidence from other sectors suggests an 18th century working day of 10–12 hours, and a maximum work week of six days.[24] However, there was likely some absenteeism or inconsistent work, so the job quality calculation uses an estimate of 48 hours per week.

Hand Spinning: Summary

Hand spinning was largely worker-directed but dependent on putters-out for employment. There is no evidence of serious accidents or long-term injury or disease. The physical and mental exertion was modest, although working with a great wheel required a moderate amount of walking, and all hand spinning was very repetitive. It was poorly-remunerated in comparison with other work, and working time was probably similar to other rural employments. It scores highly on several HOQI components, but low wages reduced the quality of this occupation (Table 3.2).

Revolutionizing Spinning

Machine spinning replaced the control of twist, draft, and winding provided by a spinner's dexterity with wooden and later metal implements and gearing.[25] James

[23] Jane Humphries and Benjamin Schneider, "Losing the Thread: A Response to Robert Allen," *The Economic History Review* 73, no. 4 (2020).
[24] Judy Z. Stephenson, "Looking for Work? Or Looking for Workers? Days and Hours of Work in London Construction in the Eighteenth Century," *University of Oxford Discussion Papers in Economic and Social History* No.162 (2018): 4–7, 14–15. Cf. Hans-Joachim Voth, "Time and Work in Eighteenth-Century London," *The Journal of Economic History* 58, no. 1 (1998).
[25] On the process of innovation, inventors, and motivations, see e.g. C. Aspin, *James Hargreaves and the Spinning Jenny* (Preston: Helmshore Local History Society, 1964). R. L. Hills,

Hargreaves' spinning jenny powered multiple spindles by hand, and it was mainly used in homes and workshops. Richard Arkwright's water frame could be operated by minimally-trained women and children and soon used inanimate power to drive many spindles. Samuel Crompton's spinning mule combined elements of the jenny and frame to spin finer yarns with human power, and it was eventually adapted to production with an external power source.[26] Spinning machines expanded the task range of work (Table 3.1), which increased the division of labor and differences between jobs, and much higher productivity eliminated work for wheel spinners.

The Spinning Jenny

The jenny's primary innovation was using one hand-powered wheel to drive multiple spindles. Turning the wheel pulled a cord that rotated a line of spindles, allowing the spinner to twist the yarn. While twisting, the operative drafted by pulling a bar, called the 'drawbar', that held the ends of the threads and lay parallel to the spindles. Like the spinning wheel, the jenny spun intermittently: once a length of yarn was drawn out and twisted, the spinner pushed the drawbar back towards the spindles while turning the wheel to wind the yarns below the spindle tip to form the cop. An experienced spinner could form a cylindrical cop with top and bottom ends beveled. The drawbar, sometimes called a 'clove', replaced the wheel spinner's hand, and enabled her to release more roving once a section had been spun and wound.[27] To

"Hargreaves, Arkwright and Crompton: Why Three Inventors?," *Textile History* 10, no. 1 (1979). J. H. Crabtree, *Richard Arkwright* (London: The Sheldon Press, 1923).

[26] R. L. Hills, *Power in the Industrial Revolution* (Manchester: Manchester University Press, 1970), 134.

[27] Harold Catling, "The Development of the Spinning Mule," *Textile History* 9, no. 1 (1978): 44. Anna P. Benson, *Textile Machines* (Princes Risborough: Shire, 1983), 2.

keep the yarns taut when winding and prevent the twisted yarn from coiling, the operative used a foot pedal to raise or lower a metal 'faller wire' across the 'sheet' of multiple yarns.[28] If threads broke while spinning, the spinner had to piece them back together by overlapping the two ends of the broken yarn and applying a small amount of twist over the breakage. Consistent twist was crucial to achieve consistent yarn, and like in hand spinning, producing good quality yarn required experience and skill. The first jennies in the 1760s had about 12 spindles, but larger machines with 60–80 spindles were built by at least the 1780s. Jennies of over 100 spindles were in use by the 1790s.[29] Larger machines meant more strenuous work and more piecing.

Jenny Work and Workers

Most jennies were used in homes and workshops.[30] The jenny demanded more effort to operate than a spinning wheel, but small jennies (10–20 spindles) only needed one operative.[31] Many early jennies were so small that they were better suited to use by children.[32] The larger machines of the 1780s and 1790s were usually operated by women and, in a new development for spinning, increasing numbers of men.[33] On longer jennies of up to 100 spindles, piecing broken threads became a separate

[28] The foot pedal was later replaced with a rod that allowed the operative to control the faller wire with the same hand as the drawbar (usually the left). Catling, *Spinning Mule*, 30.
[29] Maxine Berg, *The Age of Manufactures, 1700–1820: Industry, Innovation, and Work in Britain* (London: Routledge, 1994), 254. "Workers and Machinery in Eighteenth-Century England," in *British Trade Unionism 1750–1850: The Formative Years*, ed. John Rule (London: Longman, 1988), 67.
[30] Aspin, *Spinning Jenny*, 50–51. Many early manufacturers used jennies, frames, and mules.
[31] *Spinning Jenny*, 53.
[32] James Ogden, *A Description of Manchester: Giving an Historical Account of Those Limits in Which the Town Was Formerly Included, with a Succinct History of Its Former Original Manufactories* (Manchester: C. Wheeler, 1783), 87. Berg, *The Age of Manufactures*, 254.
[33] "Workers and Machinery," 67.

occupation. 'Piecers', usually children, were paid time rates for reconnecting broken yarn. Spinners retained control over their tasks in workshops, but piecers could be supervised harshly and had little control.[34] Both spinners' and piecers' work was repetitive.[35] There is no evidence of occupational risks for jenny spinners, but piecers may have suffered injuries from corporal punishment.

Witnesses before a Parliamentary committee investigating whether spinning machines caused unemployment stated that earnings on 24-spindle jennies had been 8 to 9 shillings a week in 1764 (compared to a supposed 10–15 d on a spinning wheel), but fell to 4–6 shillings a week by 1780 (and 3–5 d on a wheel).[36] These figures come from witnesses who may have exaggerated the earnings of jenny spinners, but the increased productivity of the jenny surely enabled higher earnings before competition from more jennies and factories reduced piece rates. Even on higher wages, operatives on jennies and mules were sometimes paid in bills rather than coin.[37]

The jenny was cheaper and easier to construct than other machines, and small-scale use continued well into the 19th century. It was operated for decades in West Country workshops and Derbyshire and Staffordshire homes.[38] There was relatively little jenny spinning in workshops when wool production became focused in West Yorkshire, but many woollen jennies were employed in Yorkshire mills before they

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[34] Aspin, *Spinning Jenny*, 52–53. The only evidence of jenny piecers' wages is from one worker in the 1820s who reported earning 4s 2d per week for 15-hour days.
[35] *Spinning Jenny*, 42–44. Catling, *Spinning Mule*, 27–28.
[36] UK Parliamentary Papers, *Report from the Committee to Whom the Petition of the Cotton Spinners Were Referred*, vol. XXXI Geo. 20 (1780), 4.
[37] George Unwin, *Samuel Oldknow and the Arkwrights: The Industrial Revolution at Stockport and Marple*, 2nd ed. (Manchester: Manchester University Press, 1968), 50.
[38] Stanley D. Chapman, *The Early Factory Masters: The Transition to the Factory System in the Midlands Textile Industry* (Newton Abbot: David & Charles, 1967), 47–48, 50, 52–59.

were replaced by powered machinery.[39] Cotton jennies survived into the 1830s, but they were a small and declining share of output and employment.[40] The productivity advantages of inanimate power meant that other machines soon dominated production.

The Water Frame

On the jenny, the spinner's fingers were replaced by the draw bar, but the operative still powered the spindles and controlled drafting. Richard Arkwright and John Kay's water frame pulled the roving through three pairs of laterally-aligned cylindrical rollers, each of which turned faster than the previous pair, to draft. The yarn then traveled down to the rotating spindle where it was twisted. Finally, the yarn fed through a ring at the bottom of a rotating inverted-U-shaped flyer and on to the static bobbin. Frame yarn was drafted, then twisted, and wound in a continuous process.[41] The frame was initially operated by a crank on the side, then adapted for use with horse power, and finally driven by water wheels when Arkwright established his mills at Cromford, Derbyshire in 1770. Water frame operatives or 'tenders' stopped spindles to piece broken threads and cleaned and lubricated the machine, but they did not control the speed of drafting or twisting. Unlike piecers on jennies and mules, who

[39] Jenkins and Ponting, *The British Wool Textile Industry*. A Leeds manufactory's records name 53 jenny spinners in the 1810s, likely operating machines of 40–80 spindles. Alexander Yewdall, "The Records of Mill Practice," in *The Leeds Woollen Industry 1780–1820*, ed. W. B. Crump (Leeds: Thoresby Society, 1931), 276.
[40] Aspin, *Spinning Jenny*, 51–52.
[41] Benson, *Textile Machines*, 13–15. John Wyatt and Lewis Paul had tried spinning using rollers, with little success, in the 1730s and 1740s. Usher, *History of Mechanical Inventions*, 295.

were employed by the spinner, workers on frames were employed directly by the firm and disciplined by overseers.[42]

The Hand Mule

The mule combined the 'roller' spinning of the water frame with the 'drafting-against-twist' of the jenny.[43] While drafting rollers stretched out the weakest parts of thread, the mule's combination of rollers and twist from rotating spindles produced more consistent and stronger yarns. At the back of the mule was a rack or 'creel' that held roving on bobbins. On one side, usually the right when facing the machine, there was a hand crank or wheel. Turning the crank rotated three pairs of rollers that stretched across the length of the mule, which pulled roving off the bobbins and drafted it.[44] The crank also turned the spindles, which were placed on a wheeled carriage. The operative pulled the carriage away from the rollers to impart additional draft while rotating the spindles to twist the yarn (called 'driving', 'drawing', or the 'outward run'), which evened out its thickness. 'Driving' required the most physical exertion.[45]

The operative then turned the crank or wheel the opposite direction, rotating the spindles in reverse to let yarn off the tip ('backing off'). Next, the operative pushed the carriage toward the rollers while rotating the spindles in the same direction as the draw to wind yarn onto the cop below the spindle tip ('winding', 'putting up', or the

[42] Isaac Cohen, *American Management and British Labor: A Comparative Study of the Cotton Spinning Industry* (New York: Greenwood, 1990), 58–59, 69–70.
[43] Catling, "Development of the Spinning Mule," 35.
[44] Albert Williams, *36 Stewart Street, Bolton: An Exercise in Nostalgia, 1901–1914* (Manchester: Neil Richardson, 1983), 4.
[45] Catling, *Spinning Mule*, 33–34.

'return run'). He controlled the tension of the yarn using a faller wire.[46] Once he returned the carriage to its starting position near the rollers, he raised the faller wire above the yarn and rotated the flywheel to pull yarn back to the top of the spindles for the next draw. The process of spinning a full set of cops on each spindle was referred to as the 'spinning cycle'. The mule was a complicated machine that required expertise to operate. Matching the carriage's motion with the rotation of the spindles was especially important. The relationship between these two speeds ensured that the yarn was neither slack nor overstretched.[47]

When the mule was used in a home the main operative was usually a man, while children or women were mostly employed as piecers.[48] Mule piecers reconnected broken ends, removed ('doffed') the completed cops, added fresh roving to the creel, lubricated the machine, and cleaned.[49] Mule spinning on Crompton's original 48-spindle design required about 50 watts of energy input, which was a substantial although not extreme amount of effort for an adult man.[50]

The Common Mule

The first mule was made of wood and powered by hand. The crank transferred power to the rollers and spindles through belts and pulleys. Mechanics substituted metal components and added gearing to improve power transfer, which allowed the

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[46] *Spinning Mule*, 33–34.
[47] "Development of the Spinning Mule," 43.
[48] "Development of the Spinning Mule," 35–36.
[49] Andrew Bullen, Terry Wyke, and Alan Fowler, *The Barefoot Aristocrats: A History of the Amalgamated Association of Operative Cotton Spinners* (Littleborough, Lancashire: G. Kelsall, 1987), 3–4.
[50] Catling, "Development of the Spinning Mule," 43–48. Catling states that about 120 spindles was the limit of hand mule operation.

use of more spindles and eventually inanimate power in factories.[51] The first mule that used inanimate power was operated by William Kelly at New Lanark, Scotland in 1790. This version is generally referred to as the 'common mule' to distinguish it from the preceding hand mule and its successor, the self-actor (Chapter 4). Kelly used power to turn the drafting rollers, to rotate the spindles during the draw, and to drive the outward run of the carriage. During winding, the operative pushed the carriage back four to six feet while turning a flywheel to rotate the spindles.[52] As on the hand mule, he had to match the return speed of the carriage to the rotation of the spindles. If the carriage moved too quickly, the yarn would slacken or snarl and form a poor cop. If it moved too slowly, the threads would be overstretched by the spindle rotation, possibly causing a 'sawney' in which many threads broke.[53]

There were three workers employed on most mules: the operative, the big (or in Bolton, side) piecer, and the little piecer, although very long mules could have three piecers and short mules only one.[54] The operative monitored one half of the mule and pieced with the little piecer, while the big piecer pieced on the other half. Most cleaning was split between the two piecers, but the little piecer also cleaned the floor and carried away spun yarn. The operative adjusted the machine and ensured that it was operating in good condition.[55]

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[51] *Spinning Mule*, 42–43.
[52] Williams, *36 Stewart Street, Bolton*, 4.
[53] Hills, *Power in the Industrial Revolution*, 126–27. Michael Huberman, *Escape from the Market: Negotiating Work in Lancashire* (Cambridge: Cambridge University Press, 1996), 11. Bullen, Wyke, and Fowler, *Barefoot Aristocrats*, 4.
[54] John Jewkes and E. M. Gray, *Wages and Labour in the Lancashire Cotton Spinning Industry* (Manchester: Manchester University Press, 1935), 8–9.
[55] Catling, *Spinning Mule*, 161–63.

On a single common mule, the spinner pieced or cleaned during the draw. With piecers, common mules could be operated in pairs. The operative put up one machine and then turned to put up another mule that faced the first. Powering the draw also enabled operatives to work on longer mules. The longest hand mules were 100–120 spindles, but common mules of the early 19th century had up to 350 spindles. The carriage for this length of mule weighted nearly 1400 pounds, and the operative had to push it while winding every 20–30 seconds.[56] Later, inventors applied inanimate power to putting up as a supplement to the operative's muscle, which enabled mules as large as 1200 spindles, but more commonly 600 spindles, by 1830.[57]

The mule operative knew the machines he used in detail, and he exercised authority over the piecers, whom he recruited, disciplined, and paid. This 'subcontracting' system meant that mule factories employed few overseers.[58] An experienced operative could spin a variety of counts from a wide spectrum of raw cotton inputs by altering the speed of the drafting rollers, the amount of roving released during the outward run, and the speed of the draw.[59] However, this flexibility required paying high wages to experienced operatives.

Into the Factory

Placing common mules and water frames in factories allowed entrepreneurs to centralize production, apply inanimate power, and control the workforce. Water

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[56] Cohen, *American Management and British Labor*, 64–65. Catling, *Spinning Mule*, 82–83. Draws were more frequent in coarse spinning.
[57] "Development of the Spinning Mule," 40–41, 43.
[58] Cohen, *American Management and British Labor*, 55–58.
[59] *American Management and British Labor*, 36. The 'count' of yarn is the number of length units spun from a pound of fiber. Higher-count yarn is finer.

wheels and steam engines drove much larger machines than could have been powered by hand. This increased the task range (Table 3.1) and enabled a new division of labor (Figure 3.1) between overlookers who monitored production, mule operatives who supervised piecers and pushed the carriage when winding, and the child piecers who repaired broken threads and cleaned. Continuous (water frame) mills featured a similarly sharp divide between the women and children monitoring the frames and the higher-paid male overseers, mechanics, and engineers. This section discusses the expanded task range, describes work locations, and then evaluates the components of job quality in factories.

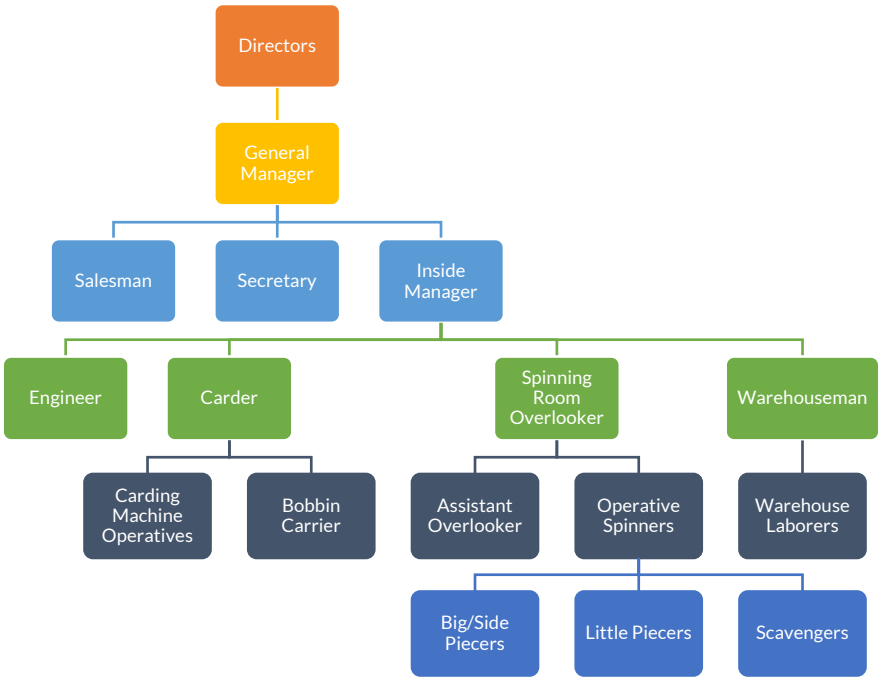
The Task Range and Division of Labor

Replacing the generalist skills of hand spinners with specialized machinery increased the task range of work and incentivized a larger scale of operations, which encouraged manufacturers to divide tasks into new bundles.[60] Changes in the task range are illustrated in Table 3.1, and the division of labor in a mule factory is displayed in Figure 3.1. Cleaning was unnecessary in wheel spinning as there was little fiber dust, and labor supervision was rare. In a factory, many spindles rotating at high speed produced large quantities of lint that workers needed to remove from the machinery. The faster-moving apparatus required lubrication, and the machinery needed repairs and adjustment. Controlling the larger workforce, which was enabled by mechanical improvements and inanimate power, necessitated hiring overseers.

[60] This argument differs from Adam Smith's discussion of the division of labor. He argued that, with static technology, dividing tasks raised productivity through increased focus and learning-by-doing. Adam Smith, *An Inquiry into the Nature and Causes of the Wealth of Nations* (London: Printed for W. Strahan and T. Cadell, 1776), 5–13, 16–20.

Hand spinners provided their own power; in the factory, inanimate power required specialized workers to operate and maintain the waterwheels or steam engines, which enabled a greater scale of production and higher productivity. Hand spinning was a one-person activity. Factory spinning added a variety of new tasks, which firms segmented into distinct jobs.

Figure 3.1: Organizational Chart of a British Mule Spinning Factory



Sources: Catling, *The Spinning Mule*, 150–154. Howe, *The Cotton Masters*, 6–15, 18–21.

Scale also changed management by increasing task depth or repetition. In putting-out, management, sales, and storage were frequently organized by a single merchant. Factories employed a general manager, inside manager, salesmen, secretary, and warehouse staff.[61] The general manager oversaw workers who ordered supplies, kept accounts, and marketed outputs.[62] Under the inside manager (or factory manager), the engineer was responsible for the power source; the carder oversaw the

[61] Catling, *Spinning Mule*, 150–54.
[62] Anthony Howe, *The Cotton Masters, 1830–1860* (Oxford: Clarendon Press, 1984), 6–15, 18–21.

carding department; the spinning room overlooker set the mule operatives' schedules and monitored yarn output. The warehouseman checked the condition of the yarn and packed it for sale. Specialization was a logical response to task repetition in sales, acquisition, and storage, as well as the increased task range described above.

The Workspace: Early Factory Architecture

The first professional spinning premises were repurposed residential buildings, workshops, and watermills. They had masonry or brick walls, wooden interior surfaces (beams, ceilings, door frames, and columns), and narrow mullioned windows.[63] Purpose-built mills of the late 18th century were rectangular and the largest establishments were composed of several small mills instead of one mammoth structure. Most were located in rural areas with access to water power. A common size was 22 x 9 m and five stories, containing about 1000 spindles, although there was substantial variation. Ceilings were low, generally around 2.75 meters, and sometimes as low as 1.8 meters.[64] Access to the spinning rooms was provided at first by wooden stairs, but later through enclosed stair towers at the center or on the exterior of the factory. The rare interior toilets were open chutes that fed into collection points at

[63] H.R. Johnson and A. W. Skempton, "William Strutt's Cotton Mills, 1793–1812," *Transactions of the Newcomen Society* 30 (1957): 179. D. T. Jenkins, *The West Riding Wool Textile Industry, 1770–1835: A Study of Fixed Capital Formation* (Edington: Pasold Research Fund, 1975), 50.
[64] Edgar Jones, *Industrial Architecture in Britain, 1750–1939* (London: Batsford, 1985), 34–35, 47; Stanley D. Chapman, "The Arkwright Mills—Colquhoun's Census of 1788 and Archaeological Evidence," *Industrial Archaeology Review* 6, no. 1 (1981). *Sir Richard Arkwright's Masson Mills Matlock Bath, Derbyshire* (Chesterfield: Merton, 2015), 18, 20. Adam Menuge, "The Cotton Mills of the Derbyshire Derwent and Its Tributaries," *Industrial Archaeology Review* 16, no. 1 (1993). Colum Giles and Ian H. Goodall, *Yorkshire Textile Mills: The Buildings of the Yorkshire Textile Industry, 1770–1930* (London: H.M.S.O, 1992), 23. Duncan Gurr, Julian Hunt, and David Collier, *The Cotton Mills of Oldham*, 3rd ed. (Oldham: Oldham Education & Leisure, 1998), 15.

ground level.[65] Early urban factories were red-brick structures built in a U- or L-shape with an interior yard. The spinning rooms of these factories were larger, 25–50 x 11.5–15 m. Ceiling heights were around 3 meters, with lower ceilings on higher floors that housed spinning machinery. These structures had larger windows with small, hinged panes to allow ventilation. Windows were sometimes omitted from the shorter walls and those on upper stories were smaller.[66]

Control & Supervision in the Factory

Moving spinning into factories enabled labor discipline.[67] The control disadvantages of factory work were obvious to contemporaries: workers could not choose their hours or pause for household tasks or childcare when they toiled in mills for 12 or more hours per day.[68] Managers imposed penalties for absenteeism or lateness, restraints on behavior, and corporal punishment.

The early mill owners used fines to ensure that their spinning rooms were fully staffed.[69] Samuel Oldknow warned his employees that 'when any Hand is absent from Work (unless unavoidably detained by Sickness, or Leave being first obtained), the same shall forfeit as many Hours of Work as have been lost; and if by the Job or Piece,

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[65] Anthony Calladine and Jean Fricker, *East Cheshire Textile Mills* (London: Royal Commission on the Historical Monuments of England, 1993), 48.
[66] Mike Williams and D. A. Farnie, *Cotton Mills in Greater Manchester* (Preston: Carnegie, 1992), 19, 51–56. Jones, *Industrial Architecture*, 54–55.
[67] Clark argued that workers accepted coercion to raise output and wages. Gregory Clark, "Factory Discipline," *The Journal of Economic History* 54, no. 1 (1994).
[68] Wadsworth and Mann, *Cotton Trade*, 392.
[69] Arkwright family papers, quoted in R. S. Fitton, *The Arkwrights: Spinners of Fortune* (Manchester: Manchester University Press, 1989), 28. Chapman, *Early Factory Masters*, 156–57. See also Columbia University Rare Books and Manuscripts, Samuel Oldknow Papers, MS 0949, letters from John Blundell to Samuel Oldknow and letters from Clerkenwell Parish Overseers to Samuel Oldknow. Pollard, *The Genesis of Modern Management*, 182–83. Huberman, *Escape from the Market*, 21.

after the Rate of 2s. 6d. per Day'.[70] In the Strutts' mills, workers who left without notice forfeited unpaid earnings.[71] Children suffered especially harsh punishment: girls who ran away from the Gregs' mill in Cheshire were punished with a week of solitary confinement and threatened that their hair would be cut off.[72] While punishment varied between mills, taking leave from work without prior approval generally resulted in a fine or dismissal.

The Strutts also imposed fines for poor quality or slow work, but employer control was not limited to work tasks. The Strutts also levied fines for 'behaving improperly', 'bad behaviour', 'being saucy', and even 'calling through the window to people in the street'. Oldknow fined his workers one shilling if 'any person, […] is heard to CURSE or SWEAR'.[73] Thomas Fernley's Stockport mills prohibited 'all shouting, loud talk, whistling, calling foul names, all mean and vulgar language, and every kind of indecency'. His fines were even higher at 5s per offense. Benjamin Gott and other Yorkshire woollen millowners prohibited drinking.[74] In hand spinning, workers suffered from slow work by receiving their piece rate earnings less frequently. Factory owners controlled work schedules, in continuous mills, they controlled the pace of work, and they restricted personal conduct.

Factory Spinning: Working Time

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[70] Columbia University Rare Books and Manuscripts, Oldknow Papers, MS 0949, Notice to Employees, Mellor, 1 December 1797.
[71] Derbyshire Record Office, W. G. and J. Strutt Papers, D6948/6/75.
[72] Manchester Archives, R. Greg and Co. Ltd of Quarry Bank Mill Records, C5/8/22.
[73] Derbyshire Record Office, W. G. and J. Strutt Papers, D6948/6/75. Columbia University Rare Books and Manuscripts, Oldknow Papers, MS 0949, Notice to Employees, Mellor, 1 December 1797.
[74] Pollard, *The Genesis of Modern Management*, 195.

Most mills scheduled six days of work per week. Oldknow's time books suggest a bimodal distribution of actual attendance: a small share of employees—perhaps 10%—worked only one or two days per week, but the majority worked five or six days. Accounts of the Strutts' mills show similar attendance.[75] 12-hour or longer days were standard, some water-powered mills operated for 16-hour shifts, and night work was common.[76] The surviving account books suggest that the typical factory employee toiled for five or six long workdays per week. While some mills incorporated brief meal breaks, other establishments required employees to work through the day and consume sustenance during their shifts.[77]

Factory Spinning: Stability of Earnings

The same workers were listed repeatedly in factory accounts, which suggests that their earnings were more consistent than those of hand spinners had been. As discussed above, there was some chance of summary dismissal in factories. Early mills

[75] Columbia University Rare Books and Manuscripts, Oldknow Papers, MS 0949, payroll records. Derbyshire Record Office, W. G. and J. Strutt Papers, D6948/6/1. University of Manchester Special Collections, John Rylands Library, Oldknow Papers, SO/12/7.
[76] Chapman, *Early Factory Masters*, 41, 175. R. S. Fitton and Alfred Powell Wadsworth, *The Strutts and the Arkwrights, 1758–1830: A Study of the Early Factory System* (Manchester: Manchester University Press, 1964), 226. UK Parliamentary Papers, *Report of the Minutes of Evidence Taken before the Select Committee on the State of the Children Employed in the Manufactories of the United Kingdom*, vol. III.235, Paper 397 (1816), 5–9, 18, 39, 240–43, 374–75. McConnel & Kennedy's mills worked from 5 AM to 7 PM in summer and 6 AM to 8 PM in winter, with one hour for dinner and fifteen minutes for breakfast and tea. University of Manchester Special Collections, John Rylands Library, McConnel & Kennedy and McConnel & Co. Papers, MCK/4/5. The Gregs' pauper apprentices worked nearly 13-hour days and only received a dinner hour two days per week. Manchester Archives, R. Greg and Co. Ltd of Quarry Bank Mill Records, C5/8/9/5. A 15-hour workday was 'standard' in the Peel mills. Katrina Honeyman, *Child Workers in England, 1780–1820: Parish Apprentices and the Making of the Early Industrial Labour Force* (Aldershot: Ashgate, 2007), 189.
[77] Nathaniel Gould, *Information Concerning the State of Children Employed in Cotton Factories, Printed for the Use of the Members of Both Houses of Parliament* (Manchester: J. Gleave, 1818), 4.

paid weekly, biweekly, or at even longer intervals.[78] The difficulty of obtaining coinage meant that, like workshop operatives, factory workers were not always paid in cash on time. Sometimes workers received 60-day bills of exchange or truck.[79] Early mills also suffered from fire and demand fluctuations with myriad causes including the French Wars and the American Embargo. These crises bankrupted some firms and caused others to reduce hours. Work improved on this dimension after 1815, although interruptions to demand from tariff changes and foreign economic crises recurred through the 19th century.[80] Factory earnings were more stable than outwork pay, but there was still volatility.

Factory Spinning: Short-Term Health Risks

In addition to the fines for absenteeism and limits on personal conduct described above, factory supervision included violence. The first Report of the Factory Inspectors contained lurid details of corporal punishment inflicted upon children in spinning mills.[81] Evidence from the Strutts' discipline book and letters from the Gregs' mill also show that violence between workers was a risk, with punishments for

[78] See the archival sources listed in the bibliography. Some factory owners asserted that factory work was more stable than outworking by the 1810s. Chapman, *Early Factory Masters*, 163.
[79] Michael M. Edwards, *The Growth of the British Cotton Trade, 1780–1815* (Manchester: Manchester University Press, 1967), 230–33. Unwin, *Samuel Oldknow and the Arkwrights*, 176.
[80] Chapman, *Early Factory Masters*, 31, 163–64, 90. Jenkins and Ponting, *The British Wool Textile Industry*, 60–67, 126–28, 53–57, 229–39, 48–51.
[81] UK Parliamentary Papers, *Royal Commission on Employment of Children in Factories, First Report*, vol. XX.1, Paper 450 (1833), 18–20.

throwing rocks at each other and for 'abusing' co-workers.[82] More evidence of corporal punishment from the 1830s is discussed in the next chapter.

The second dimension of health risks was the new danger of industrial accidents. The frequency of injuries is not documented systematically, but the preponderance of contemporary evidence suggests that they were common, even if they were not always serious. Accidents usually occurred when workers or their clothing were caught by gears, wheels, belts, or other parts of the machinery. Many workers reported receiving hand and arm injuries from fast-moving straps and interlocked gear teeth, and women and girls' hair could be caught in power transfer mechanisms. Fatigue, inexperience, the design of factory machinery, and carelessness all contributed to accidents that cost digits, limbs, or lives.[83] The outward and returning motion of the mule made it somewhat more dangerous to work with than continuous machines: there were more exposed moving parts and some children cleaning between the carriage and creel were crushed by the return run.[84]

Wood interiors, wooden machinery, oil-soaked floors, cotton dust, and candle or lamplight for illumination produced high risks of fire.[85] There are no systematic statistics on mill fires, but anecdotal evidence suggests that they were common and

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[82] Derbyshire Record Office, W. G. and J. Strutt Papers, D6948/6/75. Manchester Archives, R. Greg and Co. Ltd of Quarry Bank Mill Records, C5/8/22. See also *Select Committee on Children in Manufactories*, III.235, Paper 397, 181.

[83] J. T. Arlidge, *The Hygiene, Diseases and Mortality of Occupations* (London: Percival & co., 1892), 359–60. Jamie L. Bronstein, *Caught in the Machinery: Workplace Accidents and Injured Workers in Nineteenth-Century Britain* (Stanford: Stanford University Press, 2008), 69. UK Parliamentary Papers, *Royal Commission on Employment of Children*, XX.1, Paper 450, Appendix 1, 1–2. *Select Committee on Children in Manufactories*, III.235, Paper 397, 180, 95, 297.

[84] H. S. Richmond, "Safe-Guarding of Machinery," in *Dangerous Trades*, ed. Thomas Oliver (John Murray: London, 1902), 224–25.

[85] Jones, *Industrial Architecture*, 18–20, 35, 43–44. For a comparison with pre-industrial textile workplaces, see Stanley D. Chapman, "The Textile Factory before Arkwright: A Typology of Factory Development," *The Business History Review* 48, no. 4 (1974).

could kill and injure many operatives.[86] In East Cheshire there were five mill-destroying fires between 1819 and 1856 in an area with only 15 mills.[87] To prevent fires, mills with cast iron framing were built as early as the 1790s and they were wrongly regarded as fireproof.[88] Spinning factory work involved a far higher rate of accidental injury or death than hand spinning.

Factory Spinning: Long-Term Health Risks

The doctors consulted by the Factory Inspectors offered a variety of views on the health effects of factory work, but many stated that the number of factory workers who attained old age was small.[89] The primary long-term health risk in this period was respiratory disease.[90] Early evidence of the factory work environment comes from the Manchester Board of Health in 1796. A Dr. Percival stated that diseases spread quickly in mills and workers suffered 'from the debilitating effects of hot or impure air'.[91] Doctors investigated the dangers of cotton dust in the later 19th century, and it is discussed further in the next chapter.

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[86] For examples of mill fires see: W. G. Rimmer, *Marshalls of Leeds, Flax-Spinners, 1788–1886* (London: Cambridge University Press, 1960), 45. George Ingle, *Yorkshire Cotton: The Yorkshire Cotton Industry, 1780–1835* (Preston: Carnegie, 1997), 47.
[87] Calladine and Fricker, *East Cheshire Textile Mills*, 51.
[88] Jenkins, *The West Riding Wool Textile Industry*, 58–59. Richard L. Hills, *Power from Steam: A History of the Stationary Steam Engine* (Cambridge: Cambridge University Press, 1989), 87.
[89] *PP 1834* "Supplementary Report of Factory Inspectors", Appendix D3, 230–232.
[90] UK Parliamentary Papers, *Royal Commission on Employment of Children in Factories Supplementary Reports, Part I*, vol. XIX, Paper 167 (1834), Appendix D3, 245. Another complaint was that early throstle frames required workers to stop spindles for piecing by pressing one knee against it. Repetition injured knees until the machinery was changed c. 1830 to allow workers to stop spindles by hand. *Royal Commission on Employment of Children in Factories Supplementary Reports, Part I*, XIX, Paper 167, D2, 200. Also *Select Committee on Bill for Regulation of Factories*, vol. XV.1, Paper 706 (1832), 115–16, 20, 27–28, 46, 53.
[91] B. L. Hutchins and A. Harrison, *A History of Factory Legislation*, 2nd ed. (London: P.S. King & Son, 1911), 9–10.

Factory Spinning: Intensity

Exhaustion was common for millworkers, especially children. A child in a Bradford mill reported that he 'could not keep [his] eyes open', and one in Huddersfield stated that his colleagues would have fallen asleep if the overseers did not beat them.[92] Sometimes children were so tired by their work that they missed meals.[93] Long hours were compounded by night shifts when water wheels were operating.[94]

Factory Wages

Factory spinning wages were significantly higher than hand spinning earnings across all jobs, although some of the differential is explained by longer hours. Oldknow's spinners at Mellor earned as much as 3s per day in the 1790s, with many earning in excess of 2s a day, and Feinstein estimated wages for throstle (continuous) spinners at 4s per week in 1790, rising to 9s 1d per week in 1806.[95] Even the lower earners in factories had wages well above the roughly 2s per week earned by the average late-18th century hand spinner.[96] Tables 3.3–3.8 present evidence from more than 5000 observations of factory spinners' wages during the early decades of mechanized spinning. The gains from higher labor productivity were unequally

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[92] Thomas Whittaker, *Life's Battles in Temperance Armour* (London: Hodder & Stoughton, 1884), 58. Annie Kenney, *Memories of a Militant* (London: E. Arnold & Co., 1924), 18. UK Parliamentary Papers, *Select Committee on Factory Regulation*, XV.1, Paper 706, 124, 58, 60, 294–95. A more colorful description is James Myles, *Chapters in the Life of a Dundee Factory Boy: An Autobiography* (Dundee: J. Myles, 1850), 12–14.

[93] UK Parliamentary Papers, *Royal Commission on Employment of Children*, XX.1, Paper 450, 26–27.

[94] Honeyman, *Child Workers*, 240–42.

[95] Columbia University Rare Books and Manuscripts, Oldknow Papers, MS 0949. Feinstein, "Wage-Earnings in Great Britain," 190.

[96] Humphries and Schneider, "Spinning the Industrial Revolution," Figure 7.

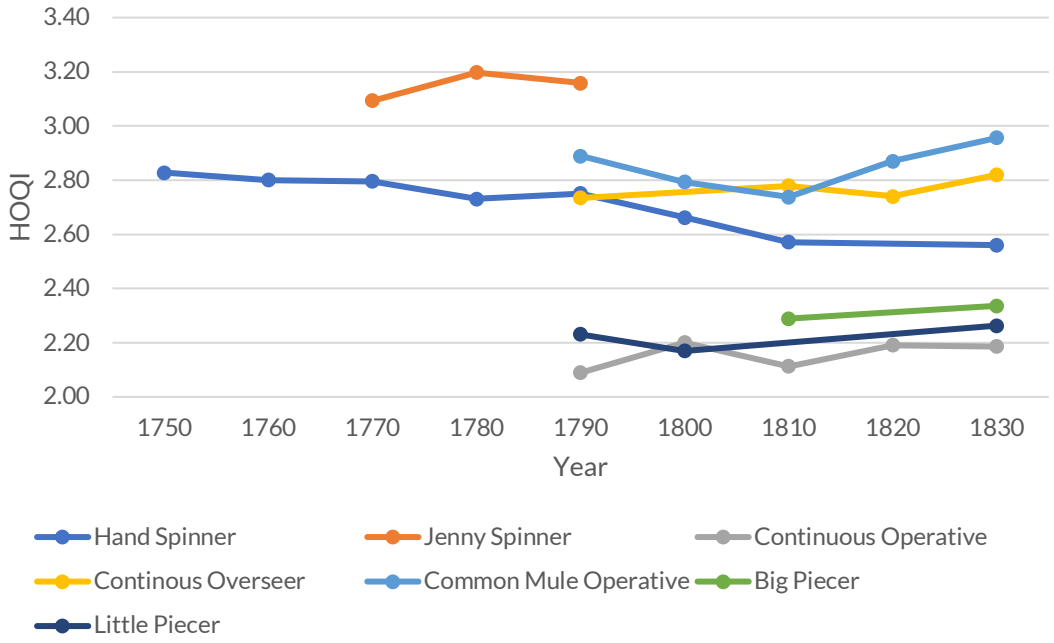
distributed: the best-paid workers were male overlookers, assistant overlookers, and mule spinners. The lowest-paid were women monitoring throstle frames and children piecing broken threads and cleaning under mules. Despite these better earnings, substantial turnover among factory workers suggests that higher wages may not have offset factory disamenities for all operatives.[97]

Composite Job Quality

Hand spinning job quality hardly changed over this period, although stability of earnings fell as factory output replaced wheel work. Jenny spinning at home briefly combined some of the best aspects of hand spinning—high control and low occupational risks—with the best parts of factory work—high wages—but it declined quickly. Factory workers earned higher wages at the cost of longer and more intense working hours, ceding control over the work process, and greater risk of injury and disease. The one common thread was that spinning remained repetitive, regardless of the technology in use. Tables 3.2–3.8 present the scores of each component of the HOQI and its final outputs; the differences and trends are summarized in Figure 3.2. Incorporating qualitative aspects illustrates the job stratification produced by the spinning macroinventions. There were also male-biased implications for wellbeing: by the 19th century many of the workers with the lowest job quality were women, all of those in the best jobs were men.

[97] Chapman, *Early Factory Masters*, 185.

Figure 3.2: Job Quality in British Spinning, 1750–1830



Sources: See Tables 3.2–3.8

Occupational Availability

Hand spinning was a very common female employment before industrialization. Muldrew has estimated that about 700,000 hand spinners of wool were needed to satisfy home demand for cloth in the mid-18th century.[98] Alternative estimates using domestic fiber output plus retained imports and the productivity evidence collected by Humphries and Schneider suggest a modestly lower but substantial workforce. On these calculations, more than 600,000 women and children may have been employed in hand spinning by 1770, with perhaps 300,000 in wool, 40,000 in cotton, and 250,000 spinning linen.[99] Statistics of employment on jennies,

[98] Muldrew, "'Th'ancient Distaff'."

[99] Benjamin Schneider, "Creative Destruction in the British Industrial Revolution: Hand Spinning to Mechanisation, c. 1700–1860" (M.Sc. Thesis, University of Oxford, 2015). "British Spinning Employment in the 18th Century: Women's Occupational Structure and Technological Unemployment," in *FRESH: Labour Markets and Institutions* (Royal Holloway, University of London 2018).

hand mules, and in factories are incomplete before the mid-19th century, but qualitative evidence suggests that mechanization produced widespread unemployment. Petitions and county agricultural surveys from the 1780s to the 1810s include many comments about the disappearance of hand spinning and the poverty of erstwhile wheel spinners.[100]

An estimate of fiber demand from machine spinning can quantify this unemployment. In 1787, Britain retained about 22 million pounds of cotton imports, and Patrick Colquhoun estimated that there were 1,605,000 jenny spindles, 50,000 mule spindles, and 286,000 water frame spindles in factories. If the average jenny had about 80 spindles and an operative could produce 3.25 pounds of cotton per day, the average mule had 120 spindles and could produce 4 pounds, and the average 60-spindle frame could process about 4.5 pounds, then mechanized production would have consumed nearly all retained cotton imports, leaving enough cotton for only 1500 hand spinners. Total employment in mechanized spinning would have been about 25,000 (20,000 jenny spinners and 5,000 factory workers), for a net employment loss of about 14,000—but many hand spinners did not purchase jennies or move to work in factories.[101] Wool and linen were mechanized later, but there is little evidence of hand

[100] UK Parliamentary Papers, *Petition of the Cotton Spinners*, XXXI Geo. 20; *Annals of Agriculture and Other Useful Arts*, vol. 13 (England: Arthur Young, 1790), 330. Board of Agriculture, *General View of the Agriculture of the County of Devon* (England: Printed for R. Phillips, 1808), 446, 64. Thomas Rudge, *General View of the Agriculture of the County of Gloucester* (England: Sherwood, 1813), 341.

[101] Harvard Business School, Baker Library Special Collections, Mss Foreign English Patrick Colquhoun Volume 1. Chapman, "The Arkwright Mills." Peter Maw et al., "After the Great Inventions: Technological Change in U.K. Cotton Spinning, 1780–1835," *The Economic History Review* Early View (2021). The productivity and spindles per machine estimates here are lower than those in Maw et al. to account for the continuing use of older, smaller, less productive machines. These calculations suggest a small number of hand mule spinners (about 400, and a similar number of piecers).

spinning of wool and linen after the 1820s, so the hundreds of thousands of workers employed in hand spinning both fibers must have lost work in the first third of the 19th century.[102] The employment implications of mechanization were determined by a race between productivity growth and demand growth, which the former won decisively.

Occupational Distribution

Age and Gender

The early factory workforce was young and mostly female. The 1816 report on child labor found that children were 30–50% of the workforce in cotton mills, with one mill employing 60% children.[103] Children were more easily disciplined, could be paid low wages for cleaning and piecing, and their small size made it easier for them to complete tasks like wiping between the carriage and creel of a mule.[104] Many child workers were pauper apprentices: poor children dependent upon their parish who were sent to work in factories. Rural mills, many of which used continuous machinery, were more likely to employ apprentices than urban mills on account of their smaller local labor market. Turnover among apprentices was high—in some mills as many as a third ran away, died (more than 8%), or returned home.[105] Frequent escape attempts

[102] Ivy Pinchbeck, *Women Workers and the Industrial Revolution, 1750–1850* (London: George Routledge & Sons, Ltd, 1930), 54–55, 57–59, 144–49.
[103] UK Parliamentary Papers, *Select Committee on Children in Manufactories*, III.235, Paper 397, 13, 17, 188, 211–16, 61, 81, 374–75. A report of workers at McConnel & Kennedy from the same year shows that most were in their late teens and early twenties. University of Manchester Special Collections, John Rylands Library, McConnel & Kennedy and McConnel & Co. Papers, MCK/4/5.
[104] Honeyman, *Child Workers*, 2–3.
[105] *Child Workers*, 7–8, 15–25, 34–35, 58–60, 91–92. Chapman states that the high mortality rate was caused by the poor physical condition of the apprentices. Chapman, *Early Factory Masters*, 168–71, 79–80. Pollard, *The Genesis of Modern Management*, 165–66.

underline the unpleasantness of apprentice life.[106] The share of very young children (13 and under) was falling by 1820, and the use of apprentices became limited to a few establishments.[107] Child labor continued in mule mills where children worked as piecers.

The gender composition of the workforce changed less from hand spinning than the age distribution, but there were important shifts. In Arkwright's Cromford mills there were 150 men in a total workforce of 1150 in 1789. While men were a minority of workers, their share had increased compared to hand spinning, and men were concentrated in the well-paid, high-control supervisory, managerial, and engineering roles.[108] Other parts of the industry had larger shares of male operatives, especially in intermittent spinning. Operating hand mules required substantial strength, which was one explanation for excluding women. The common mule was powered for the draw, but it demanded strength, endurance, and technical expertise to control the faller and counter-faller wires without breaking yarns during winding, and women had few opportunities to learn the details of operation. While women did spin on common mules, male operatives successfully resisted their widespread employment.[109] The 1816 Select Committee investigation into children's work showed that men were nearly a third of the workforce in Scottish mills, and several English mills had similarly high, or even higher, proportions of men.[110] Mechanization

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[106] Chapman, *Early Factory Masters*, 169.
[107] Per Bolin-Hort, *Work, Family, and the State: Child Labour and the Organization of Production in the British Cotton Industry, 1780–1920* (Lund: Lund University Press, 1989), 35–37, 40–41, 45.
[108] Chapman, *Early Factory Masters*, 165–66.
[109] William Lazonick, *Competitive Advantage on the Shop Floor* (Cambridge: Harvard University Press, 1990), 82–83.
[110] UK Parliamentary Papers, *Select Committee on Children in Manufactories*, III.235, Paper 397, 211–16, 40–43.

produced substantial unemployment for women and enabled men to claim the best jobs in the factory system.

Factory Locations

Although there had been pre-industrial centers of textile production such as East Anglia and the West Country, hand spinning employed women across the country.[111] Factory production was centralized and so was employment. Colquhoun's inventory of mills in 1787 showed that most establishments were located in the Midlands, Lancashire, and Yorkshire, with some in southern Scotland.[112] Rural mills were located in areas with good water power, but steam-powered urban mills operated from the 1790s. The development of the governor and other improvements in the late 18th and early 19th century enabled engines to produce the steady power that was essential to spinning consistent thread.[113] The first factories in Manchester were built in the 1780s, and by 1802 there were 111 spinning firms (with many sharing premises). Steam engines allowed concentrated employment in growing cities.[114] This moved the locations of employment far from most hand spinners; retaining employment in spinning by finding one of the few new factory jobs would have required nearly all hand spinners to move, and few did.

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[111] Jenkins and Ponting, *The British Wool Textile Industry*, 1–2.
[112] Harvard Business School, Baker Library Special Collections, Mss Foreign English Patrick Colquhoun Volume 1. Chapman, *Early Factory Masters*, 11. Cf. "The Arkwright Mills."
[113] John K. Walton, *Lancashire: A Social History, 1558–1939* (Manchester: Manchester University Press, 1987), 107. Hills, *Power from Steam*, 85–86. Hills, *Power in the Industrial Revolution*, 176.
[114] Jones, *Industrial Architecture*, 53–54; Williams and Farnie, *Cotton Mills*, 18–20.

Conclusion

The impact of spinning innovations on work-related wellbeing was dramatically different for men and women. Tens or even hundreds of thousands of women who had been hand spinners lost work, and the new jobs were concentrated, first in areas with water power, and then in cities. Those who found employment in factories faced a series of tradeoffs. While wages were higher and more stable, hours were much longer, the work was more dangerous, and they ceded control of the work process. In sharp contrast, men entered spinning in large numbers as well-paid mule operatives, overseers, and mechanics or engineers. This technological change was not neutral, but male-biased, although contemporaries may have claimed it was skill-biased.[115]

The core of this transformation was driven by features of the spinning macroinventions. The common mule and water frame were a dramatic productivity advance over hand spinning, which caused technological unemployment. This was partly the result of their suitability for inanimate power, which enabled centralization in factories. Once manufacturers could exploit centralized power, they increased the scale of production, which incentivized supervision. By externalizing tasks that were implicit (such as power provision) or unnecessary (like cleaning) in hand spinning, machine production expanded the task range, which enabled greater division of labor and stratification of work-related wellbeing.

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[115] On skill-biased technical change, see e.g. George E. Johnson, "Changes in Earnings Inequality: The Role of Demand Shifts," *Journal of Economic Perspectives* 11, no. 2 (1997): 47–48; Eli Berman, John Bound, and Zvi Griliches, "Changes in the Demand for Skilled Labor within U.S. Manufacturing: Evidence from the Annual Survey of Manufacturers," *The Quarterly Journal of Economics* 109, no. 2 (1994).

Table 3.1: Task Range by Spinning Technology

Hand Spinning	Jenny Spinning	Hand Mule	Common Mule	Water Frame
• Turning wheel (power) • Drafting & Twisting • Winding • Removing spun yarn • Repairs (rare)	• Turning wheel (power) • Drafting & twisting • Winding • Removing spun cops • Piecing • Repairs	• Cranking flywheel (power) • Drafting & twisting (draw) • Backing off • Winding (putting up) • Creeling • Doffing • Piecing • Repairs • Machinery adjustments	• Cranking flywheel (power for winding) • Drafting & twisting (draw) • Backing off • Winding (putting up) • Piecing • Creeling • Doffing • Repairs • Machinery adjustments • Cleaning • Oiling • Labor supervision Ancillary: • Steam engine or waterwheel operation and maintenance • Sales & marketing • Payroll	• Piecing • Replacing bobbins • Doffing • Repairs • Machinery adjustments • Cleaning • Oiling • Labor supervision Ancillary: • Steam engine or waterwheel operation and maintenance • Sales & marketing • Payroll

Sources: See the text of Chapters 3 & 4.

Table 3.2: Occupational Quality for Hand Spinners, 1750–1830

Year	Daily Wage (d)	CN (d)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1750	3.73	2.48	2.13	48.00	3.25	3	5	5	4	4	1	3.26	2.83
1760	3.56	2.66	2.07	48.00	3.25	3	5	5	4	4	1	3.26	2.80
1770	4.09	3.11	2.06	48.00	3.25	3	5	5	4	4	1	3.26	2.80
1780	3.06	3.09	1.92	48.00	3.25	3	5	5	4	4	1	3.26	2.73
1790	3.52	3.24	1.97	48.00	3.25	3	5	5	4	4	1	3.26	2.75
1800	4.39	4.59	1.91	48.00	3.25	2	5	5	4	4	1	3.05	2.66
1810	3.30	5.49	1.72	48.00	3.25	2	5	5	4	4	1	3.05	2.57
1830	2.29	4.07	1.69	48.00	3.25	2	5	5	4	4	1	3.05	2.56

Sources for Tables 3.2–3.8: Chapters 2, 3, Appendix 1, manuscript sources in the Bibliography, Allen, 'London Prices & Wages Dataset', Wood, *History of Wages in the Cotton Trade* (1910). Notes: Decade gaps (e.g. 1820 in Table 3.2) are periods for which there is no wage data. For Hand Spinners, Jenny Spinners, and Continuous Operatives, Consumption Needs are scaled to 85% of an adult male basket; for Little Piecers, Consumption Needs are scaled to 60% (see Appendix 1). Continuous Operatives and Overseers worked on water frames or throstles. Hours/Week figures for factory workers are based on scheduled hours (described in the text) and archival evidence of average days worked per week.

Table 3.3: Occupational Quality for Jenny Spinners, 1770–1790

Year	Daily Wage (d)	CN (d)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1770	13.50	3.11	2.93	48.00	3.25	3	5	5	4	3	1	3.11	3.09
1780	18.00	3.09	3.24	48.00	3.25	3	5	5	4	3	1	3.11	3.20
1790	17.00	3.24	3.12	48.00	3.25	3	5	5	4	3	1	3.11	3.16

Table 3.4: Occupational Quality for Continuous Operatives, 1790–1830

Year	Daily Wage (d)	CN (d)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1790	8.70	3.24	2.49	69.24	1.92	4	3	2	1	2	1	1.91	2.09
1800	20.25	4.59	2.91	69.24	1.92	4	3	2	1	2	1	1.91	2.20
1810	16.54	5.49	2.58	69.24	1.92	4	3	2	1	2	1	1.91	2.11
1820	19.71	4.65	2.87	69.24	1.92	4	3	2	1	2	1	1.91	2.19
1830	16.90	4.07	2.85	69.24	1.92	4	3	2	1	2	1	1.91	2.19

Table 3.5: Occupational Quality for Continuous Overseers, 1790–1830

Year	Daily Wage (d)	CN (d)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1790	24.60	3.81	3.33	70.80	1.83	5	4	2	4	3	3	3.36	2.73
1810	47.90	6.46	3.50	70.80	1.83	5	4	2	4	3	3	3.36	2.78
1820	36.00	5.47	3.35	70.80	1.83	5	4	2	4	3	3	3.36	2.74
1830	40.00	4.78	3.65	70.80	1.83	5	4	2	4	3	3	3.36	2.82

Table 3.6: Occupational Quality for Common Mule Operatives, 1790–1830

Year	Daily Wage (d)	CN (d)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1790	44.00	3.81	4.01	66.00	2.13	4	4	2	4	2	2	2.83	2.89
1800	47.5	5.40	3.63	66.00	2.13	4	4	2	4	2	2	2.83	2.79
1810	48.00	6.46	3.42	66.00	2.13	4	4	2	4	2	2	2.83	2.74
1820	60.00	5.47	3.93	66.00	2.13	4	4	2	4	2	2	2.83	2.87
1830	60.00	4.78	4.14	66.00	2.13	5	4	2	4	2	2	2.94	2.96

Table 3.7: Occupational Quality for Big Piecers, 1810–1830

Year	Daily Wage (d)	CN (d)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1810	20.00	6.46	2.60	69.24	1.92	4	3	2	2	2	2	2.40	2.29
1830	18.00	4.78	2.76	69.24	1.92	4	3	2	2	2	2	2.40	2.34

Table 3.8: Occupational Quality for Little Piecers, 1790–1830

Year	Daily Wage (d)	CN (d)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1790	8.00	2.29	2.70	69.24	1.92	4	3	2	1	2	2	2.14	2.23
1800	8.64	3.24	2.48	69.24	1.92	4	3	2	1	2	2	2.14	2.17
1830	11.50	2.87	2.82	69.24	1.92	4	3	2	1	2	2	2.14	2.26

Chapter 4
British Spinning, 1830–1910

Chapter Abstract

The second half of the British spinning case study assesses the impact of more modest technological changes, government intervention, and the unionization of mule operatives and self-actor minders. The self-acting mule reduced some of the effort of mule spinning, but managers later intensified work by increasing machine speeds and purchasing lower-quality raw fiber to reduce costs. Regulation began with limits on children's and then women's employment and conditions. The Factory Acts gradually reduced working hours, but safety regulations were weakly enforced. From the 1830s, the male mule operatives and their successors, the self-actor minders, fought to maintain the best jobs in spinning, excluding women and limiting promotion to these highly-paid, high-control roles. Improvements in work-related wellbeing were largely the result of increasing wages and regulation-limited hours, but the inequality of wellbeing established in the early 19th century remained.

Introduction

In the late 1820s British manufacturers nearly found another macroinvention in the form of an automatic or 'self-acting' mule, but the self-actor produced less dramatic change than the inventions discussed in Chapter 3. It reduced the effort required in mule spinning but did not eliminate operatives. Firms continued to seek higher productivity by other routes, including installing longer mules and operating them at higher spindle speeds. Combined with managers' purchases of lower-quality raw cotton, these changes increased work intensity in the later 19th century, and were part of the race between productivity and good jobs.

Unions of mule operatives and self-actor minders that had originated in the late 18th century became a significant force by the 1820s and protected entry, pay, and control for the best jobs. However, the unions excluded most of the workforce: piecers and scavengers on cotton mules, operatives tending continuous machinery, and most workers outside of cotton. Subordinate workers did benefit when Parliament limited working hours from the mid-19th century, but factory regulation was much slower to address occupational health and safety. Respiratory disease, accidents, and a new type of cancer among mule spinners were important health risks.

The chapter begins with the self-actor and its limitations, and then describes spinning rooms, factory design, and power transfer technology. It presents evidence on the components of occupational quality and considers the development of regulation and the mule spinners' unions. Finally, it synthesizes the evidence on job quality, discusses growing occupational availability, and notes the continuing

exclusionary forces in job distribution. The analysis focuses on mule spinning of cotton in Lancashire, which was the largest part of the British spinning industry.[1]

The Self-Actor

The most significant technological change in intermittent spinning during the 19th century was Richard Roberts' invention of the self-acting mule in 1825. The self-actor was a complex machine that powered all three parts of spinning and regulated the speed of the carriage during driving and winding. It changed the work of the mule operative (called a 'self-actor minder') from a strenuous job to one focused on machine adjustments, piecing, and supervision. Despite its name, the self-actor was not automatic and required extensive adjustment to produce a cylindrical cop with beveled ends. Throughout the spinning cycle, the minder changed the position of the faller wire and a new component called the quadrant nut to maintain appropriate

[1] Mike Williams and D. A. Farnie, *Cotton Mills in Greater Manchester* (Preston: Carnegie, 1992), 14; Andrew Marrison, "Indian Summer, 1870–1914," in *The Lancashire Cotton Industry: A History since 1700*, ed. Mary B. Rose (Preston: Lancashire County Books, 1996), 238–40. Continuous machinery was primarily used for coarse yarn, and employment in spinning wool, worsted, and linen was substantially lower than in cotton. The reasons for British manufacturers' preference for intermittent spinning machines have been debated extensively. Lars G. Sandberg, *Lancashire in Decline: A Study in Entrepreneurship, Technology, and International Trade* (Columbus: Ohio State University Press, 1974). Sandberg claimed British manufacturers preferred mules based on a rational assessment of factor conditions: economizing on raw cotton, employing the larger pool of trained self-actor minders, and continuing to use their existing capital stock. By comparison, militant American mule spinners' unions incentivized ring frame adoption in the US. William Lazonick, *Competitive Advantage on the Shop Floor* (Cambridge: Harvard University Press, 1990), 135–37, 77–78. Lazonick emphasized more conciliatory British labor relations and the ability of British minders to use lower-quality cotton inputs. However, he also claimed that union demands for craft control produced 'institutional rigidity' that inhibited adoption of ring spinning. Other arguments include the American focus on coarser spinning and vertical integration, which reduced the cost of transporting the heavy wooden bobbins that held ring-spun yarn. Isaac Cohen, *American Management and British Labor: A Comparative Study of the Cotton Spinning Industry* (New York: Greenwood, 1990), 133–34.

tension in the yarn. The speed of the carriage during the return run was regulated by a chain attached to a quarter wheel (the 'quadrant arm'). Adjusting the quadrant nut altered the relationship between the rotation of the spindles and the speed of the carriage. If the quadrant nut was adjusted improperly (or not adjusted), the threads would be overtensioned and break, or be too slack and snarl. Adjusting the quadrant nut was most important and frequent at the start of the cycle; tweaks became less frequent during the middle of the cycle and could be entrusted to a little piecer at the minder's direction.[2]

To ensure that the spindle rotation and carriage speed matched the tapering diameter of the top of the spindle, the self-actor had a moveable peg on the quadrant arm that the minder could shift at the end of the spinning cycle, which was called the 'nosing motion'.[3] Finally, the self-actor added a 'counter-faller' wire underneath the yarn sheet, placed closer to the creel than the faller wire, to keep yarn taut during winding, and attached the faller wire to rods that automatically moved it up and down.[4] The self-acting mule enabled the minder to assist the piecers when he was not

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[2] Harold Catling, *The Spinning Mule* (Newton Abbot: David & Charles, 1970), 82–83. Draws were about twice as frequent in coarse as fine spinning. Cohen, *American Management and British Labor*, 77. Michael Huberman, *Escape from the Market: Negotiating Work in Lancashire* (Cambridge: Cambridge University Press, 1996), 59.

[3] Catling, *Spinning Mule*, 98–101. Thomas Thornley, *Practical Treatise Upon Self-Acting Mules* (Manchester: John Heywood, 1894), 32–33. One manual option to reduce slack as the spindle tapered toward the top was to adjust the faller wire during winding. The wire took up slack resulting from the reduced amount of yarn wound, preventing snarls. On the self-actor (without Roberts' adjustment mechanism for nosing), the minder needed to adjust the faller wire during the final hour of a spinning cycle. In a second option, the 'hastening motion', the minder shifted the driving belt to a 'fast pulley' shortly before the end of winding to accelerate the spindles and take up any slack resulting from the narrowing of the spindle. The 'hastening motion' required focus and experience to time the speed increase correctly.

[4] Andrew Bullen, Terry Wyke, and Alan Fowler, *The Barefoot Aristocrats: A History of the Amalgamated Association of Operative Cotton Spinners* (Littleborough, Lancashire: G. Kelsall, 1987), 5. Anthony F. C. Wallace, *Rockdale: The Growth of an American Village in the Early Industrial Revolution* (New York: Norton, 1980), 194.

engaged in adjustments to the quadrant nut and monitoring the faller wire, both of which were focused at the start of a spinning cycle.[5] Monitoring, piecing, and adjusting a self-actor was much less exhausting and slightly less repetitive than putting up a common mule every twenty to thirty seconds.

The self-actor was adopted first to spin coarse yarn, but fine spinning firms used common mules until the final decades of the 19th century.[6] The first self-actors were difficult to operate in fine spinning because they required more piecing. Experienced common mule operatives could limit breakages during winding and form good yarn packages.[7] Mechanics improved both machines: common mules reached 600 spindles by the 1830s, and eventually applied inanimate power to the return run of the carriage.[8] By the 1890s the self-actor quadrant nut only needed a handful of adjustments per cycle (in the 1830s nearly 100 adjustments had been required).[9]

A fully automatic mule would have enabled factory owners to replace their expensive adult male mule operatives with lower-waged women or children. However, only experienced minders could operate early self-actors without excessive piecing, and minders tweaked or 'customized' their machines so that workers could not spin easily on an unfamiliar mule.[10] The incompleteness of automation meant that

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[5] Cohen, *American Management and British Labor*, 80.
[6] *American Management and British Labor*, 82. Bullen, Wyke, and Fowler, *Barefoot Aristocrats*, 5–6.
[7] Catling, *Spinning Mule*, 51.
[8] Bullen, Wyke, and Fowler, *Barefoot Aristocrats*, 5–6.
[9] Cohen, *American Management and British Labor*, 78.
[10] Catling, *Spinning Mule*, 148–49. Lazonick contends that manufacturers were satisfied with the subcontracting system in the 1830s. The unions were relatively weak, minders were paid less than mule operatives, and minders saved management time by recruiting piecers. William Lazonick, "Industrial Relations and Technical Change: The Case of the Self-Acting Mule," *Cambridge Journal of Economics* 3, no. 3 (1979): 239–42.

minders were still required, and they exploited their advantageous position and training monopoly for many decades.

Spinning Rooms in the 19th Century

After the invention of the self-actor, intermittent spinning technology changed relatively little up to 1910, which allows a general description of the spinning room during this period. Spinning was generally carried out on the higher floors of a factory, which received bobbins of roving via a hoist. The spinning room was hot and humid to aid piecing, with temperatures frequently above 80˚F, and 80% or higher relative humidity. It smelled of cotton dust, machinery oil, and the wood of the floor and beams. The floors were a continual source of splinters. The ceiling-held line shafts, whirring power straps, grinding gears, and thousands of rotating spindles produced a steady din.[11] To maximize the number of spindles in each room, there was little space between the creel and the wall. If the carriages of two facing mules were extended, only a few feet remained in the middle of the room as a passage called the 'mule gate'. Even in the early 20th century mills rarely had running water; toilets were in the corners of the building or outdoors. Water buckets were placed around the room in case of fire.[12]

When the steam engine started in the morning, it began turning the line shafts on each floor. Before starting spinning, the piecers oiled the headstock (the mechanism

[11] Catling, *Spinning Mule*, 167–68. James Whittaker, *I, James Whittaker* (London: Rich & Cowan, Ltd., 1934), 186–87. Low temperatures and humidity outdoors increased yarn breakages. Thornley, *Self-Acting Mules*, 232–33.
[12] Catling, *Spinning Mule*, 169–70, 75. Williams and Farnie, *Cotton Mills*, 99. Colum Giles and Ian H. Goodall, *Yorkshire Textile Mills: The Buildings of the Yorkshire Textile Industry, 1770–1930* (London: H.M.S.O, 1992), 27.

that powered the draw) and the spindles by touching an oil can to the base of each spindle.[13] Excess oil would spray from the rotating spindle and stain the yarn, while too little allowed the bearings to overheat.[14] Oil dripped down onto the floor, which was unpleasant to work on and a slip hazard.

The youngest, least experienced workers carried messages around the factory and did other simple errands. After a few weeks of minor tasks, they were put to harder work as scavengers. Scavengers cleaned and oiled the machinery, carried heavy boxes of bobbins, and swept under the mules. They were frequently put in danger by overseers and minders who did not stop machinery for cleaning. Next, children shifted to creeling, piecing, and doffing as little piecers.[15]

Creeling was the provision of fresh roving to the creel. The piecer or dedicated 'creeler' removed a bobbin as it ran out of roving, held onto the last foot of roving from the old bobbin, disposed of the bobbin in a box, retrieved a fresh bobbin, placed it onto the creel, and joined the roving from the new bobbin to the old. This maneuver needed to be completed in a handful of seconds to allow uninterrupted draws. Spinning coarse counts used roving more quickly, which meant more frequent creeling.[16]

The chief role of the piecers was, as their title suggests, piecing. Yarn breakages varied with roving quality and the fineness and speed of spinning, but Catling

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[13] Albert Williams, *36 Stewart Street, Bolton: An Exercise in Nostalgia, 1901–1914* (Manchester: Neil Richardson, 1983), 6.
[14] Catling, *Spinning Mule*, 171.
[15] UK Parliamentary Papers, *Report of the Minutes of Evidence Taken before the Select Committee on the State of the Children Employed in the Manufactories of the United Kingdom*, vol. III.235, Paper 397 (1816), 163; *Select Committee on Bill for Regulation of Factories*, vol. XV.1, Paper 706 (1832), 319, 24–25, 470. Joseph Barlow Brooks, *Lancashire Bred: An Autobiography* (Church Army Press: Oxford, 1950), 117–19.
[16] Catling, *Spinning Mule*, 154–55.

estimates that on late 19th century 1200-spindle mules, 5 or 6 ends required piecing each minute. There was more piecing at the start of a new spinning cycle and in the morning because the mule room was colder. The broken end on the carriage (near) side usually curled from the rotation imparted by the spindle. The piecer grasped it between the thumb and index finger of one hand, held the roving (far) end of the breakage with the other hand, overlapped the two, and applied twist between the ends. Finally, he might need to adjust the number of coils on the spindle, because piecing may have changed the amount of slack in the pieced yarn and it needed to match the neighboring yarns. This was achieved by lifting some yarn up and off the spindle. When ends broke during winding (rather than the draw), the piecer needed to stop the spindle with one hand, find the broken end with the other hand, and piece it in the same manner as during the outward run. Keeping up with broken ends required near-constant walking along the mule.[17]

Once the cop was completed, the minder and piecers removed yarn from the spindles ('doffed'). A few draws before doffing, the minder struck a metal bar on the mule with a wrench to alert the piecers. Then the minder stopped the mule during winding, and the piecers pushed the cops up an inch on the spindles, a task referred to as 'thrutching-up'. The minder wound a few rotations of yarn on the spindle below the completed cops, in preparation for the next cycle. The minder and piecers then moved along the mule, collecting cops (and breaking the yarn at the bottom) with the right hand, piling the cops along the opposite forearm, and dropping them into containers along the mule. Doffing a 1200-spindle mule took several minutes and

[17] *Spinning Mule*, 156–57, 73.

piecers from adjacent mules usually assisted. The minder labeled the boxes of yarn with the count, spin date, and mule number, and the little piecer carried them to a hoist, which took boxes to the warehouse. Once the cops had been removed, the next spinning cycle could begin. In some mills, piecers applied starch paste over the first few layers of yarn (after the first handful of draws) to hold the base of the cop together. Piecers tried to avoid applying paste directly on the spindle. At the end of the 19th century, some manufacturers substituted paper tubes to hold the bottom of the cop, which made doffing take slightly longer.[18] The frequency of doffing, like creeling, varied significantly with fineness. A medium-fine spinning cycle (60s) could take about 12 hours, while a very fine cycle of 230s took nearly 100 hours.[19] Fine spinning usually required more piecing, and there were more piecers per operative or minder. The mules were also generally shorter and ran more slowly.[20]

Spinning sprayed cotton fiber into the air, and this residue built up on the machinery. Cleaning prevented lint clumps from falling onto the yarn (which would make the output inconsistent) and kept it from clogging the machinery. To clean the drafting rollers, workers removed them and wiped them with a cloth. Cleaning between the two parts of the mule was more difficult: piecers ran, bent double at the waist, under the yarn sheet while holding a cloth in one hand to clean the mule carriage and a brush in the other hand to clean the beam under the drafting rollers.

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[18] *Spinning Mule*, 157–58, 73–74. Some manufacturers disliked paste because excess starch could drip down the spindles and slow their rotation, and yarn covered in paste was not saleable. On the other hand, replacing tubes took workers' time away from spinning, and damaged tubes could prevent the minder from forming a good cop. Thornley, *Self-Acting Mules*, 172–78.

[19] Williams, *36 Stewart Street, Bolton*, 5.

[20] Williams and Farnie, *Cotton Mills*, 31. Cohen, *American Management and British Labor*, 79.

This process ('wiping down') was supposed to be done with the mule stopped, after a hand signal from the minder, and usually twice per day on each mule. It needed to be done quickly and without the piecers tripping or raising their head, thereby breaking the yarn sheet.[21] Operatives and minders punished piecers who damaged the yarn sheet while cleaning, and piecers described wiping down as 'back breaking' on account of the hunched posture. Using hand signals and having the piecers stand in specific places for potentially dangerous cleaning activities likely only emerged after many accidents in which piecers were trapped under a mule. Piecers also had to sweep the floor on hands and knees with a small brush because the floorboards were covered in lubricating oil.[22]

Maintenance tasks included replacing the thin bands (called strings) that drove each spindle when they broke or became overstretched. Replacing strings required a piecer to open an access door and pull the leather driving band turning the spindle down into an idle position. Then he pulled out the old string, tied a new string in place, cut the loose ends of the knot, and returned the driving band. The fast-moving band could easily cut a finger to the bone, and piecers replaced strings while the mule ran inward and outward.[23] Minders monitored the power straps that linked the machine to the line shafts because any slack could impair the performance of the mule and reduce piece-rate earnings. Straps and bands shrank slightly over cold nights and stretched from heavy running during the day, which required compensatory

[21] The mule carriage wheels ran on raised metal bands, which were a trip hazard. H. M. Crawford, "The Protection of Employees in Cotton Mills," *Cassier's Magazine* 37, no. 6 (1910): 726.
[22] Catling, *Spinning Mule*, 159–61. Williams, *36 Stewart Street, Bolton*, 6.
[23] Catling, *Spinning Mule*, 171–72.

adjustments to prevent, for example, the mule carriage running too quickly during winding and crashing into the creel.[24] To replace straps, the mule team cut a length of leather using markings on the floor and pulled the band from both ends to pre-stretch it, helped by workers on adjacent mules. After it was pre-stretched, the new band was placed on the machine, tied in place, and stretched again after running it briefly.[25]

The overseer or 'gaffer' was responsible for quality control and managing the minders or operatives. He and the assistant overseer ('under-gaffer') worked in small rooms at the corner or side of the spinning room. The overseer tested yarn strength and count, passed on changes in production requirements from the general manager, and instructed the minder to alter the mule's gearing if the output was unsuitable. While minders and piecers worked barefoot, in shirtsleeves and light cotton pants, the overlooker and assistant wore boots and a jacket.[26]

Factory Architecture, 1830–1910

The factories that housed these noisy, dusty spinning rooms were built larger in more standard layouts during the 19th century. A central engine drove a vertical power transmission shaft, which interlocked with horizontal line shafts on each ceiling through bevel gears. Vertical belts transferred power from line shafts to the machinery, which was positioned across the longer dimension of a room.[27] Ceiling heights increased to 3–3.5 meters on the top floors used for spinning by the end of the 19th

[24] *Spinning Mule*, 161–63.
[25] *Spinning Mule*, 175–77.
[26] *Spinning Mule*, 150–54. Williams, *36 Stewart Street, Bolton*, 6. Whittaker, *I, James Whittaker*, 187.
[27] Williams and Farnie, *Cotton Mills*, 4–8, 67–73, 88–89.

century. Taller windows provided more light, although larger rooms placed many workers further from natural light and air sources.[28] The early 20th century saw further growth in mill size and increased power. Workers in a minority of new mills enjoyed improved air quality from ventilation ducts.[29]

New construction methods in the mid-19th century aimed to 'fireproof' factories, although the measures were mitigation rather than prevention. Builders added plaster or metal sheets over wooden beams or joists and replaced wooden pillars and beams with cast iron to limit the spread of flames between stories. Cast iron was itself dangerous in the early 1800s: faulty casting produced several fatal collapses before improvements from the 1820s reduced the danger of catastrophe. Iron- and then steel-framed buildings became common late in the 19th century. Other fire-retarding measures included thicker floorboards that burned slowly and brick-vaulted ceilings. In many cases the brick was covered with plaster and whitewashed to reflect light onto the working space below. Brick vaulting became the most common approach to limit the spread of fire, but mills were built through the mid-19th century without fire mitigation.[30] By the last third of the century, most new cotton mills incorporated some mitigation, although rural mills were less well-protected.[31] Mill builders installed fire escapes from around 1850, but adoption was also slow. Early fire escapes were ladders

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[28] Joseph Nasmith, *Recent Cotton Mill Construction and Engineering* (Manchester: John Heywood, 1894), 17–19.
[29] Williams and Farnie, *Cotton Mills*, 120–32.
[30] *Cotton Mills*, 58–61, 80–81. Edgar Jones, *Industrial Architecture in Britain, 1750–1939* (London: Batsford, 1985), 45–46, 162. H.R. Johnson and A. W. Skempton, "William Strutt's Cotton Mills, 1793–1812," *Transactions of the Newcomen Society* 30 (1957): 179–82.
[31] Williams and Farnie, *Cotton Mills*, 101. Anthony Calladine and Jean Fricker, *East Cheshire Textile Mills* (London: Royal Commission on the Historical Monuments of England, 1993), 119–20.

affixed to exterior walls, which may have been as dangerous as a smoke-filed staircase.[32] Factory owners began to install sprinkler systems from the mid-1880s, although they were only widely adopted after a catastrophic fire in 1901.[33] Fire mitigation retarded the spread of fires and increased workers' chances of escape.

Developments in Power Sources & Transfer

Power transfer technology became lighter and enabled the use of larger machines with higher spindle speeds through the 19th century. Some improvements also reduced the risk of operative injuries from fast-moving belts and gears. In the first third of the 1800s engineers replaced wooden line shafts with cast iron, although, like structural iron, it was heavy and susceptible to failure. Later in the 19th century narrower, lighter, and more durable wrought iron shafts enabled higher rotational speeds.[34] Even so, bevel gearing required frequent oiling, and much energy was lost to friction. If an operative switched a machine belt onto a moving shaft too quickly, the rapid infusion of power might strip gears in the machine, requiring repairs at the cost of workers' wages.[35]

From the 1870s ropes, belts, and cables began to replace shafts for power transfer between floors. Rope drive was safer because it separated power transfer between floors from most of the working area, more efficient because the machinery was lighter, and less susceptible to failure than a single shaft because each floor was

[32] Duncan Gurr, Julian Hunt, and David Collier, *The Cotton Mills of Oldham*, 3rd ed. (Oldham: Oldham Education & Leisure, 1998), 17–18.
[33] Williams and Farnie, *Cotton Mills*, 26, 31, 92. Nasmith, *Cotton Mill Construction*, 58–65.
[34] Richard L. Hills, *Power from Steam: A History of the Stationary Steam Engine* (Cambridge: Cambridge University Press, 1989), 113–14.
[35] *Power from Steam*, 208.

powered with a separate set of ropes turned by a drum on the engine.[36] In the early 20th century electric power improved efficiency but changed little in the organization of the spinning room. Electric engines drove shafts and belts to power the machinery, although electricity reduced noise and fire risk from the engine house.[37]

Air and Light in Spinning Rooms

Spinning factories were kept warm and humid, with thermometers placed on the walls of some factories for overseers to ensure rooms were at the correct temperature. Temperatures from 80–100˚F (26–38˚C) were common in cotton spinning, and fine mills were usually hotter than coarse mills.[38] The rooms were heated by operating the machines, preventing ventilation, and steam pipe heating.[39] The earliest mills had been lit by candles or oil lamps, and both remained in use for decades. Gas lighting was first used during the early 1800s and became common by the middle of the century. Electric lighting was introduced at the end of the 19th century, but most factories continued to be lit by gas.[40]

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[36] Giles and Goodall, *Yorkshire Textile Mills*, 160–62. Nasmith, *Cotton Mill Construction*, 233, 37, 43. Hills, *Power from Steam*, 209–12.

[37] Giles and Goodall, *Yorkshire Textile Mills*, 163–65. Hills, *Power from Steam*, 217.

[38] UK Parliamentary Papers, *Select Committee on Factory Regulation*, XV.1, Paper 706, 235, 52, 309, 24, 521. J. T. Arlidge, *The Hygiene, Diseases and Mortality of Occupations* (London: Percival & co., 1892), 355–56, 63. John Tatham, "Dust-Producing Occupations," in *Dangerous Trades*, ed. Thomas Oliver (John Murray: London, 1902), 147. James Wheatley, "Manufacture of Cotton," in *Dangerous Trades*, ed. Thomas Oliver (John Murray: London, 1902). Temperatures in spinning factories may have increased across the 19th century, perhaps to allow for finer spinning: the Sadler Committee witnesses (1831) reported temperatures in the 80–86˚F range; Wheatley (1902) reported temperatures 'commonly above 90˚F, and occasionally above 100˚F'.

[39] UK Parliamentary Papers, *Select Committee on Factory Regulation*, XV.1, Paper 706, 253.

[40] Williams and Farnie, *Cotton Mills*, 119. Nasmith, *Cotton Mill Construction*, 81. There are some reports of candle lighting in the second quarter of the 19th century. Benjamin Brierley, *Home Memories, and Recollections of a Life* (Manchester: Abel Heywood & Son, 1887), 20–21. Bill Naylor, *Lancashire Leatherneck* (Swinton: N. Richardson, 1985), 8.

Intensity in the 19th Century Factory

When spinning good quality cotton on well-functioning self-actors, minders' and piecers' work could be of moderate intensity: tiring, but not as exhausting as putting up a common mule after each draw and piecing many broken threads. Focus was more important than exertion for self-actor minders, as it enabled them to reduce breakages and spin consistent yarn at the desired count. Piecing required dexterity as well as endurance, especially on longer mules: children reported walking up to 20 miles per day along a mule while piecing and cleaning.[41] Compounding the difficulty of long hours was the frequent requirement that workers remain standing throughout the day.[42]

Although the self-actor reduced work effort for minders in the 1830s, manufacturers demanded higher effort levels in the middle and later 19th century. The gradual improvement of machinery enabled higher spindle speeds and more spindles per worker. This raised productivity, but also intensity for operatives.[43] Longer mules with faster-rotating spindles, particularly for fine spinning, required more piecing.[44] The average self-acting mule had 109 spindles turning at 5000 rpm in 1850, and 234 spindles at 11,000 rpm in 1890.[45] By the 20th century, the fastest outward and return

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[41] Thomas Whittaker, *Life's Battles in Temperance Armour* (London: Hodder & Stoughton, 1884), 8. A lower estimate of walking distance was 10 miles per day. UK Parliamentary Papers, *Select Committee on Factory Regulation*, XV.1, Paper 706, 253–54.
[42] *Select Committee on Factory Regulation*, XV.1, Paper 706, 182, 308.
[43] *Select Committee on Factory Regulation*, XV.1, Paper 706, 170, 80, 279. Gray claims that manufacturers increased discipline and intensity after regulations limited working hours. Robert Gray, *The Factory Question and Industrial England, 1830–1860* (Cambridge: Cambridge University Press, 1996), 216.
[44] Cohen, *American Management and British Labor*, 88. Bullen, Wyke, and Fowler, *Barefoot Aristocrats*, 74.
[45] Keith Burgess, *The Origins of British Industrial Relations: The Nineteenth Century Experience* (London: Croom Helm, 1975), 236. Mike Holbrook-Jones, *Supremacy and Subordination of Labour: The Hierarchy of Work in the Early Labour Movement* (London: Heinemann, 1982), 168–

traverse could be as rapid as 12 seconds: 7 seconds for the draw and 5 seconds for winding. More commonly, coarse (counts under 20) draws and winding took around 14–15 seconds, and fine (51s–70s) 18–20 seconds.[46] To spin at these increased speeds, operatives and minders demanded more work from piecers.[47] Another factor that intensified work in the late 19th century was changes in cotton inputs. Manufacturers economized on raw materials by purchasing lower grade, cheaper cotton that produced more broken threads, which workers called 'bad spinning'.[48] More piecing meant more work, and bad spinning was a common complaint in late 19th century industrial actions. Purchasing cheaper raw cotton and demanding more work from the minders and piecers raised productivity for manufacturers at the cost of job quality.

Working Time and Regulation

Hours and Breaks in the 1830s

Reduced working hours eventually offset rising intensity, but 1830s saw hours little different from the early factory system. Witnesses to the Sadler Committee stated that mills without apprentices continued to work for 11–12 hours. 6 AM to 7 PM was a common schedule, with between 30 and 70 minutes of scheduled breaks. Some mills

69. John Jewkes and E. M. Gray, *Wages and Labour in the Lancashire Cotton Spinning Industry* (Manchester: Manchester University Press, 1935), 65.

[46] *Wages and Labour*, 8, 70.

[47] Cohen, *American Management and British Labor*, 133–34.

[48] Joseph L. White, *The Limits of Trade Union Militancy: The Lancashire Textile Workers, 1910–1914* (London: Greenwood, 1978), 103–04. William H. Lazonick, "Production Relations, Labor Productivity, and Choice of Technique: British and U.S. Cotton Spinning," *The Journal of Economic History* 41, no. 3 (1981): 503–06. Other causes of bad spinning included higher spindle speeds or spinning higher counts without purchasing higher-quality cotton.

provided time for breakfast and water during the day, but many only allowed a mid-day meal. In exceptional cases, hours could be 3 AM to 9 PM in summer, although long shifts were usually 15 hours.[49] Factories also worked longer shifts to make up for time lost from low water or problems with machinery.[50]

Pauses were rare, brief, and at the discretion of managers. Overseers made workers eat while standing and tending machinery, or demanded they clean for up to 30 minutes during mealtimes.[51] Overseers in some mills prevented workers from taking meal and toilet breaks entirely, and workers reported soiling themselves as a result.[52] The most common break was at midday. Some mills had insect infestations that made food left out unsanitary; workers also complained that food became inedible under layers of fiber dust.[53] With the exception of operatives who lived close to a mill, employees sat on the oily wooden floor to eat.[54]

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[49] UK Parliamentary Papers, *Select Committee on Factory Regulation*, XV.1, Paper 706, 114, 24–25, 48, 57, 67, 99, 230, 349. There are many claims that 13 or more hours per day was a regular schedule, including William Chadwick, *Reminiscences of a Chief Constable* (London: J. Heywood, 1900), 9.

[50] UK Parliamentary Papers, *Select Committee on Factory Regulation*, XV.1, Paper 706, 232, 35, 52, 349. Some workers said factory owners kept false time (an early starting bell and a late closing bell) to lengthen the day. James Myles, *Chapters in the Life of a Dundee Factory Boy: An Autobiography* (Dundee: J. Myles, 1850), 13.

[51] UK Parliamentary Papers, *Select Committee on Factory Regulation*, XV.1, Paper 706, 189, 230, 35, 84. *Select Committee on Factory Regulation*, XV.1, Paper 706, 235. Katrina Honeyman, *Child Workers in England, 1780–1820: Parish Apprentices and the Making of the Early Industrial Labour Force* (Aldershot: Ashgate, 2007), 188.

[52] UK Parliamentary Papers, *Select Committee on Factory Regulation*, XV.1, Paper 706, 165.

[53] Williams, *36 Stewart Street, Bolton*, 6. UK Parliamentary Papers, *Select Committee on Factory Regulation*, XV.1, Paper 706, 126, 67, 74, 294.

[54] Williams, *36 Stewart Street, Bolton*, 5.

Regulation of Children's Work and Working Time

Factory regulation began with restrictions on children's work and gradually expanded to encompass women's hours and working conditions. In 1802 Parliament passed the first limits on apprentices' hours, and in the 1810s and 1820s further legislation added rules for all cotton mills and then all child workers. However, regulation was weakly enforced by local magistrates and had limited effects. Manufacturers could avoid the working time rules by claiming a temporary loss of water power, which permitted them to make up time.[55] From the 1820s workers and some manufacturers lobbied for more robust legislation to reduce working hours, contending that only regulation could prevent 'low-road' labor practices.[56]

The 1833 Factory Act prohibited work for under-nines and limited hours for nine- to 13-year-olds to nine per day and 48 per week. Workers between 13 and 18 could only work 12 hours per day and 69 per week, and these 'young persons' were supposed to receive 1.5 hours of breaks each day. Work between 8:30 PM and 5 AM was prohibited for all children.[57] In 1844, new regulations limited 9–13 year olds to seven hours per day, creating a 'half-time' system of work and schooling. The 1844 Act also added 12-hour day and nighttime work limits for women.[58]

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[55] Adam Henry Robson, *The Education of Children Engaged in Industry in England, 1833–1876* (London: Kegan Paul, Trench, Trubner, 1931), 4–5. B. L. Hutchins and A. Harrison, *A History of Factory Legislation*, 2nd ed. (London: P.S. King & Son, 1911), 16–18, 23–25, 30–33.
[56] Ursula R. Q. Henriques, *The Early Factory Acts and Their Enforcement* (London: Historical Association, 1971), 4–8. Hutchins and Harrison, *Factory Legislation*, 43–50. Steven Toms and Alice Shepherd, "Accounting and Social Conflict: Profit and Regulated Working Time in the British Industrial Revolution," *Critical Perspectives on Accounting* 49 (2017).
[57] *Her Majesty's Inspectors of Factories, 1833–1983: Essays to Commemorate 150 Years of Health and Safety Inspection*, (London: H.M.S.O., 1983), 11.
[58] *Her Majesty's Inspectors of Factories*, 13. Hutchins and Harrison, *Factory Legislation*, 85–86.

While child workers were essential in many factories, regulations on their working hours in the 1830s did not necessarily curtail the work of adults. Factories ignored regulations and scheduled children to work in shifts so that mule operatives always had piecers to assist them.[59] Shifts deprived child workers of rest as they worked in the morning, were sent away in the middle of the day, and then had to return to complete their legally-permissible hours. The 'relay system' also made it difficult for the Factory Inspectors to monitor excessive hours.[60]

Parliament continued to reduce permitted hours and raise the minimum work age in the rest of the 19th century. In 1847, the Ten Hours Act reduced maximum hours to 10 per day and 58 per week. This was modified in 1853, returning the week to 60 hours but prohibiting relays.[61] The minimum age for work rose to 10 in 1876, 11 in 1893, and 12 in 1899.[62] Labor by children under 12 was finally prohibited in 1901, and full-time work was not permitted until age 13.[63] The mid-19th century workday was 6 AM to 6 PM with 1.5 hours for meals from Monday to Friday, and 6 AM to 2 PM on Saturday, totaling 60 hours. From the 1870s, Saturday work stopped at 1 PM, which reduced maximum hours to 59.[64] Parliament shortened working time further in 1875, to 56.5 hours per week, and 55.5 hours in 1902.[65]

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[59] *Factory Legislation*, 65.
[60] *Factory Legislation*, 100–04. Rhodes Boyson, *The Ashworth Cotton Enterprise: The Rise and Fall of a Family Firm, 1818–1880* (Oxford: Clarendon Press, 1970), 176–77.
[61] Hutchins and Harrison, *Factory Legislation*, 96–99, 107–08.
[62] Michael J. Winstanley, "The Factory Workforce," in *The Lancashire Cotton Industry: A History since 1700*, ed. Mary B. Rose (Preston: Lancashire County Books, 1996), 133.
[63] Hutchins and Harrison, *Factory Legislation*, 270–71. Henry Adolphus Mess, *Factory Legislation and Its Administration, 1891–1924* (London: P.S. King & Son, 1926), 87.
[64] Catling, *Spinning Mule*, 178.
[65] Alan Fowler, *Lancashire Cotton Operatives and Work, 1900–1950: A Social History of Lancashire Cotton Operatives in the Twentieth Century* (Aldershot: Ashgate, 2003), 59–62. A. L. Bowley, *Wages and Income in the United Kingdom since 1860* (Cambridge: Cambridge University Press, 1937), 25.

Regulation of Mill Premises

In contrast to the many debates over children's work and working time, factory conditions were lightly regulated. Apart from a 1802 requirement to limewash premises employing pauper apprentices, sanitary regulation was almost nonexistent. Limewashing was only extended to all factories in 1864, and replaced by a vague requirement for general cleanliness in 1867.[66] Legally-permissible working conditions were usually described as 'reasonable', 'adequate', or 'suitable', and these terms were difficult to enforce. Factory inspectors only introduced objective, sometimes quantitative standards (e.g. a permissible proportion of carbonic acid in factory air) at the end of the 19th century.[67]

Ventilation was not subject to any meaningful regulation until 1867, when factory inspectors were permitted to require fans or other mechanisms to circulate air. There was no specific regulation of air, lighting, or temperature.[68] Mill owners were reluctant to improve ventilation because humidity and warmth limited yarn breakages. Improved ventilation could also introduce pollutants such as soot that would damage and discolor yarn. The first extractor fans were installed in the last decades of the 19th century, but they were rare.[69] The 1901 Factory and Workshop Act only stated that premises be 'kept in a cleanly state' and 'ventilated in such a manner

[66] Mess, *Factory Legislation, 1891–1924*, 16–17. Hutchins and Harrison, *Factory Legislation*, 16–18.
[67] Mess, *Factory Legislation, 1891–1924*, 168–69.
[68] *Factory Legislation, 1891–1924*, 17–18.
[69] Nasmith, *Cotton Mill Construction*, 89–90.

as to render harmless, so far as is practicable, all the gases, vapours, dust or other impurities […] that may be injurious to health'.[70]

The 1844 Factory Act included the first rules to protect workers from moving machinery: it required employers to place guards on some equipment and prohibited sending children between the carriage and creel of a self-actor. However, millowners resisted placing guards over, or 'fencing' gearing, shafts, and machinery. They opposed interference with the arrangement of their machinery and were concerned that boxing would impede operations and repairs.[71] Rules about protecting machinery changed little until 1901, when legislation required that all components of mill gearing, and shafts and driving pulleys within a specified distance of workers, should be boxed. Women and under-18s were not allowed to clean gearing in motion.[72]

Unsurprisingly given the underlying regulations, the factory inspectors had a poor reputation for ensuring safe working conditions.[73] The Home Office rarely pursued violators of regulations as prosecutions in jurisdictions where many magistrates were factory owners were unlikely to succeed, and fines for convictions were modest.[74] Further, workers reported that manufacturers altered the conditions of work ahead of inspections by lowering the temperature and humidity, cleaning the

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[70] Peter Neild, *Byssinosis: The Lancashire Disease* (London: Chartered Insurance Institute, 1982), 27.
[71] UK Parliamentary Papers, *Chief Inspector of Factories and Workshops Report, 1885–86*, vol. XVII.539, Paper 17, C.5002 (1887), 12–13.
[72] Anthony Howe, *The Cotton Masters, 1830–1860* (Oxford: Clarendon Press, 1984), 188–90. H. S. Richmond, "Safe-Guarding of Machinery," in *Dangerous Trades*, ed. Thomas Oliver (John Murray: London, 1902), 208–10.
[73] Fowler, *Lancashire Cotton Operatives*, 181.
[74] P. W. J. Bartrip, *Workmen's Compensation in Twentieth Century Britain: Law, History and Social Policy* (Aldershot: Avebury, 1987), 3–5. Factory inspectors rarely collected the fines stipulated for injury-producing accidents. P. W. J. Bartrip and Sandra Burman, *The Wounded Soldiers of Industry: Industrial Compensation Policy, 1833–1897* (Oxford: Clarendon Press, 1983), 54, 56–60. *Her Majesty's Inspectors of Factories*, 6.

factory, and running machinery at lower speeds.[75] For their part, the minders' unions were more interested in wages than safety. They only began to check that machinery was correctly boxed from the 1880s and raised the issue of ventilation concertedly in the 1900s.[76] Little piecers and scavengers—the workers most likely to suffer from unguarded machinery—were not unionized.

Working Time and Regulation: Summary

Factory regulation complemented other developments that incentivized a shift away from young child labor, but it did not prohibit all children from working, and half-timers continued to be employed as scavengers and little piecers into the 20th century. The thin end of the regulatory wedge—controlling child labor—limited working time for most employees, reducing hours from more than 70 per week to under 60. By contrast, regulation of safety and working conditions was imprecise and ineffective. Exposed belts and gearing remained a hazard and most spinning rooms had little ventilation.

Short-Term Health Risks

Accidents

In the absence of effective safety regulation, many of the same occupational hazards discussed in the previous chapter remained through the 19th century. Belts

[75] R. S. Fitton, *The Arkwrights: Spinners of Fortune* (Manchester: Manchester University Press, 1989), 158–60.
[76] Fowler, *Lancashire Cotton Operatives*, 131–32, 74, 81.

running at high speed sliced through skin and gears easily crushed bones.[77] Most injuries were nonfatal but could be debilitating—broken digits or limbs and occasionally the loss of appendages.[78] Long and exhausting hours made accidents more likely, as fatigue contributed to injuries.[79] Accidents were more common in the hours before the lunch break and the end of the day.[80] Moreover, some workers were not paid for cleaning at the end of shifts, so they frequently began to clean running machinery.[81] There may have been a modest decrease in accident rates over the 19th century because of guarding technology and learning-safety-by-doing, such as procedures for signaling wiping down, but the statistical evidence is limited.[82]

As well as weak factory regulation, financial incentives to prevent accidents were minimal. There were few common law precedents for compensation, and *Priestly v. Fowler* (1837) established that employees could not sue employers for injuries caused by other workers.[83] Employers were only liable if they alone were responsible for an

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[77] For examples, see UK Parliamentary Papers, *Select Committee on Factory Regulation*, XV.1, Paper 706, 142–43, 93, 233, 371, 77, 82.

[78] Nathaniel Gould, *Information Concerning the State of Children Employed in Cotton Factories, Printed for the Use of the Members of Both Houses of Parliament* (Manchester: J. Gleave, 1818), 24. While the Factory Acts required firms to compile accident data, the factory inspectors believed reports omitted many injuries. Bartrip and Burman, *Wounded Soldiers of Industry*, 11–15, 37–38. Bartrip and Burman review evidence on injuries in Stockport and Manchester from the 1830s and 1840s and suggest that 1–2.5% of workers suffered an injury that was serious enough to require medical attention each year. For comparison, death rates (not injury rates) in mining were 5–8 per 1000 workers per year in the 1850s.

[79] UK Parliamentary Papers, *Select Committee on Factory Regulation*, XV.1, Paper 706, 319, 38–39, 82. Myles, *The Life of a Dundee Factory Boy*, 14.

[80] Fowler, *Lancashire Cotton Operatives*, 177–78.

[81] *Lancashire Cotton Operatives*, 179.

[82] Establishments counted as textile factories changed over time and the figures do not disaggregate by type of textile work. Bartrip and Burman, *Wounded Soldiers of Industry*, 46, 49. Some factories added implements to guard machinery in the late 19th and early 20th century, especially on mules. Crawford, "The Protection of Employees in Cotton Mills."

[83] Bartrip, *Workmen's Compensation*, 2–3, 6–8. Bartrip and Burman, *Wounded Soldiers of Industry*, 28–30, 32, 117–18. Most workers did not receive voluntary compensation and employers stopped wages when an employee was unable to work. Jamie L. Bronstein, *Caught in the*

injury. The Workmen's Compensation Act (1897) reduced the burden of proof on injured workers and raised the maximum compensation claim.[84] However, compensation was usually paid by insurers; because premiums were rarely merit-based there were few incentives to improve safety. The limited statistical evidence suggests the 1897 Act did not reduce industrial accidents.[85]

Violence

Corporal punishment remained common, with child workers the main victims. Violence was more frequent towards the end of the day as overseers or mule operatives sought to maintain effort levels.[86] The most common punishment was 'strapping': striking child workers with a leather strap. Mule operatives and throstle overseers also used sticks, and other instances of punishment included shoving workers against nails in walls, smashing children's heads into the spindles, flogging, and kicking.[87] Workers were most frequently beaten for poor piecing, but also for talking, sitting down, damaging machinery or tools, and lateness.[88] While contemporaries focused on physical injuries, some mentioned that beatings produced psychological trauma.[89] There is some evidence of child sexual abuse, and its

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Machinery: Workplace Accidents and Injured Workers in Nineteenth-Century Britain (Stanford: Stanford University Press, 2008), 34–35.

[84] Bartrip, *Workmen's Compensation*, 10–11.

[85] Bartrip and Burman, *Wounded Soldiers of Industry*, 212–14. Fowler, *Lancashire Cotton Operatives*, 175.

[86] UK Parliamentary Papers, *Select Committee on Factory Regulation*, XV.1, Paper 706, 116–17, 25, 29, 49–52, 58, 65, 68–69, 74, 93, 232, 451–52. Honeyman, *Child Workers*, 182–85, 240–42.

[87] UK Parliamentary Papers, *Select Committee on Factory Regulation*, XV.1, Paper 706, 39, 99, 129, 45, 99, 237, 377, 89. William Marcroft, *The Marcroft Family* (Manchester: John Heywood, 1886), 33.

[88] UK Parliamentary Papers, *Select Committee on Factory Regulation*, XV.1, Paper 706, 147, 59, 66, 96.

[89] *Select Committee on Factory Regulation*, XV.1, Paper 706, 325.

comparative scarcity could be explained by infrequency or a reluctance of survivors to share their experiences.[90]

Long-Term Health Risks

The mid- and late 19th century saw the first studies of industrial disease. Researchers found that work in the dusty, poorly-ventilated environment of a spinning room first produced 'mill fever' within a few days or weeks of starting work, including 'chills, nausea, and vomiting, quickly followed by headache, thirst, and heat of skin'.[91] Another ailment was skin irritation produced by frequent contact with oils used to lubricate machinery, or applied to fiber to reduce breakages.[92] The longer-term effects of dust and lubricating oil were potentially fatal, although evidence for these ailments took decades to compile.

Byssinosis

Workers' complaints of 'mill fever' gained a scientific basis in the later 19th century. Exposure to cotton dust caused difficulty breathing, chest tightness, coughing, and spitting blood.[93] By the middle of the 19th century doctors considered textile fiber dust one of the more dangerous inhaled substances, and in the early 20th century medical professionals applied the term 'byssinosis' to lung damage from

[90] Honeyman, *Child Workers*, 186–87.
[91] Arlidge, *Hygiene of Occupations*, 375–76. Henry S. Purdon, "Flax and Linen," in *Dangerous Trades*, ed. Thomas Oliver (John Murray: London, 1902), 699.
[92] Arlidge, *Hygiene of Occupations*, 376. Purdon, "Flax and Linen," 699.
[93] UK Parliamentary Papers, *Select Committee on Factory Regulation*, XV.1, Paper 706, 166. Arlidge, *Hygiene of Occupations*, 360.

cotton dust.[94] Also called 'brown lung', it begins with the acute symptoms listed above, followed by reduced ventilatory capacity. After extended exposure, the acute symptoms become persistent and it can eventually lead to chronic obstructive pulmonary disease, which generally causes disability and death.[95] The air in older, more cramped factories and coarse spinning mills contained more cotton dust.[96]

The factory inspectors had authority to order ventilation improvements in the 19th century, but made no direct efforts to measure and improve air quality until 1908. A report on cotton dust, which focused on carding, recommended some ventilation and the use of respirators. While most mills adopted exhaust ventilation for carding rooms, there was little change in spinning premises until 1946.[97]

Cancer

At the end of the 19th century another industrial hazard emerged: 'mule spinners' cancer'. This potentially fatal disease of the scrotum was first identified in the 1880s, and scientific investigations followed from the 1920s to the 1940s. Rotating

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[94] Jesse Leach, "Surat Cotton, as It Bodily Affects Operatives in Cotton Mills," *The Lancet* 82, no. 2101 (1863). Thomas Oliver, "Dust as a Cause of Occupation Disease," in *Dangerous Trades*, ed. Thomas Oliver (John Murray: London, 1902), 271–73. Factory inspectors required some textile operatives to use primitive respirators in the late 19th century, but these were ineffective. Purdon, "Flax and Linen," 693. Because cardroom workers were most affected, they were the subjects of early systematic studies of respiratory illness. These studies found very high prevalence (over 70% of strippers and grinders affected). Investigations into spinners found that tuberculosis and bronchitis were common. Jacqueline K. Corn, *Response to Occupational Health Hazards: A Historical Perspective* (New York: Van Nostrand Reinhold, 1992), 155–59.

[95] *Response to Occupational Health Hazards*, 148. Neild, *Byssinosis*, 17–18.

[96] P. W. J. Bartrip, *The Home Office and the Dangerous Trades: Regulating Occupational Disease in Victorian and Edwardian Britain* (Amsterdam: Rodopi, 2002), 23–24. Arlidge, *Hygiene of Occupations*, 355, 63. Tatham, "Dust-Producing Occupations," 147. Neild, *Byssinosis*, 19. Jewkes and Gray, *Wages and Labour*, 11.

[97] Neild, *Byssinosis*, 23–24, 38–39.

spindles sprayed shale or other mineral oils onto the groin area of operatives, and oil also came into contact with light clothing and skin when workers leaned over a mule to piece. Mineral oil had replaced animal oils by the 1870s, so this cancer afflicted workers from the later part of the 19th century, primarily those with long terms of service (20 to 30 years). The incidence of mortality from scrotal cancer among spinners (or former spinners) aged 55–75 was 100 times higher than in the general population. The cancer was primarily found on the left side of the scrotum, which later research ascribed to the fact that most spinners leaned over the mule to piece with their left hand while standing on their left leg. It was not observed in woollen spinning, where operatives pieced with both hands and wore more clothing.[98]

Stability of Earnings

While work remained dangerous, employees' earnings were more stable during the second phase of industrial spinning. Employers could not pay in truck or bills of exchange following the Truck Act of 1831.[99] Turnover and changes in wages were both lower by the middle of the 19th century. Instead of laying off experienced

[98] Bullen, Wyke, and Fowler, *Barefoot Aristocrats*, 184–96. Mineral oils enabled smooth and long running at high spindle speeds. Anna P. Benson, *Textile Machines* (Princes Risborough: Shire, 1983), 29; Catling, *Spinning Mule*, 179. James Robertson, "An Enquiry in Regard to the Cause of Spinners' Scrotal Cancer," (Glasgow: University of Glasgow, 1926). "Mule-Spinner's Cancer," *The British Medical Journal* 1, no. 3408 (1926); "Report of the Departmental Committee on Mule-Spinner's Cancer," *The British Medical Journal* 1, no. 3408 (1926). "Mule-Spinner's Cancer," *The Lancet* 239, no. 6175 (1942). Suggested mitigation included using different types of (non-carcinogenic) oil, regular medical inspections of the potentially affected area, and protective ointments or clothing to impede contact. E. M. Brockbank, "Mule-Spinner's Cancer," *British Medical Journal* 1, no. 4190 (1941). *Mule Spinners Cancer: Epithelioma of the Skin in Cotton Spinners* (London: H. K. Lewis & Co. Ltd., 1941). Fowler, *Lancashire Cotton Operatives*, 141–43.

[99] "An Act to Prohibit the Payment of Wages in Goods," Wm. 4, c. 37 (1831). Payment in cash had been required for woollen, linen, and fustian manufacture from 1701, but not cotton. Mess, *Factory Legislation, 1891–1924*, 10.

workers in downturns, firms reduced hours.[100] Even so, workers did suffer wage reductions, short hours, and unemployment during contractions.[101] Cyclical downturns led to short working or unemployment in 1842, 1847, the Cotton Famine of 1861–65, 1877–79, 1884–85, and 1891–93.[102] Industrial action could also interrupt working and earning. There are no statistics on days of work lost before the final decade of the 19th century, and many small disputes were not recorded, but there were sporadic strikes during periods of union strength in the late 19th and early 20th century.[103]

Unions

Industrial action was enabled by exceptionally high unionization in parts of cotton spinning. The first labor combinations were local associations of jenny and hand mule operatives in the 1780s, followed by unions of mule spinners in Stockport and Manchester in 1792.[104] The Combination Acts prohibited collective bargaining from 1799 to 1824.[105] Illegal strikes from 1801 to 1818 were mostly unsuccessful at equalizing

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[100] Huberman, *Escape from the Market*, 3–5, 111–12.
[101] C. H. Lee, *A Cotton Enterprise, 1795–1840: A History of M'connel & Kennedy Fine Cotton Spinners* (Manchester: Manchester University Press, 1972), 122.
[102] John K. Walton, *Lancashire: A Social History, 1558–1939* (Manchester: Manchester University Press, 1987), 171. H. I. Dutton and J. E. King, *"Ten Per Cent and No Surrender": The Preston Strike, 1853–1854* (Cambridge: Cambridge University Press, 1981), 23. Walton, *Lancashire: A Social History*, 201. Norman Longmate, *The Hungry Mills* (London: Temple Smith, 1978), 55–56, 70. Cohen, *American Management and British Labor*, 96.
[103] For examples of brief disputes, see White, *The Limits of Trade Union Militancy*, 204–15. UK Parliamentary Papers, *Board of Trade Report on Strikes and Lock-Outs and on Conciliation and Arbitration Boards in the United Kingdom in 1910*, vol. Cd. 5850 (1911), 125–26.
[104] A. Aspinall, *The Early English Trade Unions: Documents from the Home Office Papers in the Public Record Office* (London: Batchworth Press, 1949), xiv–xvi. Cohen, *American Management and British Labor*, 15.
[105] John V. Orth, "The English Combination Laws Reconsidered," in *Labour, Law, and Crime: An Historical Perspective*, ed. Francis G. Snyder and Douglas Hay (London: Tavistock Publications, 1987), 123–25; Bullen, Wyke, and Fowler, *Barefoot Aristocrats*, 24.

wages across Lancashire, but they made manufacturers reluctant to challenge the unions on control and recruitment.[106]

Attempts to unite the localized district associations of spinners were unsuccessful in the first half of the 19th century.[107] The Amalgamated Association of Operative Cotton Spinners was founded in 1870 to unite the groupings; it collapsed during the 1870s depression, was re-formed in 1884, and grew to cover 93% of Lancashire self-actor minders by 1891.[108] Piecers were excluded from the minders' unions, but in some places they were allowed to form subordinate organizations. However, unionized piecers could only strike with permission from the minders, and they had to receive permission to move for spinning work in another area of Lancashire.[109]

Lancashire cotton was unusual in its union density. There was little unionization in woollen and worsted spinning or continuous spinning. Only overlookers were well organized and woollen mule spinners had no equivalent to the cotton spinners' combination.[110] The most organized workers in the textile industry

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[106] *Barefoot Aristocrats*, 17. Walton, *Lancashire: A Social History*, 146; Cohen, *American Management and British Labor*, 113–14. Bullen et al. state that for several periods in the early 19th century manufacturers held the upper hand over the operatives' unions. Bullen, Wyke, and Fowler, *Barefoot Aristocrats*, 36–38.

[107] *Barefoot Aristocrats*, 36–51.

[108] Alan Fowler, "Great Britain: Textile Workers in the Lancashire Cotton and Yorkshire Wool Industries," in *The Ashgate Companion to the History of Textile Workers, 1650–2000*, ed. Lex Heerma van Voss, Els Hiemstra-Kuperus, and Elise van Nederveen Meerkerk (Farnham: Ashgate, 2010), 240–41. Walton, *Lancashire: A Social History*, 266. Fowler, *Lancashire Cotton Operatives*, 15. H. A. Turner, *Trade Union Growth, Structure and Policy: A Comparative Study of the Cotton Unions* (London: George Allen & Unwin, 1962), 136–37. White, *The Limits of Trade Union Militancy*, 76.

[109] Bullen, Wyke, and Fowler, *Barefoot Aristocrats*, 77–78. White, *The Limits of Trade Union Militancy*, 99. Burgess, *British Industrial Relations*, 256.

[110] J. H. Clapham, *The Woollen and Worsted Industries* (London: Methuen, 1907), 208–11. J. A. Jowitt, "The Retardation of Trade Unionism in the Yorkshire Worsted Textile Industry," in

earned the highest wages and had more control: combination supported improved job quality, but only for organized workers.[111]

Wages

Unionization helped to maintain senior workers' high incomes. Mule operatives and minders were paid based on local piece rate lists ('price lists'), negotiated between unions and manufacturers, that stated payment for output by count.[112] Common mule operatives earned more than self-actor minders, though their work was more taxing. Their numbers declined as common mules were replaced for coarse and then medium counts.[113] Piecers were usually paid a time rate based on the length of the mules worked.[114] Minders on long mules could earn up to 50% more than those on short mules, but piecers saw little of the benefit from higher output. When manufacturers installed longer mules and ran them at higher speeds, minders' piece rate earnings rose more than piecers' time rates, which increased job inequality.[115] Even when the big piecer's and the minder's work were nearly identical, the latter received a much higher income.[116] The mule room's wage hierarchy was stable: a

Employers and Labour in the English Textile Industries, 1850–1939, ed. J. A. Jowitt and Arthur McIvor (London: Routledge, 1988).

[111] White, *The Limits of Trade Union Militancy*, 41.

[112] Cohen, *American Management and British Labor*, 83–84. The first example of a price list is from Bolton in 1813. Huberman, *Escape from the Market*, 134. There were two main types of list; the differences are described in e.g. *Escape from the Market*, 135–39. Jewkes and Gray, *Wages and Labour*, 56–58, 69, 104.

[113] Huberman, *Escape from the Market*, 127. H. M. Boot, "How Skilled Were Lancashire Cotton Factory Workers in 1833?," *The Economic History Review* 48, no. 2 (1995): 285. Fine spinning wages were more variable because of larger demand fluctuations. Lee, *A Cotton Enterprise*, 115–16.

[114] Jewkes and Gray, *Wages and Labour*, 63.

[115] Burgess, *British Industrial Relations*, 239–40. Jewkes and Gray, *Wages and Labour*, 33–34.

[116] Cohen, *American Management and British Labor*, 83.

scavenger earned less than a shilling per day, a little piecer around a shilling (until the 1880s), a big piecer about 20d, and an operative or minder took home two to three times the wages of the big piecer. All groups of workers saw real wage gains by the 20th century, but inequality persisted.[117]

Continuous spinning workers were paid time rates for tending a specified number of spindles producing a certain count of yarn. Tending more spindles that spun higher counts enabled higher rates. However, spinners on fine counts generally monitored fewer spindles, which meant their earnings were frequently lower than workers in coarse spinning.[118] Overseers usually earned similar wages to self-actor minders or mule operatives and were paid about twice as much as the workers tending the spindles.

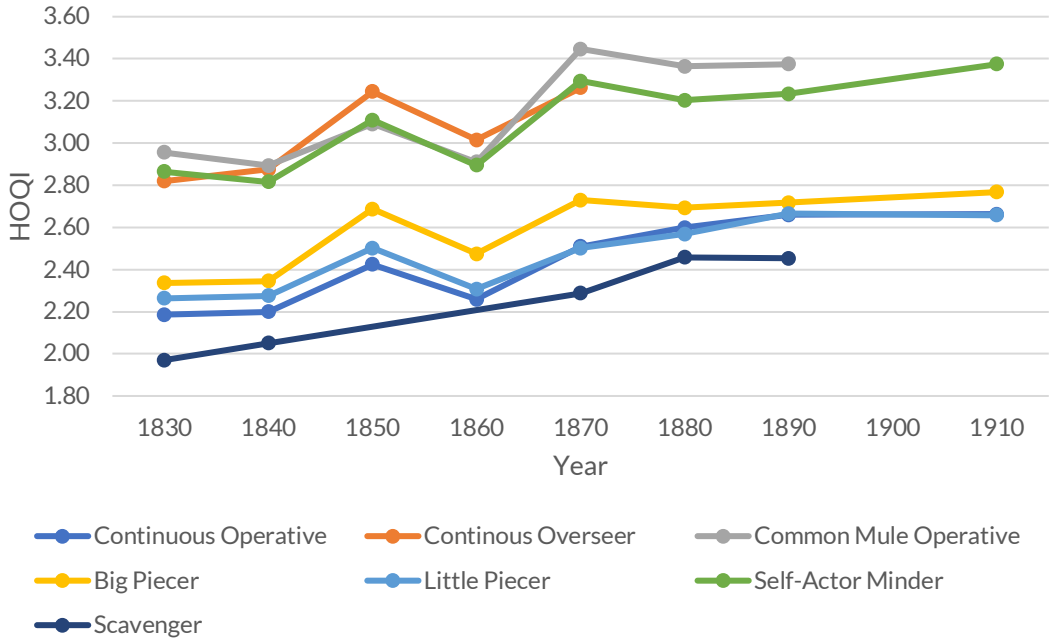
Control & Supervision

Harsh discipline and little control for mule assistants and continuous operatives continued in this period. Absenteeism or lateness, unclean work areas, poor piecing, and neglect for machinery remained causes for discipline. For example, a mill in Haslington, Lancashire around 1850 imposed fines for lateness (starting at 2d for five minutes), uncleanliness, bobbins left on the floor, wasted machine oil, broken bobbins, insufficient oiling, talking, damaging machinery, and swearing (with dismissal for the second offense). The rules required cleaning during each meal break and sweeping the spinning room five times per day. Smoking was cause for dismissal,

[117] George Henry Wood, *The History of Wages in the Cotton Trade During the Past Hundred Years* (London: Sherratt and Hughes, 1910).
[118] Jewkes and Gray, *Wages and Labour*, 118–19, 51.

and workers were required to wash themselves at least twice per week.[119] In other mills, fines for lateness could be up to a quarter of a day's pay for being five minutes late, and the most severe punishments still included dismissal.[120] Mule operatives and minders retained control over their work, despite the adoption of the self-actor. They still had the authority to adjust mules, recruit assistants, and discipline piecers and scavengers.[121]

Figure 4.1: Job Quality in Cotton Spinning, 1830–1910



Sources: See Tables 4.1–4.7

Composite Job Quality

The task range of intermittent and continuous spinning hardly changed in this period, and the unequal structure of wages, control, and job quality persisted. All jobs improved modestly from the mid-19th century into the 20th century, as rising wages

[119] Lancashire Archives, Blackburn and District Cotton Manufacturers' Association Records, DDX 1115/22/1.
[120] UK Parliamentary Papers, *Select Committee on Factory Regulation*, XV.1, Paper 706, 192, 352.
[121] Cohen, *American Management and British Labor*, 79–82, 92–94.

and falling working time offset rising intensity, the risk of new industrial diseases, and the continuing danger of accidents (Figure 4.1). Apart from a dip during the 1860s Cotton Famine, textile work had become stable. Overseers and minders continued to control production and subjected assistants to corporal punishment. The relatively static task range was matched by no discernible alteration in the repetitiveness of work: spinning remained monotonous.

Occupational Availability

The 1830–1910 period was characterized by growth across most of the textile industry, led by expansion in cotton production, particularly for export. Cotton became the dominant fiber from the middle of the 19th century as consumers responded to falling prices.[122] Employment in wool dipped below cotton in the early 19th century and never caught up.[123] Spinners and piecers were grouped together in the English & Welsh census from 1851, with 54,057 counted in cotton, 13,710 in woollen, and 17,159 in worsted wool. By 1911, cotton spinning employment had grown unabated to 93,129, woollen had fallen to 10,946, and worsted had reached 33,067.[124] Despite this growth, spinning factory workers were a far smaller share of the population than the hundreds of thousands of women and children who had sat at spinning wheels in the 18th century. Even clothing the world did not produce enough demand to keep pace with the productivity increases of mechanization.

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[122] D. A. Farnie, "Cotton, 1780–1914," in *The Cambridge History of Western Textiles*, ed. D. T. Jenkins (Cambridge: Cambridge University Press, 2003), 721–22.
[123] D. T. Jenkins and Kenneth G. Ponting, *The British Wool Textile Industry: 1770–1914* (London: Heinemann, 1982), 298.
[124] Censuses of England & Wales, 1851, 1911. Accessed using icem-nesstar.data-archive.ac.uk. The census data did not specifically enumerate linen or jute spinners.

Occupational Distribution: Age, Gender, and Locations

Children's and women's employment declined across this period, making spinning, especially on mules, male-dominated. By the 1830s the combination of protective legislation, more urban mills with a local labor supply, and a general fall in child labor made pauper apprentices a small and declining share of the workforce. Apprenticeship disappeared in the late 1840s.[125] Child labor continued under the half-time system established by the 1844 Factory Act, but children's work was in a long decline.[126] Most operatives were 20–44 by the first decade of the 20th century, though teenagers were still about a third of all textile employees.[127]

While women had been a large share of workers in the early factories, by the late 19th century most spinning workers were male. The cotton industry was the most male-dominated, with male control of mules, training, and promotion combining to keep the male share of enumerated spinning workers above 60%.[128] The picture was even more skewed in mule factories: by the 1830s, more than three-quarters of these workers were men, while 30% of operatives in throstle factories were men.[129]

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[125] Mary B. Rose, *The Gregs of Quarry Bank Mill: The Rise and Decline of a Family Firm, 1750–1914* (Cambridge: Cambridge University Press, 1986), 55–57. Explanations for the decline in children's employment after the first third of the 19th century include family decisions about labor supply, technological changes, and regulation. Clark Nardinelli, *Child Labor and the Industrial Revolution* (Bloomington: Indiana University Press, 1990). Peter Kirby, *Child Labour in Britain, 1750–1870* (London: Palgrave Macmillan, 2003). Jane Humphries, *Childhood and Child Labour in the British Industrial Revolution* (Cambridge: Cambridge University Press, 2010).

[126] White, *The Limits of Trade Union Militancy*, 18, 56 (note 79), 58–63.

[127] H. M. Boot and J. H. Maindonald, "New Estimates of Age- and Sex-Specific Earnings and the Male—Female Earnings Gap in the British Cotton Industry, 1833–1906," *The Economic History Review* 61, no. 2 (2008): 384–85, 403–04.

[128] Censuses of England & Wales, 1851, 1861, 1881, 1891, 1901. Accessed using icem-nesstar.data-archive.ac.uk.

[129] Cohen, *American Management and British Labor*, 62–64.

Piecers and scavengers were normally boys because minders did not want to train girls to become big piecers (and eventually minders) and because they believed girls could not sustain the physical exertion of carrying roving or spun bobbins, running up and down the mule piecing threads, and monitoring winding when the minder took a break.[130] The little piecer was normally between 12 and 15, and worked in that role for 1–3 years before becoming a big piecer. At 21, after at least five years as a big piecer, he could become a mule operative or self-actor minder—if such a role were available.[131]

There were always many more piecers than operatives or minders. Periods of growth in employment smoothed over these difficulties, but as expansion slowed, the problem became more pressing. When a minder retired or died, there was intense competition among big piecers and unemployed minders to replace him.[132] The unions limited entry to mule spinning throughout this period and particularly resisted the employment of women.[133] While they enjoyed high wages, a minder who lost his position could find it difficult to obtain a similarly high-paying job. The senior big piecers might strike if he attempted to fill an open minder position in another mill.[134] The self-actor minders' exalted social status and high wages were fragile.

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[130] *American Management and British Labor*, 66–67.
[131] *American Management and British Labor*, 93–94.
[132] White, *The Limits of Trade Union Militancy*, 36. "Lancashire Cotton Textiles," in *A History of British Industrial Relations*, ed. Chris Wrigley (Brighton: Harvester, 1982), 216–17.
[133] Cohen, *American Management and British Labor*, 65–66, 79–82, 92–94. Janet Greenlees, *Female Labour Power: Women Workers' Influence on Business Practices in the British and American Cotton Industries, 1780–1860* (Aldershot: Ashgate, 2007), 152–55. Women were restricted to smaller mules, small firms, and less unionized areas. Bullen, Wyke, and Fowler, *Barefoot Aristocrats*, 82.
[134] White, *The Limits of Trade Union Militancy*, 36. "Lancashire Cotton Textiles," 216–17.

It may have been possible to replace minders by the late 19th century, but the complexity of the self-actor meant that experienced workers were valuable and the slow pace of improvement reduced the incentive to remove them at any one time.[135] Some mule-spinning firms hired women operatives in the first quarter of the 19th century because they could be paid lower wages. However, firms believed they did not discipline piecers sufficiently to ensure high productivity and good-quality yarn. This was compounded by generalized discrimination and a belief that women could not operate longer mules.[136] Women who spun on common mules were also unable to learn how to adjust the self-actor on the job.[137]

The first 50 years of machine spinning had been characterized by centripetal forces: centralization in factories, and then concentration in cities, enabled by inanimate power technology. In the late 19th century southern Lancashire became the center of production and Manchester transformed into a commercial hub. There was growth in surrounding towns, especially Oldham, where firms mostly spun coarse yarn (20s to 60s), and Bolton, which specialized in medium-fine (60s).[138] Specialization was concurrent with a decline in combined mills: scale produced external economies

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[135] Harold Catling, "The Development of the Spinning Mule," *Textile History* 9, no. 1 (1978): 56–57.

[136] Huberman, *Escape from the Market*, 27–28, 34–35. Greenlees, *Female Labour Power*, 93. Lazonick, *Competitive Advantage on the Shop Floor*, 88–90.

[137] *Competitive Advantage on the Shop Floor*, 91–92. Other explanations for the persistent gender division of labor in mule spinning are discussed in Paul Minoletti, "The Importance of Ideology: The Shift to Factory Production and Its Effect on Women's Employment Opportunities in the English Textile Industries, 1760–1850," *Continuity and Change* 28, no. 1 (2013).

[138] Catling, *Spinning Mule*, 115–18. John Jewkes, "The Localisation of the Cotton Industry," *Economic History* 5 (1930).

that allowed unbundling.[139] The Midlands had been an early industrial center, but it was eclipsed as mills reached the limit of their water power, and they lacked access to Lancashire's technical improvements, raw material, and labor pool.[140] Sectoral growth produced networks and agglomeration benefits, but only for proximate firms.

Conclusion

The period after 1830 featured more modest technological changes than the preceding 60 years. The main addition to the task range was new adjustments needed on the self-actor, which did not disrupt the hierarchy of mule spinning. The operatives' and minders' unions successfully resisted replacement by women or lower-paid workers, and retained high wages and shopfloor control. After manufacturers reaped the productivity gains of the self-actor and improved common mules, they raised work intensity by installing longer mules, running machines at higher speeds, and purchasing cheaper raw cotton that caused 'bad spinning'. Regulation that began with limits on children's work expanded to reduce working time but did little to improve safety. Factory work still caused respiratory ailments, new machine oils produced mule-spinners' cancer, and 'fencing' of open belts and gears was adopted slowly. When harm to workers also harmed capital, manufacturers made changes: fire mitigation reduced damage to factories and, incidentally, saved workers from burns or death. Improved work-related wellbeing was primarily the result of rising wages

[139] Williams and Farnie, *Cotton Mills*, 20–21, 28–30, 90. Stephen Broadberry and Andrew Marrison, "External Economies of Scale in the Lancashire Cotton Industry, 1900–1950," *The Economic History Review* 55, no. 1 (2002).
[140] Stanley D. Chapman, *The Early Factory Masters: The Transition to the Factory System in the Midlands Textile Industry* (Newton Abbot: David & Charles, 1967), 67–70, 211–14, 17–18.

and regulation-reduced work hours. The job inequality first established during the 1790s was nearly as wide by the First World War as it had been in 1830.

Table 4.1: Occupational Quality for Continuous Operatives, 1830–1910

Year	Daily Wage (d)	CN (d)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1830	16.90	4.07	2.85	69.24	1.92	4	3	2	1	2	1	1.91	2.19
1840	18.24	4.16	2.90	69.24	1.92	4	3	2	1	2	1	1.91	2.20
1850	17.13	4.23	2.83	57.70	2.64	4	3	2	1	2	1	1.91	2.42
1860	18.75	4.38	2.88	57.70	2.64	1	3	2	1	2	1	1.51	2.26
1870	25.42	4.60	3.13	57.70	2.64	4	3	2	1	2	1	1.91	2.51
1880	26.07	4.21	3.26	54.82	2.82	4	3	2	1	2	1	1.91	2.60
1890	28.58	3.79	3.49	54.82	2.82	4	3	2	1	2	1	1.91	2.66
1910	28.58	4.09	3.40	53.37	2.91	4	3	2	1	2	1	1.91	2.66

Sources for all tables: Chapters 2, 3, 4, Appendix 1, manuscript sources in the Bibliography, Allen, 'London Prices & Wages Dataset', Wood, *Wages in the Cotton Trade* (1910). Notes: Decade gaps (e.g. 1900 in the table above) are periods for which there is no wage data. For Continuous Operatives, Consumption Needs are scaled to 85% of an adult male basket; for Little Piecers and Scavengers, Consumption Needs are scaled to 60% (see Appendix 1). Hours/Week figures are based on scheduled hours (see the text) and archival evidence of days worked per week. The 'half-time system' for scavengers was adopted from 1844.

Table 4.2: Occupational Quality for Continuous Overseers, 1830–1870

Year	Daily Wage (d)	CN (d)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1830	40.00	4.78	3.65	70.80	1.83	5	4	2	4	3	3	3.36	2.82
1840	48.00	4.90	3.87	70.80	1.83	5	4	2	4	3	3	3.36	2.87
1850	52.00	4.98	3.97	59.00	2.56	5	4	2	4	3	3	3.36	3.24
1860	61.11	5.16	4.16	59.00	2.56	1	4	2	4	3	3	2.57	3.01
1870	59.00	5.42	4.03	59.00	2.56	5	4	2	4	3	3	3.36	3.26

Table 4.3: Occupational Quality for Common Mule Operatives, 1830–1890

Year	Daily Wage (d)	CN (d)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1830	60.00	4.78	4.14	66.00	2.13	5	4	2	4	2	2	2.94	2.96
1840	51.83	4.90	3.88	66.00	2.13	5	4	2	4	2	2	2.94	2.89
1850	42.00	4.98	3.58	55.00	2.81	5	4	2	4	2	2	2.94	3.09
1860	46.00	5.16	3.65	55.00	2.81	1	4	2	4	3	2	2.40	2.91
1870	91.13	5.42	4.64	55.00	2.81	5	4	2	4	3	2	3.14	3.45
1880	94.60	4.95	4.88	52.25	2.98	5	4	1	4	2	2	2.62	3.36
1890	87.33	4.46	4.92	52.25	2.98	5	4	1	4	2	2	2.62	3.37

Table 4.4: Occupational Quality for Self-Actor Minders, 1830–1910

Year	Daily Wage (d)	CN (d)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1830	38.75	4.78	3.52	66.00	2.13	5	4	2	4	3	2	3.14	2.86
1840	34.22	4.90	3.34	66.00	2.13	5	4	2	4	3	2	3.14	2.82
1850	36.50	4.98	3.40	55.00	2.81	5	4	2	4	3	2	3.14	3.11
1860	44.00	5.16	3.59	55.00	2.81	1	4	2	4	3	2	2.40	2.89
1870	64.00	5.42	4.05	55.00	2.81	5	4	2	4	3	2	3.14	3.29
1880	64.83	4.95	4.21	52.25	2.98	5	4	1	4	2	2	2.62	3.20
1890	63.00	4.46	4.33	52.25	2.98	5	4	1	4	2	2	2.62	3.23
1910	87.67	4.81	4.78	50.88	3.07	5	4	1	4	2	2	2.62	3.37

Table 4.5: Occupational Quality for Big Piecers, 1830–1910

Year	Daily Wage (d)	CN (d)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1830	18.00	4.78	2.76	69.24	1.92	4	3	2	2	2	2	2.40	2.34
1840	19.14	4.90	2.79	69.24	1.92	4	3	2	2	2	2	2.40	2.35
1850	20.75	4.98	2.85	57.70	2.64	4	3	2	2	3	2	2.57	2.69
1860	20.50	5.16	2.81	57.70	2.64	1	3	2	2	3	2	2.04	2.47
1870	26.15	5.42	3.00	57.70	2.64	4	3	2	2	3	2	2.57	2.73
1880	29.83	4.95	3.23	54.82	2.82	4	3	1	2	2	2	2.14	2.69
1890	29.17	4.46	3.32	54.82	2.82	4	3	1	2	2	2	2.14	2.72
1910	33.58	4.81	3.40	53.37	2.91	4	3	1	2	2	2	2.14	2.77

Table 4.6: Occupational Quality for Little Piecers, 1830–1910

Year	Daily Wage (d)	CN (d)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1830	11.50	2.87	2.82	69.24	1.92	4	3	2	1	2	2	2.14	2.26
1840	12.38	2.94	2.86	69.24	1.92	4	3	2	1	2	2	2.14	2.28
1850	11.33	2.99	2.77	57.70	2.64	4	3	2	1	2	2	2.14	2.50
1860	11.33	3.09	2.74	57.70	2.64	1	3	2	1	2	2	1.70	2.31
1870	12.33	3.25	2.77	57.70	2.64	4	3	2	1	2	2	2.14	2.50
1880	16.64	2.97	3.15	54.82	2.82	4	3	1	1	2	2	1.91	2.57
1890	20.58	2.67	3.52	54.82	2.82	4	3	1	1	2	2	1.91	2.67
1910	19.83	2.89	3.38	53.37	2.91	4	3	1	1	2	2	1.91	2.66

Table 4.7: Occupational Quality for Scavengers, 1830–1890

Year	Daily Wage (d)	CN (d)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1830	5.29	2.87	1.52	69.24	1.92	4	2	2	1	1	2	1.78	1.97
1840	8.22	2.94	2.31	69.24	1.92	4	2	2	1	1	2	1.78	2.05
1870	5.50	3.25	0.73	42.00	3.63	4	2	2	1	1	2	1.78	2.29
1880	11.67	2.97	1.68	42.00	3.63	4	2	2	1	1	2	1.78	2.46
1890	10.33	2.67	1.66	42.00	3.63	4	2	2	1	1	2	1.78	2.45

Chapter 5
Spinning in the American Industrial Revolution, 1750–1840

Chapter Abstract

This chapter analyzes work in Northeastern American spinning during the Industrial Revolution. It describes the limited market for hand-spun yarn and the three models of mechanized production, in Rhode Island, Massachusetts, and Philadelphia, that supplanted the spinning wheel in the 19th century. It presents the first data on earnings by American hand spinners and new evidence of early industrial workers' income and hours based on more than 2000 observations of wages and working time. It uses this data and qualitative evidence to analyze job quality for American spinning workers. The small size of the market-facing hand spinning sector meant that factories caused little technological unemployment; mechanization substituted for homespun textiles and British imports. The tradeoff of higher and somewhat more stable earnings for longer hours, less control, and more dangerous work in factories also emerges in this case. However, there was heterogeneity between the three models of factory production. The smaller and more competitive Philadelphia or Mid-Atlantic model had slightly lower work-related wellbeing than the paternalistic Lowell mills.

Introduction

The Americans who adopted British spinning technology during the late 18th century introduced the three macroinventions to a markedly different economy. There was little market-facing hand spinning and most spinners worked sporadically, so factories caused little job destruction. Instead, industrialization substituted for homespun manufactures and competed with imports. Tariff protection of low-value cloth and relatively homogenous demand led most factories to adopt a high-volume, low-margin approach using continuous machines.[1] Moreover, as discussed in Chapters 3 and 4, the mule demanded experienced operatives, who were scarce except near Philadelphia. The expanded task range in factories also increased the division of labor and job inequality in the United States, and American firms usually mirrored British organizational hierarchies. One important difference was that the Northeastern US had three distinct models of factory production in the early industrial period. These systems differed in labor relations and technical choice, which produced variation in work-related wellbeing, job stratification, and occupational distribution.

The first model of factory production in the United States, established by Samuel Slater in Rhode Island, used water frames, some mules, and employed families. The second, founded at Waltham, Massachusetts and expanded in Lowell and other New England mill towns, gathered single young women in large, vertically-integrated mills to tend continuous machines. The third, based around Philadelphia in the Mid-Atlantic, was characterized by smaller firms, more British immigrant labor,

[1] S. N. Broadberry, *The Productivity Race: British Manufacturing in International Perspective, 1850–1990* (Cambridge: Cambridge University Press, 1997). Isaac Cohen, *American Management and British Labor: A Comparative Study of the Cotton Spinning Industry* (New York: Greenwood, 1990).

and more fine spinning on mules. The Lowell and Slater systems attempted to limit the downsides of industrialization and apply social control. Within the factory, this was modestly preferable to lower wages and less stable pay in the Mid-Atlantic model, although it was partially offset by longer shifts in Massachusetts and higher New England prices. By the mid-19th century paternalism faded and work across the American textile industry became more disciplined and intense (see Chapter 6).

The chapter begins by describing pre-industrial textile production and presents the first data on American hand spinning wages. It then describes the introduction of hand-powered spinning machines and the three industrial models established in the late 18th and early 19th centuries by Samuel Slater, the Boston Associates, and Philadelphia manufacturers. The New England models imposed suffocating social controls, but they provided slightly better work conditions than the Philadelphia system. The following sections describe mill design, technical choice, and components of job quality, noting common features and variation across the three systems. The final sections discuss the availability and distribution of jobs, including estimates of work availability in factories.

Textiles in 18th Century America

The evidence of work in colonial American textile production befits a frontier economy: there are few records of carding, spinning, or weaving employment, and qualitative material suggests that production was irregular.[2] In addition to low

[2] Native Americans did not have spinning wheels or looms before Europeans arrived, and they mainly wove baskets and mats using leaves, reeds, and rushes. By the 18th century, much Native American cloth was probably of European origin, although they also used

population density, market-facing spinning was limited by Britain's cost advantage in textile production and mercantilist commercial policies that restricted inputs and markets for American manufactures.[3] In the 17th century colonists had imported sheep, but Parliament prevented their sale to North America in 1660, and the Woolens Act (1699) prohibited the export of colonially-produced wool-based textiles. The committee that revised the bill for the House of Commons stated its intent was to 'prevent the setting up of the Woollen Manufacture in the English Plantations in America'.[4]

Despite imperial trade restrictions, the colonial governments tried to promote cloth manufacturing by offering bounties, encouraging immigration, and even requiring women, girls, and boys to spin.[5] During the mid-18th century social organizations set up spinning enterprises in Boston, New York, and Philadelphia to provide employment to the poor. Some enterprises used outwork systems, while others had centralized premises. Centralized hand spinning enterprises struggled with discipline, none of them could compete against British imports on cost or quality, and all were short-lived.[6] There were some proposals for spinning schools in the 18th

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animal skins extensively. Laurel Thatcher Ulrich, *The Age of Homespun: Objects and Stories in the Creation of an American Myth* (New York: Knopf, 2001), 45–50.

[3] Frances Little, *Early American Textiles* (New York: Century Co., 1931), 3–9, 52–53. Arthur Harrison Cole, *The American Wool Manufacture*, vol. I (Cambridge, MA: Harvard University Press, 1926), 49–50. William N. Parker, "New England's Early Industrialization: A Sketch," in *Quantity & Quiddity: Essays in U.S. Economic History*, ed. Peter Kilby, Stanley Lebergott, and Jeremy Atack (Middletown, CT: Wesleyan University Press, 1987), 28.

[4] Cole, *American Wool Manufacture*, I, 5, 40–43.

[5] Little, *Early American Textiles*, 31–32, 36–37. Cole, *American Wool Manufacture*, I, 35–36. Edith Abbott, *Women in Industry: A Study in American Economic History* (New York: D. Appleton and Company, 1910), 20, 328. J. Thomas Scharf, *History of Philadelphia, 1609–1884* (Pennsylvania: L. H. Everts, 1884), 2300.

[6] Cynthia J. Shelton, *The Mills of Manayunk: Industrialization and Social Conflict in the Philadelphia Region, 1787–1837* (Baltimore: Johns Hopkins University Press, 1986), 26–27. Brooke Hindle and Steven D. Lubar, *Engines of Change: The American Industrial Revolution,*

century, but few were established.[7] Americans promoted home spinning as import-substituting political resistance against British manufactures leading up to the Revolution, but many returned to purchasing imported cloth after the Treaty of Paris (1783).[8]

Hand spinning involved the same tasks, tools, and gender division of labor as in pre-industrial Britain. Women and children cleaned and carded or combed wool, frequently using imported preparatory tools. Most spinners spun on wheels, but some still used the spindle and distaff.[9] Spinning wheels were inexpensive and common: up to two-thirds of households in some Connecticut counties owned a wheel in the mid-18th century. Loom ownership became more widespread during the 1700s, which meant there were more weavers to purchase yarn.[10] Home-produced textiles were usually coarse, heavy, and durable wool or wool-flax mixes made with locally-produced fiber.[11] Cotton was rarely spun in the Northeast until the mid-18th century.[12]

Textile production within a single household was the most common work organization until the second half of the 18th century, and most cloth was used by a

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1790–1860 (Washington, D.C: Smithsonian Institution Press, 1986), 186–87. Little, *Early American Textiles*, 76.

[7] *Early American Textiles*, 59–61. Abbott, *Women in Industry*, 21.

[8] T. H. Breen, *The Marketplace of Revolution: How Consumer Politics Shaped American Independence* (New York: Oxford University Press, 2004), 231–32. Little, *Early American Textiles*, 78–79. Jeanne Boydston, *Home and Work: Housework, Wages, and the Ideology of Labor in the Early Republic* (Oxford: Oxford University Press, 1990), 30–35.

[9] Cole, *American Wool Manufacture*, I, 7–10, 15–16, 19. Some textile technologies transferred slowly. The flying shuttle, for example, was rarely used in America before the Revolution.

[10] Harvard Business School, Baker Library Special Collection, Plumer Family Business Records, Mss:1 1793-1847 P734, Volume 3. Ulrich, *The Age of Homespun*, 103–04.

[11] Cole, *American Wool Manufacture*, I, 27, 30. Little, *Early American Textiles*, 42–45.

[12] Edward Stanwood, "Cotton Manufacture in New England," in *The New England States, Their Constitutional, Judicial, Educational, Commercial, Professional and Industrial History*, ed. William T. Davis (Boston: D. H. Hurd & Co., 1897), 117–18.

family rather than sold.[13] Market-facing spinning during the late colonial period is recorded in ledgers and account books of farmers, weavers, and dyers. Irregular entries suggest that even at the end of the 18th century textile production involving multiple households was episodic. When spinners produced yarn for sale, it was usually for specific customers rather than a general market.[14] There were few powerful local yarn merchants to exclude spinners from employment, which meant that workers had more control, although income from spinning was less stable.[15] Spinners were paid in coin, goods, or labor, and currency payment became more common in the 18th century.[16]

Hand Spinning Wages

The scarcity of payments for hand spinning makes constructing an earnings series difficult. The data presented below are based on extensive research in dyers', weavers', and farmers' account books from the 18th and 19th centuries. The dataset contains 439 observations of hand spinners' earnings from 15 sources in five repositories. Most observations are from New England, especially Massachusetts and Connecticut.

Recorded American spinning earnings are almost all piece rates, frequently using different measurements than those applied in Britain. Spinners were most commonly paid by the 'run'. One 'thread', or a single revolution of the wheel, was usually 74", and 40 threads made one 'knot'. Twenty knots composed one 'run', or

[13] Abbott, *Women in Industry*, 18–19.
[14] Cohen, *American Management and British Labor*, 19–20.
[15] Abbott, *Women in Industry*, 19. Americans called yarn factors 'commission merchants'.
[16] Boydston, *Home and Work*, 22–24, 36–37.

seven knots made one 'skein'. Spinners were supposedly able to spin between four and six skeins per day, depending on whether they carded the wool.[17] Based on these measurements, one American skein was about 575.5 yards, slightly longer than the British skein (560 yards). American hand spinning payments were also itemized on other bases: 'runs' and 'skeins' were the most common, but workers were also paid by the pound, the 'cut', the 'knot', the 'score', and the 'double skein'. The score was probably another term for a run of twenty knots, and the cut may have been a length of 300 yards.[18]

Hand spinners generally spun lowish counts around 10s and produced about 0.4 pounds per day.[19] When converted into lengths for measuring piece rates, this would have been 4 skeins (2 double skeins), 28 knots, or 1.4 runs or scores per day. Figure 5.1 presents effective daily wages, multiplying the piece rate by estimated productivity. Based on the limited available data, American hand spinners generally earned around $0.08/day in the late colonial period, rising to around $0.10–15/day up to c. 1820, when mechanization eliminated most market-based hand spinning.

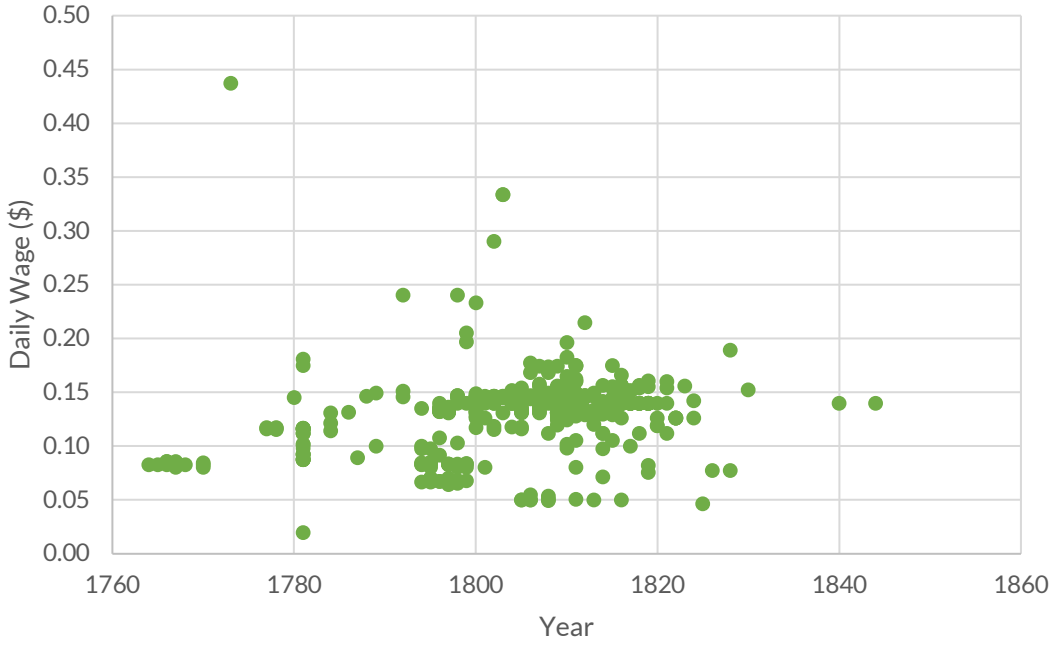
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[17] Abbott, *Women in Industry*, 25. Cf. Craig Muldrew, "'Th'ancient Distaff' and 'Whirling Spindle': Measuring the Contribution of Spinning to Household Earnings and the National Economy in England, 1550–1770," *The Economic History Review* 65, no. 2 (2012): 503. In Yorkshire and Norfolk worsted, a 'hank' or 'skein' was 560 yards. American spinners produced coarse yarn, perhaps counts of 8–12. Four skeins per day would be close to the productivity of around 0.4 lbs/day used by Humphries and Schneider to convert piece rates to daily wages. Jane Humphries and Benjamin Schneider, "Spinning the Industrial Revolution," *The Economic History Review* 72, no. 1 (2019): 134–40.

[18] Patricia Baines, *Spinning Wheels, Spinners and Spinning* (London: Batsford, 1977), 110. Baines suggests the 'cut' was interchangeable with the 'lea', which Muldrew states was 120 yards. There are only three observations that measured by the cut, all from the 1820s. Muldrew, "'Th'ancient Distaff'," 503.

[19] Humphries and Schneider, "Spinning the Industrial Revolution."

Figure 5.1: Effective Daily Wages in American Hand Spinning



Sources: See the Manuscript Sources section of the Bibliography and Abbott, *Women in Industry*.

There are a handful of claims about daily earnings in spinning. Abbott reports that at two unstated points in the 18th century, hand spinners earned 8¢/day and board, and in the Wyoming Valley of Northeastern Pennsylvania a 'good spinner' could earn 5s. per week, which was about 10¢ per day.[20] Two observations from a Worcester, Massachusetts weaver's account book from the 1790s show lower rates of around 5–6¢/day.[21]

Spinners' welfare ratios were generally between 1 and 2, with low real earnings from the 1780s to 1810, and higher levels before and after. Real earnings were similar to British levels, and occasionally slightly higher. Occupational health, intensity, and repetitiveness in American hand spinning were very similar to Britain, but workers'

[20] Abbott, *Women in Industry*, 23. Conversions here and for Figure 5.1 use the UC-Davis Global Prices and Incomes Database.
[21] Cornell University, Kheel Center for Labor-Management Documentation, American Textile History Museum Collections, David Briant Account Book, 2002.74.

earnings were less stable and there is little evidence of monopsonistic yarn purchasers or supervised spinning, so the *s* and *c* components of job quality are coded lower and higher, respectively.[22]

Technological Transition

Information about British spinning machines spread to the American colonies by the 1770s. The British government restricted emigration for mechanics and machinery exports, but Americans eventually acquired all three inventions. They had little success using diagrams or machines alone; operating the inventions and building new machines for factory-scale production required in-person knowledge from mechanics or industrial spies.[23]

The jenny was used in North America from the 1770s, although it was much less common than in Britain.[24] At least a dozen jennies were in 'manufactories' (workshops) by 1790, and the 1810 census reported fewer than 100 jennies in use.[25] There were a few putting-out enterprises in urban areas that used jennies, but they shared the problems of wheel-spinning businesses discussed above.[26] American

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[22] See Table 5.1

[23] David J. Jeremy, *Artisans, Entrepreneurs, and Machines: Essays on the Early Anglo-American Textile Industries, 1770–1840s* (Aldershot: Ashgate Variorum, 1998), 18–21. David I. Jeremy, "Damming the Flood: British Government Efforts to Check the Outflow of Technicians and Machinery, 1780–1843," *The Business History Review* 51, no. 1 (1977). Jeremy argues that British restrictions on emigration and machinery exports were ineffective.

[24] Little, *Early American Textiles*, 102.

[25] Steve Dunwell, *The Run of the Mill: A Pictorial Narrative of the Expansion, Dominion, Decline, and Enduring Impact of the New England Textile Industry* (Boston: D. R. Godine, 1978), 12. 1810 US Census, 'A Series of Tables of the Several Branches of American Manufactures' (Philadelphia, 1813). Cf. note 130 below about machinery counts in the 1810 Census.

[26] Shelton, *The Mills of Manayunk*, 27–28. Philip Scranton, *Proprietary Capitalism: The Textile Manufacture at Philadelphia, 1800–1885* (Philadelphia: Temple University Press, 1983), 78–79. Abbott, *Women in Industry*, 36–39. Arthur Harrison Cole, *The American Wool Manufacture*, vol. II (Cambridge, MA: Harvard University Press, 1926), 264–65.

jennies were generally smaller, with only 30–50 spindles.[27] The first American mules were built in 1796 near Philadelphia, which became a center for mule spinning when British mule operatives and handloom weavers settled there in the 1790s and 1800s. Philadelphia specialized in fine cloth using a putting-out system.[28] The mule was also used in Rhode Island to produce weft, while continuous machines spun warp.[29]

Old techniques survived for decades in some places, as they did in Britain. Against the advancing tide of machines, Americans tried to improve the spinning wheel. The 'accelerating' head, patented in 1803, attached the main, large spinning wheel to a smaller wheel that directly drove the spindle, which raised spindle speeds and productivity.[30] The 1810 Census counted more than 150,000 spinning wheels, and Albert Gallatin asserted that two-thirds of American textiles were still produced at home.[31] Wheel spinning and hand-powered machines persisted longer in the Mid-Atlantic and rural areas, where transportation was poor and there was less competition from mills.[32] Around Philadelphia, substantial hand production continued until factory output grew between 1816 and 1820.[33] Home-based spinning with jennies and mules was less common in New England, and factory-spun yarn

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[27] C. Aspin, *James Hargreaves and the Spinning Jenny* (Preston: Helmshore Local History Society, 1964), 66.
[28] Cohen, *American Management and British Labor*, 33. Shelton, *The Mills of Manayunk*, 33–34.
[29] George Sweet Gibb, *The Saco-Lowell Shops: Textile Machinery Building in New England, 1813–1949* (Cambridge, MA: Harvard University Press, 1950), 32.
[30] There were attempts to improve spinning wheels in Britain, but these developments were rarely adopted. Baines, *Spinning Wheels*, 65–66, 164–67. James L. Bishop, *A History of American Manufactures from 1608 to 1860*, vol. 2 (Philadelphia: Edward Young & Co., 1864), 167. James L. Garvin, "Report on the Piece Shops, Spofford Village, Chesterfield, New Hampshire," (Concord, NH: New Hampshire Division of Historical Resources, 2005).
[31] 1810 Census, 'Tables of American Manufactures'. But see note 130 about the enumeration of machines in the 1810 Census. Albert Gallatin, *Report of the Secretary of the Treasury on American Manufactures* (Boston: Farrand, Mallory, & Co., 1810), 13.
[32] Cole, *American Wool Manufacture*, I.
[33] Scranton, *Proprietary Capitalism*, 121–22.

replaced outwork earlier.[34] The McLane Report (1832) confirmed that household manufacturing had declined significantly across the Northeastern states, except in remote parts of western Pennsylvania.[35]

Samuel Slater and the First Factories

The American factory system for spinning began with Samuel Slater in Rhode Island. Slater had worked as a pauper apprentice for the British manufacturer Jedediah Strutt for six years and came to America in 1789, where he partnered with two local textile manufacturers to set up a spinning factory in 1790. This small mill was financially successful, but the partners had difficulty securing fiber supplies and handloom weavers to turn their factory yarn into cloth.[36] The first machines in the factory were water frames, to which Slater added mules in 1803.[37] Spinning was the only mechanized process for decades: home-based workers prepared fiber until the late 1810s, and yarn was woven on handlooms until the late 1820s.[38]

Over the first decades of the 1800s, Slater joined with other investors to construct 13 mills that used a similar productive system and organization in Rhode Island, Connecticut, Massachusetts, and New Hampshire. During Samuel Slater's

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[34] Cohen, *American Management and British Labor*, 22–26.
[35] Cole, *American Wool Manufacture*, I, 183–86.
[36] Barbara M. Tucker, *Samuel Slater and the Origins of the American Textile Industry, 1790–1860* (Ithaca: Cornell University Press, 1984), 45–58. Thomas Dublin, *Women at Work: The Transformation of Work and Community in Lowell, Massachusetts, 1826–1860* (New York: Columbia University Press, 1979), 15–18. There was one factory in Beverly, Massachusetts in 1789, probably using rudimentary copies of Arkwright's frame, but it was commercially unsuccessful and closed c. 1800. Stanwood, "Cotton Manufacture in New England," 119–20.
[37] Evelyn H. Knowlton, *Pepperell's Progress: History of a Cotton Textile Company, 1844–1945* (Cambridge, MA: Harvard University Press, 1948).
[38] Jonathan Prude, *The Coming of Industrial Order: Town and Factory Life in Rural Massachusetts, 1810–1860* (Cambridge: Cambridge University Press, 1983), 72–73.

lifetime (d. 1835), the system used these small, mill-based partnerships and family labor. In the family labor system, women and children worked in the factory and men were employed in agricultural jobs. The gender division of labor mirrored Slater's experience in Britain: factory supervisors were men, as were mule spinners (when mules were used), machinists, and overseers, when he eventually hired the latter.[39] The factories were smaller than the Lowell mills, but nonetheless had a division of labor and hierarchy. Agents or superintendents of individual mills directed the room overseers and reported to the 'mill master' or owner.[40]

Slater's enterprise used child labor extensively, employing pauper apprentices and waged children, although he soon dispensed with apprentices because of high maintenance costs. Children were paid around 7–10¢ per day, substantially less than adult men.[41] While Slater used corporal punishment against children, he only hired overseers in 1800 and did not levy fines in the early years, probably to attract workers concerned by the discipline reputation of British mills.[42] For many years, fathers were allowed and expected to discipline and control their children. When Horatio Nelson Slater succeeded his father, mill managers and overseers exerted more control over employees and shifted away from family labor.[43]

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[39] Labor contracts in the Slater system were agreed with whole families; the male head of household agreed to the conditions for his spouse and children's work. University of Connecticut Special Collections, Slater Company Records, 1979.0017 Box 2. Tucker, *Samuel Slater*, 122–23, 40–42, 89–91, 99–200; Cohen, *American Management and British Labor*. Abbott, *Women in Industry*, 121. After Samuel Slater's death in 1835, his son Horatio Nelson Slater hired professional mill managers and cut costs to compete in fine production.
[40] Prude, *Industrial Order*, 80–82.
[41] Tucker, *Samuel Slater*, 71–78.
[42] Prude, *Industrial Order*, 45–46.
[43] Tucker, *Samuel Slater*, 216–18.

The Lowell Model

The Rhode Island mills pioneered factory spinning in America, but they were small operations. The Non-Importation Act (1806), the Embargo (1807), and the War of 1812 stimulated a new wave of textile mechanization. The first of these forbade the import of some British textiles, although cotton was exempted.[44] The Embargo prohibited all trade with Britain, and during the war the Royal Navy blockaded American ports from fall 1812 until mid-1815. Trade restrictions damaged New England's merchant economy but provided opportunities for import substitution in textiles.[45] The first census of manufactures in 1810 counted 230 textile mills, including 55 in Massachusetts and 30 in Rhode Island.[46]

Francis Cabot Lowell exploited the brief respite from British competition with the fruits of industrial espionage. While visiting Britain from 1810–1812, Lowell memorized the design of Edmund Cartwright's powerloom and, on his return, instructed a mechanic on how to construct one. He combined the powerloom with water frames for spinning and brought together other Boston Brahmins to organize the Boston Manufacturing Company, which built America's first vertically integrated spinning and weaving mill at Waltham, Massachusetts in 1813.[47] After the war, British imports flooded the market and drove many American spinning firms out of business.

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[44] Herbert Heaton, "Non-Importation, 1806–1812," *The Journal of Economic History* 1, no. 2 (1941): 179.
[45] Cole, *American Wool Manufacture*, I, 144–45. Brian Arthur, *How Britain Won the War of 1812: The Royal Navy's Blockades of the United States, 1812–1815* (Boydell & Brewer, 2011), 189–90, 204–05.
[46] 1810 Census, 'Tables of of American Manufactures'.
[47] Robert F. Dalzell, *Enterprising Elite: The Boston Associates and the World They Made* (Cambridge, Mass: Harvard University Press, 1987), 6.

However, the Waltham mill survived, and tariffs protected coarse textile production from 1816.[48]

Lowell and his partners, the Boston Associates, expanded their operations in the 1810s until they reached the limit of power from the Charles River. In 1820 they purchased land for new factories in East Chelmsford (now Lowell), which had a thirty-foot waterfall to turn waterwheels for many more spindles and looms.[49] The Lowell mills used continuous spinning to manufacture coarse cloth (counts 10–20), so they could avoid hiring expensive and militant mule spinners.[50] Instead, they employed single women, and, unlike British mills and the Slater system, they employed few children.[51] In addition to profit, the Associates had social and political goals. To prevent the 'degradation' of the British factory system and avoid the development of class politics, they imposed paternalistic control on their employees. Workers' socializing and conduct were limited, they had to live in company-approved boardinghouses, and they were required to attend church weekly.[52]

Lowell workers started as 'sparehands' who filled in for absent colleagues as they adapted to factory employment. They were not expected to work a full schedule

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[48] Tucker, *Samuel Slater*, 91. Scranton, *Proprietary Capitalism*, 127–28. Cole, *American Wool Manufacture*, I, 154.

[49] Laurence F. Gross, *The Course of Industrial Decline: The Boott Cotton Mills of Lowell, Massachusetts, 1835–1955* (Baltimore: Johns Hopkins University Press, 1993), 3–5. The Associates, led at first by Francis Cabot Lowell, were the owners and directors of the main mills at Waltham, Lowell, and later Suffolk, Tremont, and Lawrence.

[50] *Industrial Decline*, 4, 12. Henry A. Miles, *Lowell, as It Was, and as It Is*, 2nd ed. (Lowell: N.L. Dayton, 1846), 12. Slater's output was somewhat finer than the Lowell system.

[51] Charles Edward Person, "The Early History of Factory Legislation in Massachusetts," in *Labor Laws and Their Enforcement*, ed. Susan M. Kingsbury (New York: Longmans, Green, 1911), 6.

[52] Norman Ware, *The Industrial Worker, 1840–1860: The Reaction of American Industrial Society to the Advance of the Industrial Revolution* (Boston: Houghton Mifflin, 1924), 72. Janet Greenlees, *Female Labour Power: Women Workers' Influence on Business Practices in the British and American Cotton Industries, 1780–1860* (Aldershot: Ashgate, 2007), 56.

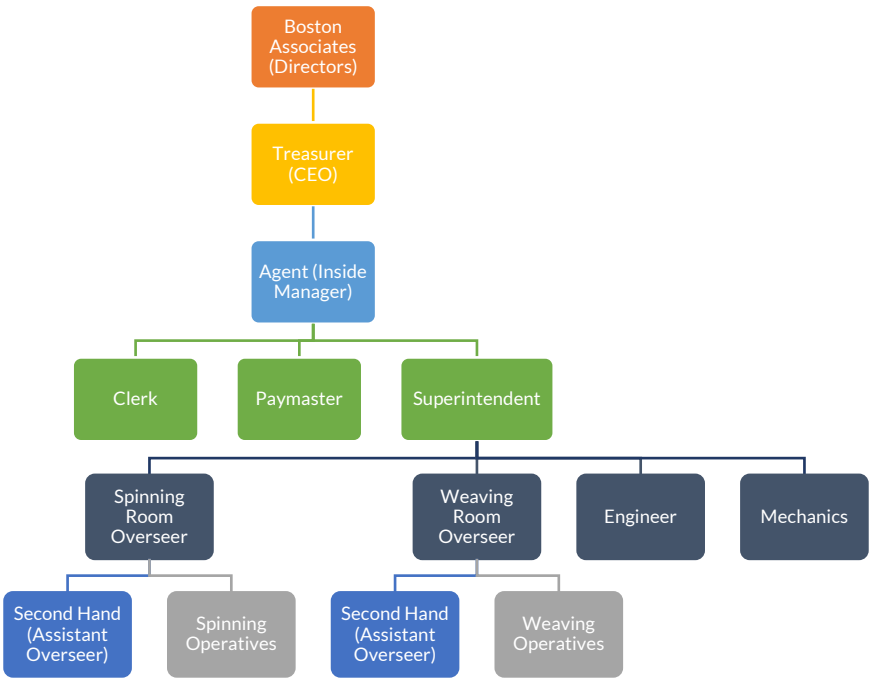
for 2–3 months and were paired with an experienced operative who taught them how to operate a 'side' of throstles or a pair of looms. These trainees were paid low rates totaling $0.55 per week.[53] Once each worker had learned the basics, she tended a frame of 128 spindles, piecing broken threads while child doffers replaced filled bobbins of yarn with empty ones.[54] Managers considered spinning a low-skill operation and frame tenders' pay was lower than all other women workers except drawers and sparehands.[55] The frames were small enough that operatives were close to other workers and the pace of work in the early years was modest, so employees could have short conversations and even rest on occasion.[56]

The organization of the Lowell system used an early corporate approach (Figure 5.2) with a substantial division of labor. The president of the company chaired board meetings and professional managers directed day-to-day affairs. The treasurer was analogous to a chief executive: he made business strategy decisions, reviewed the firm's finances, ordered machines and fiber inputs, and sold output. His immediate subordinate, the agent, was the on-site manager. The agent corresponded with the treasurer on input procurement and new machinery, and oversaw the workforce. Reporting to the agent, a superintendent coordinated production across the mill rooms, each of which had an overseer and assistant overseer. A clerk accounted for inputs, expenditure, and outputs, and coordinated with the paymaster to calculate

[53] Dublin, *Women at Work*, 71–73. Stanwood, "Cotton Manufacture in New England," 130.
[54] Dublin, *Women at Work*, 63–64, 69.
[55] *Women at Work*, 66–67.
[56] *Women at Work*, 69–70. Hannah Josephson, *The Golden Threads: New England's Mill Girls and Magnates* (New York: Duell, Sloan and Pearce, 1949), 80–81. Harriet Jane Hanson Robinson, *Loom and Spindle, or, Life among the Early Mill Girls: With a Sketch of "the Lowell Offering" and Some of Its Contributors* (New York: T.Y . Crowell, 1898), 71.

wages due to workers. At the bottom of the organizational chart were the young women operatives of the spinning and weaving rooms.[57] As in the other case studies (Chapters 3–4 and 7–9), the white-collar jobs were safer, better-remunerated, and had more control.

Figure 5.2: Organizational Chart of a Waltham-Lowell Mill, c. 1830



Sources: Dublin, *Women at Work*, 21–22, Dalzell, *Enterprising Elite*, 49–50, Tucker, *Samuel Slater*, 120–121

The expanded division of labor was the result an increased task range that required supervision and technical specialization, also observable in the Slater mills, and increased scale, which produced greater task depth. Scale demanded coordination between spinning and weaving departments to purchase inputs and monitor the flow of intermediate products across the factory. In 1750 a single hand spinner had received fiber from a local weaver, spun it, and returned it. By 1830 specialized employees purchased fiber and machinery, others repaired spinning machines, and overseers

[57] Dalzell, *Enterprising Elite*, 49–50. Tucker, *Samuel Slater*, 120–21. Dublin, *Women at Work*, 120–21.

controlled the shopfloor. These jobs had distinct functions, but also differing occupational risks, control, stability, and pay (Tables 5.2–5.4).

The Waltham-Lowell mills were incorporated rather than Slater-style partnerships, which allowed the Associates to accumulate more capital to build larger factories.[58] In 1832 about two-thirds of Massachusetts workers were in 185 Slater model mills (9200), with one-third (4800) in just seven Lowell model establishments, which illustrates the disparity in the size of production units.[59] Investors replicated the Lowell model in other New England towns such as Manchester, New Hampshire in the 1830s and Lawrence, Massachusetts in the 1840s.[60]

The Third Model: Mid-Atlantic Mechanization

The Philadelphia putting-out system of the 1790s and 1800s, discussed above, used hand mules and handlooms. It gave rise to a distinct system of production that was probably most similar to conditions in British factory towns. When capitalists built water-powered factories in the late 1810s and 1820s, many of them hired experienced British operatives to work on common mules.[61] The factories were smaller than New England mills and few were corporations. This produced extensive churn as firms failed or their owners died, which made earnings inconsistent.[62] To recruit

[58] Dalzell, *Enterprising Elite*, 27–28.
[59] Cohen, *American Management and British Labor*, 33, note 14. These figures count all textile workers.
[60] James P. Hanlan, *The Working Population of Manchester, New Hampshire, 1840–1886*, Studies in American History and Culture (Ann Arbor, Mich.: UMI Research Press, 1981), 14–15, 17, 30–31, 123.
[61] Shelton, *The Mills of Manayunk*, 54–58.
[62] Scranton, *Proprietary Capitalism*, 9–11, 50, 131. Of the five largest firms in 1830, four had closed by 1850. These short-lived operations left few records.

children for work as mule assistants, Philadelphia mills employed large families. The reportedly impoverished workforce was a contrast to the respectable young women tending frames in Lowell.[63]

These short-lived businesses produced few surviving records, but conditions in the Philadelphia mills may have been worse than in New England. An 1837 Pennsylvania State Senate committee reported 11–14 working hours per day were common. Most workers were women and girls, with 20% under 12 years old, and some piecers were as young as 7 or 8.[64] Spinners frequently received poor quality roving, which required more piecing. As a result, mule teams sometimes had a third, 'middle', piecer.[65] Mill owners periodically lengthened work days by a half-hour or hour without changing daily wages. Intensity caused exhausted children to fall asleep at work, and overseers beat them as a result. Wages were lower than those paid in New England, with children earning at most a dollar per week, and some as little as 50¢. Managers threatened to replace the militant mule operatives with throstles or self-actors, and by the late 1830s their wages were $6–7.50 per week.[66]

The paternalistic New England systems were generally successful in imposing social control up to the 1840s. By contrast, the Philadelphia mills had no social motivations and there were many strikes over wages and hours during the 1820s and

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[63] Shelton, *The Mills of Manayunk*, 62–63.
[64] Pennsylvania General Assembly, *Journal of the Senate, 1837–38*, vol. 1 (Harrisburg, PA: Thompson & Clark, 1838), 322–27. On working hours in Philadelphia see also William A. Sullivan, "The Industrial Revolution and the Factory Operative in Pennsylvania," *The Pennsylvania Magazine of History and Biography* 78, no. 4 (1954): 487–88. James Lynn Barnard, *Factory Legislation in Pennsylvania: Its History and Administration* (Philadelphia: J.C. Winston, 1907), 10–11.
[65] Cohen, *American Management and British Labor*, 60.
[66] Shelton, *The Mills of Manayunk*, 63–65, 69–72. Scranton, *Proprietary Capitalism*, 17, 155–56. But see note 87 below on differences in prices.

1830s, sometimes led by militant mule operatives. The large number of small mills made the system very competitive, so wage reductions were more common.[67] Workers complained of harsh supervision, which also contributed to conflictual labor relations.[68]

Factory Work and Division of Labor

The three American factory systems of the late 18th and early 19th century differed in in plant size, technical choice, and labor recruitment. The following sections provide more detail on the components of job quality, noting common elements and variation across the Slater, Lowell, and Philadelphia models.

The machines in American factories were like those described in Chapter 3, and both countries used the same division of labor for most of the 19th century. In continuous spinning, women (called 'operatives', 'tenders', or 'spinners') monitored one frame (a 'side') of spindles, removed empty bobbins of roving and replaced them, and pieced broken threads. Frames were placed in rows, so most workers had machinery in front and behind them. Many mills employed doffers to remove full bobbins, replace them with empty bobbins, and carry off the yarn.[69] Former operatives stated that frame tending was one of the easiest jobs to learn, and young workers could pick up the main points from a colleague in 2–3 weeks.[70] Workers who began as doffers

[67] Shelton, *The Mills of Manayunk*, 119–22, 34–53, 63–65, 70–73. Scranton, *Proprietary Capitalism*, 128, 35, 50–52.
[68] Bruce Laurie, *Working People of Philadelphia, 1800–1850* (Temple University Press, 1980), 19.
[69] Benita Eisler, *The Lowell Offering: Writings by New England Mill Women (1840–1845)* (Philadelphia: Lippincott, 1977), 51.
[70] Tamara K. Hareven and Randolph Langenbach, *Amoskeag: Life and Work in an American Factory-City in New England* (London: Methuen, 1979), 115, 18.

or bobbin girls could become spinning operatives and, in combined mills, eventually move to higher-paid processes such as weaving.[71] Overseers supervised continuous work, and mechanics maintained and repaired the machinery. On mules, the operative hired and disciplined the piecers, who cleaned, creeled, pieced threads, and doffed.

The interior environment was hot and humid, as described in Chapters 3 & 4. The Lawrence Corporation recorded temperatures in their mill rooms for a week in January 1834; average temperatures in the spinning rooms were 75–79˚F, which was the highest of any process in the factory. Workers in all-male rooms frequently rolled up their pants and toiled shirtless.[72] Across American factories work rooms were poorly lit with candles or oil lamps, which polluted the air and reportedly led to shortsightedness.[73]

The Lowell managers' work was discussed above, but tasks differed in smaller mills where managers had more responsibilities. In such factories managers were sometimes selected for mechanical expertise and repaired machines or even operated them.[74] Managers for the Slater mills handled recruitment, correspondence with other Slater administrators, and communicated with wholesalers or retailers.[75] Overseers of small mills worked directly under the agent or manager and were responsible for discipline and operation of machines in one room of the productive process. Larger operations had greater task depth (repetition) for management, and therefore more

[71] Dublin, *Women at Work*, 185–88.
[72] Cornell University, Kheel Center, American Textile History Museum Collections, 2013.211.1, Merrimack Manufacturing Company business records, Box 2. Gross, *Industrial Decline*, 61–62.
[73] *Industrial Decline*, 15. Dunwell, *The Run of the Mill*, 24.
[74] Tucker, *Samuel Slater*, 201–02.
[75] *Samuel Slater*, 201–05.

division of labor, while smaller mills bundled more tasks that managers repeated less frequently into fewer supervisory occupations.

Mill Architecture

The first factories in the 1790s were 2–4 stories and had dimensions around 20′ x 40′.[76] The Lowell mills were much larger red-brick structures built on a similar scale to many early British factories, generally four to six stories tall. Ceilings were 10′ high, and the spinning rooms were large: 40′ x 150′ was a common size.[77] Narrow, tall designs reduced the distance from the windows to the center of the floor and kept machines close to the prime mover. They also lowered the cost of the foundation and allowed construction in steep river valleys.[78] Mill complexes with multiple buildings had structures arranged in courtyards or quadrangles. An elaborate clocktower remained the single expression of architectural flair through much of the 1800s. The large Lowell mills had elevators to move raw materials and output to and from the spinning rooms, which were usually on the second floor, above the carding machines, with warping and dressing on the top floors.[79] As noted, the Mid-Atlantic mills were smaller and had smaller workforces, with the Slater mills in a middle ground for size.[80]

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[76] Cole, *American Wool Manufacture*, I.
[77] Scranton, *Proprietary Capitalism*, 17. William Scoresby, *American Factories and Their Female Operatives; with an Appeal on Behalf of the British Factory Population and Suggestions for the Improvement of Their Condition* (Boston: W. D. Ticknor, 1845), 18.
[78] Dunwell, *The Run of the Mill*, 24–25.
[79] Dublin, *Women at Work*, 61–62.
[80] Scranton, *Proprietary Capitalism*, 48.

Power Technology and Technical Choice

Spinning factories in the United States exhibited two important differences in technology from most British mills, although both countries had a diversity of machinery. First, water power was more plentiful and cheaper, so most American mills were wheel-powered up to the 1860s. Engineers improved water wheels to exploit more potential energy, built wheels up to 40′ across to take in more water, and controlled watercourses to steady power supplies. The undershot wheel was the first prime mover in American textiles, but millwrights replaced it with overshot wheels and breast-shot wheels to improve efficiency.[81]

While water was a cheap and reliable power source in most of inland New England, Mid-Atlantic and Rhode Island manufacturers found steam power was preferable to slower waterways. A few mills installed steam engines during the 1810s and 1820s, and new mills were built with steam engines when railroads began transporting anthracite coal from Pennsylvania the 1830s, first in coastal cities that lacked falls or rapids for water wheels. [82] Like in Britain, steam engines required specialized operators and maintenance, and added the risk of boiler explosions. They allowed factory construction in new areas and provided a more reliable power source for existing mills, but inland mills using water power remained the majority of

[81] Dunwell, *The Run of the Mill*, 62–63. Louis C. Hunter, *A History of Industrial Power in the United States, 1780–1930*, vol. 1 (Charlottesville: University Press of Virginia, 1979), 65–71, 88–91, 291–338. Undershot wheels used about 15–30% of water's potential energy and overshot wheels 50–70%, but overshots required a longer drop. Water entered breast-shot wheels above the axis of rotation, so they did not require as great a drop as overshot wheels.
[82] Dunwell, *The Run of the Mill*, 64–66. Hunter, *Industrial Power*, 1, 483–84. Anthracite from eastern Pennsylvania was soon supplemented by the larger bituminous mines of the central Appalachians in the early 1840s. On the difficulties of using anthracite, see *A History of Industrial Power in the United States, 1780–1930*, vol. 2 (Charlottesville: University Press of Virginia, 1985), 414–20.

establishments and employment. Unlike in Britain, steam power did not produce centripetal forces that concentrated spinning in cities.

American firms used throstle frames and mules, with the former predominant especially in the largest mills. The first comparison between mule and throstle spindles is available for New York in 1832. At this date, 37% of the 137,000 enumerated spindles were on mules, and the remainder were continuous spindles. New England was dominated by the large throstle spindle capacity of Lowell and similar mill towns.[83] Like waterwheels, extensive use stimulated innovation. The first American improvement to the throstle was the 'dead spindle', which was adopted in the Waltham mills from 1813. The spindle was fixed while the rotating flyer could run at much higher speeds, up to 5000 rpm, which raised productivity.[84] By contrast, as late as the 1830s only the rollers and spindles of American common mules were powered. This meant that the operative had to pull and push the carriage for the draw and winding, which was tiring, limited the number of spindles on a machine, and held down piece rate earnings.[85]

Early Factories: Wages

Earnings for factory workers were higher than in hand spinning, although Mid-Atlantic and New England mill owners combined to control wages.[86] Lowell

[83] Cohen, *American Management and British Labor*, 29–30.
[84] Anthony F. C. Wallace, *Rockdale: The Growth of an American Village in the Early Industrial Revolution* (New York: Norton, 1980), 197.
[85] Cohen, *American Management and British Labor*, 60.
[86] Shelton, *The Mills of Manayunk*, 122. Harvard Business School, Baker Library Special Collections, Hamilton Manufacturing Company Records, Mss:442 1825-1917 Volume 19 Carton 19 Folder 8.

throstle tenders earned 40–50¢ per day in the first half of the 19th century, and wages for Slater's continuous spinners were 30–35¢/day. Wages in Massachusetts were higher than those reported for the Philadelphia region, especially for operatives, although this was partially offset by higher prices.[87] Philadelphia throstle spinners earned around 25¢ per day in 1840, substantially lower nominal earnings than continuous spinning workers in Lowell, and slightly lower in real terms.[88] Mule operatives unsurprisingly earned far more than throstle tenders, with New Englanders making wages of $1.25–1.50 per day, close to the five-to-one ratio between mule operatives and throstle tenders in Britain. Real wages in American spinning were slightly higher than Britain, but alternative occupations in New England were generally compensated better.[89] Managers could earn several times the wages of shopfloor workers. The Slaters hired managers for $800 annually in the 1830s and $1000 in the 1840s.[90]

[87] Most comparable commodities in the UC-Davis GPI Database are food, which was about 40% more expensive in Massachusetts than Pennsylvania. Accordingly, the consumption basket prices for Massachusetts are 30% higher than Pennsylvania (the base basket), and 25% higher for Rhode Island, in Tables 5.1–7 and Tables 6.2–5. Cf. Philip Coelho and James Shepherd, "The Impact of Regional Differences in Prices and Wages on Economic Growth: The United States in 1890," *The Journal of Economic History* 39, no. 1 (1979).
[88] James Montgomery, *A Practical Detail of the Cotton Manufacture of the United States of America* (Glasgow: J. Niven, 1840), 133.
[89] Dalzell, *Enterprising Elite*, 32. Tucker, *Samuel Slater*, 199–200. Harvard Business School, Baker Library Special Collections, Slater Family Business Records, Mss:442 1793-1926 S631 Volume R17, Volume H98. Massachusetts Historical Society, Robert Hammett Papers, Ms. N-373. Dublin, *Women at Work*, 66; Bureau of Labor Statistics, *History of Wages in the United States from Colonial Times to 1928* (Washington: Government Printing Office, 1934).
[90] Tucker, *Samuel Slater*, 199–200.

Early Factories: Stability of Earnings

Factory spinning operatives in America could experience inconsistent earnings, non-specie payment, and many saw their wages held back by employers to ensure attendance. During 1796, Slater's mill ran out of cotton once and closed twice because there were insufficient workers for operation. At other points in the early years work halted because of low demand for yarn or insufficient water power.[91] Factories placed below falls could flood, damaging equipment and suspending operations. Sometimes work ceased for repairs or upgrades to machinery.[92]

In some New England mills, workers were paid quarterly until the 1860s.[93] Waltham-Lowell establishments paid workers in cash monthly, but many Rhode Island mills paid credit that could only be used in the company store.[94] Other mill owners paid in bank notes rather than specie, and monthly or delayed payment was common.[95] This was particularly a problem early in the 19th century; insufficient cash for payments became less common, although it did not disappear entirely, up to the 1860s.

Employers delayed payment to keep workers at their factory in hope of receiving their earnings. The common justification was that workers who left without the required two weeks' notice forfeited their pay. There were also fines for lateness:

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[91] *Samuel Slater*, 77, 79.
[92] Dunwell, *The Run of the Mill*, 159. Wallace, *Rockdale*, 374–79. Robinson, *Loom and Spindle*, 35.
[93] John Borden Armstrong, *Factory under the Elms: A History of Harrisville, New Hampshire, 1774–1969* (Cambridge: M.I.T. Press, 1969), 122.
[94] Dublin, *Women at Work*, 18.
[95] Eisler, *The Lowell Offering*, 25. Some American mill towns had company stores, including the Slater woolen mill at Webster, Massachusetts. Employees could only purchase from a Slater-owned store. Other mills paid employees in bills that were only accepted at the company store. Cole, *American Wool Manufacture*, I, 242.

workers who were fifteen minutes late lost one-fourth of a day's wages in some Philadelphia mills. Other fines were imposed for poor quality work and for damaging machinery. Summary dismissal was a risk, especially for repeated lateness.[96] Factory owners also prohibited workers from leaving their workroom without the overseer's permission.[97]

Early Factories: Working Time

US millowners faced the same scheduling incentives as their British counterparts: long shifts spread out the high fixed costs of the plant and machinery. Surveys of Massachusetts manufacturers during the 1820s showed that most schedules were 12 to 14 hours per day.[98] A standard working day in New England mills began between 5 and 5:30 AM and ended at 7 PM, with total meal breaks of between 30 and 90 minutes.[99] Contemporaries commented that short intervals for breakfast and lunch made it difficult for operatives to consume their food.[100] The Rhode Island mills operated for 12–16 hours per day and six (or seven) days per week, but most employees did not work a full week consistently because of exhaustion, illness, or

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[96] Shelton, *The Mills of Manayunk*, 72–74. Scranton, *Proprietary Capitalism*, 155. Sullivan, "The Industrial Revolution and the Factory Operative," 480, 82. Tucker, *Samuel Slater*, 84, 154–59. In the Slater mills families sometimes received small plots of land with their rented company cottages.

[97] Gary Kulik, Roger N. Parks, and Theodore Z. Penn, *The New England Mill Village, 1790–1860* (Cambridge: MIT Press, 1982), 464.

[98] Person, "Factory Legislation in Massachusetts," 7.

[99] Tucker, *Samuel Slater*, 113–15. Vera Shlakman, *Economic History of a Factory Town: A Study of Chicopee, Massachusetts* (Northhampton, Mass.: Smith College History Department, 1935), 54–55. Constance McLaughlin Green, *Holyoke, Massachusetts: A Case History of the Industrial Revolution in America* (New Haven: Yale University Press, 1939), 47. Knowlton, *Pepperell's Progress*, 62. Prude, *Industrial Order*, 135.

[100] Citizen of Lowell, *Corporations and Operatives: Being an Exposition of the Condition of Factory Operatives* (Lowell: Samuel J. Varney, 1848), 10.

problems with the machinery.[101] Two meal breaks during the day, signaled by a factory bell, totaled 60 to 75 minutes.[102] In non-paternalistic mills, some employees were required to spin and repair machinery on Sundays.[103] While most factories did not operate on the Sabbath, workers could toil around frames for up to 75 hours per week. In 1840, British observer James Montgomery stated that hours varied across the year. The shortest work days were during December and January (11 hours, 24 minutes per day) and the longest were in April (13 hours, 31 minutes). In the winter months, there was no breakfast break.[104] Far from reducing hours as the century went on, the Lowell mill managers lengthened the work day so that it was 15 minutes longer in 1841 than it had been at the end of the 1820s.[105] Another common practice was to work on 'mill time', which was set earlier than the actual time in the morning and later in the evening to lengthen the day.[106]

Early Factories: Supervision & Control

Control in American mills replicated many aspects of British practice, and included more inter-employer coordination and penalties for conduct outside the factory. Tardiness or absenteeism were a serious problem that could slow output, so missing work was punishable with fines or discharge.[107] Factories also prohibited

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[101] Tucker, *Samuel Slater*, 77, 79.
[102] *Samuel Slater*, 160.
[103] Thomas W. Leavitt, *The Hollingworth Letters: Technical Change in the Textile Industry, 1826–1837* (Cambridge: M.I.T. Press, 1969), 22.
[104] Montgomery, *Cotton Manufacture of the United States*, 173–74.
[105] Ware, *The Industrial Worker*, 73, 84.
[106] *The Industrial Worker*, 148. Hanlan, *The Working Population of Manchester*, 65. Slater used a bell rather than a clock to lengthen the work day by up to 15 minutes. Tucker, *Samuel Slater*, 227.
[107] Sullivan, "The Industrial Revolution and the Factory Operative," 479. Wallace, *Rockdale*, 327. Kulik, Parks, and Penn, *The New England Mill Village*, 283–307.

smoking (an obvious fire risk), and in some cases eating. Books and other distracting materials were occasionally banned.[108]

As noted above, the Lowell system included extensive social control: workers had to live in company housing, dress respectably, behave properly, and attend church weekly.[109] Religious observance was also required at the Slater mills.[110] One supporter of the Lowell approach described it favorably as 'a strict system of moral police.'[111] Workers could be fired for swearing, dancing, 'disrespectful conduct', or other indiscretions inside or outside the factory. There were even specified times for eating and sleeping. To receive an 'honorable discharge', mill girls had to work for a year and provide two weeks' notice before leaving. Workers who were dismissed for rules violations or did not give notice could be blacklisted from employment by other Lowell manufacturers, although such rules were not always enforced during labor shortages. By contrast, manufacturers could dismiss employees or change wages, working time, and conditions at any point.[112] Mid-Atlantic manufacturers also blacklisted workers who left employment without two weeks' notice or committed other misdemeanors, including lobbying for hours regulation.[113]

The Slater mills became more restrictive and controlling in the 1830s. First, workers lost their rations of hard liquor, then drinking spirits at work was prohibited.

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[108] Sullivan, "The Industrial Revolution and the Factory Operative," 479. Wallace, *Rockdale*, 327.
[109] Dalzell, *Enterprising Elite*, 33–34. Gross, *Industrial Decline*, 16.
[110] Tucker, *Samuel Slater*, 164–65.
[111] Miles, *Lowell*, 128.
[112] Ware, *The Industrial Worker*, 107. Dublin, *Women at Work*, 59–60. Similar rules applied in Chicopee, Massachusetts. Shlakman, *Factory Town*, 51, 54.
[113] Sullivan, "The Industrial Revolution and the Factory Operative," 480–81. Stanwood, "Cotton Manufacture in New England," 132.

Extending this principle, many millowners preferred to hire teetotalers.[114] In the same period, the Slater system replaced family discipline with overseer control. Fathers were prohibited from entering the mill to supervise their children, and the whole family could be dismissed for violating this rule. Managers began to demand work on the Sabbath, split up family members' shifts, impose fines for poor work or tardiness in place of family discipline, and reduced or eliminated break times.[115] Moreover, in the 1840s, Slater mills shifted to paying household members individually.[116] These changes moved authority and discipline to the factory manager or room overseer and individualized employment relationships.[117] Overall, American manufacturers sought to control labor supply and, in the Lowell and Slater models, the conduct of workers inside and outside of the factory. Mule operatives had more discretion, but mule assistants, frame tenders, and doffers had little say over the organization of work. The tendency towards greater management control continued in the late 19th century and is discussed in Chapter 6.

Early Factories: Intensity

The experience of shopfloor operatives was not as uniformly negative as in the British case, though the early months of work were challenging. Workers were exhausted by adjusting to the speed of machinery, the dexterity required to repair threads and avoid accidents, and the noise and atmosphere of the factory.[118] Physical

[114] Tucker, *Samuel Slater*, 180–81.
[115] *Samuel Slater*, 223–24.
[116] The Slater mills had attempted to pay weavers directly in the 1830s but reverted to family payment when parents objected. *Samuel Slater*, 224–25.
[117] *Samuel Slater*, 214–28.
[118] Gross, *Industrial Decline*, 13–15.

exhaustion from carrying bobbins or long hours, compounded by respiratory illness, were common.[119] Some factory workers complained of being on their feet for 12-hour days, six days per week, which caused discomfort and pain.[120] Others noted that frequent piecing made their fingers sore, at least at first.[121] However, not all workers were pushed equally: child doffers might only remove bobbins for 15 minutes in each hour, and some overseers allowed them to rest and read when not doffing.[122] Before the 1840s, workers in the Lowell system noted that they were not driven and had some respite during the day.

Early Factories: Short- and Long-Term Health Risks

Accidents in American spinning factories had similar causes and produced similar injuries as described in Chapter 3. Exposed machinery, few safety features, and worker exhaustion led to lacerations from fast-running power belts, fingers snapped by gearing, and children crushed between the carriage and creel of mules. Limbs and especially digits were most at risk.[123] Some employers offered voluntary compensation for accidents, but most commonly this meant payments for medical treatment, and companies rarely paid wages to injured workers. Agents encouraged injured workers

[119] *Industrial Decline*, 15.
[120] Eisler, *The Lowell Offering*, 52.
[121] Letter from Mary Cowles, Cornell University, Kheel Center, American Textile History Museum Collections, ATHM Correspondence & Papers, 0022.379.
[122] Robinson, *Loom and Spindle*, 30.
[123] Hanlan, *The Working Population of Manchester*, 61. Tucker, *Samuel Slater*, 84. Letter from Aaron Jewett Jr, Cornell University, Kheel Center for Labor-Management Documentation, American Textile History Museum Collections, ATHM Correspondence & Papers, 0022.385.

to settle for a sum decided by the company rather than taking legal action, which was likely a reasonable course given the unsympathetic attitude of American courts.[124]

There are no national-level sources analogous to the Factory Inspectors that give a broad picture of corporal punishment, but qualitative evidence suggests that American mule operatives used knotted ropes or leather strips, sometimes with tacks, to punish child workers and young women who pieced and cleaned.[125] There is little evidence of corporal punishment in the Lowell mills, fitting the paternalistic paradigm. Industrial disease and 'mill fever' received relatively little comment in the United States during the early period of industrialization. However, the use of similar machinery without allowances for superior ventilation suggests that workers likely suffered similar hazards.[126]

Composite Job Quality

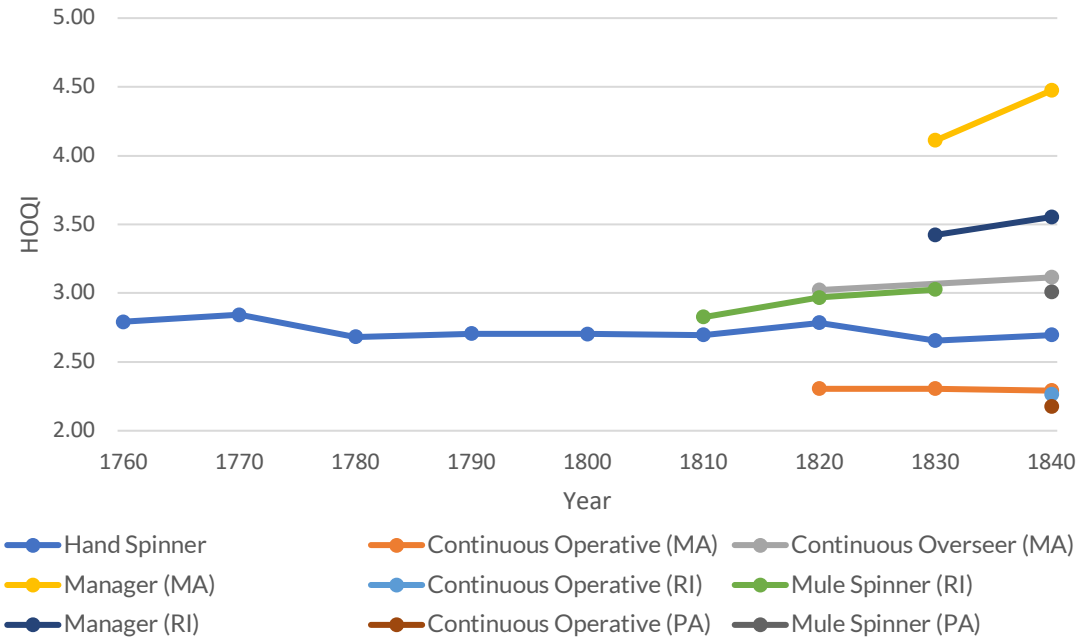
Figure 5.3 below encapsulates the changes and differences in job quality across spinning occupations during this period. Hand spinning was modestly remunerated, high-control, and hours were not very long, but earnings were unstable. Like all spinning operative occupations, it was highly repetitive. Some factory jobs were superior: mule operatives earned good wages in the Slater mills, and reasonable incomes in Pennsylvania. Throstle tenders suffered chiefly from the very long hours

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[124] Daniel Nelson, *Managers and Workers: Origins of the New Factory System in the United States, 1880–1920* (Madison: University of Wisconsin Press, 1975), 31–32.
[125] Cohen, *American Management and British Labor*, 67–68. Sullivan, "The Industrial Revolution and the Factory Operative," 482–83.
[126] Gross, *Industrial Decline*, 15. As discussed in Chapter 4, the worst air quality was in the carding room. *Industrial Decline*, 61. Retired spinning operatives said that spinning was the next-worst process for fiber dust. Hareven and Langenbach, *Amoskeag*, 55.

required across all branches of early textile manufactures. Overseers enjoyed high control and good wages, and mill managers or agents received even higher earnings and benefitted from less hazardous work environments than the hot, humid, dusty spinning rooms. Systems that operated on a larger scale, like the Lowell mills, had greater specialization and inequality of work-related wellbeing.

Figure 5.3: Job Quality in American Spinning, 1760–1840



Source: See Tables 5.1–5.9

Occupational Availability

The lack of analogous statistics on fiber inputs makes it impossible to replicate the approach used in Chapter 3 for estimating hand spinning employment and technological unemployment. The evidence presented above about the ubiquity of spinning wheels suggests that it was common work, although rarely a consistent occupation. Irregular employment was likely one reason that concerns about technological unemployment were scarce in the United States. Any objections were

quickly allayed when factories employed women and children in import-substituting production.[127]

Factory numbers vary between sources and rarely distinguish between spinning and generic textile mills, and spindle counts are also inconsistent. Albert Gallatin reported that there were 62 cotton mills turning 30,000 spindles by 1809. He estimated 40 workers for each mill of 800 spindles, or 20 spindles per worker.[128] This was probably too low, as Slater was using 72-spindle frames in the 1790s and other manufacturers had 84-spindle frames, but it provides a high-end estimate of 1500 spinning operatives.[129] There was rapid growth during the Embargo, and the 1810 Census of Manufactures reported 99,827 spindles in 230 wool and cotton manufacturing establishments in the ten Northeastern states. At a more conservative ratio of 50 spindles per worker, there may have been 2000 factory spinners before the War of 1812.[130] Some mills closed when British imports returned in 1816, but tariffs protected low-quality production and integrated mills using powerlooms proliferated from the 1820s.

At the end of this period, the 1840 Census reported 81,920 Northeastern workers in cotton, wool, and flax manufacturing, with a quarter employed in cotton manufacturing in Massachusetts alone. The Census did not distinguish spinners from

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[127] Abbott, *Women in Industry*, 56–62.
[128] Gallatin, *Report on American Manufactures*.
[129] James L. Bishop, *A History of American Manufactures from 1608 to 1860*, vol. 1 (Philadelphia: Edward Young & Co., 1864), 408.
[130] 1810 Census, 'Tables of American Manufactures'. The first Census of Manufactures in 1810 reported spindles in use, but the machinery counts were inconsistent. For example, Massachusetts had twice the population of Vermont, but the census reported five times as many spinning wheels in Vermont. Moreover, enumerators grouped together many types of machinery when counting spindles, or did not report the type of machinery. The 1820 Census data is similarly patchy and there was no Census of Manufactures in 1830.

other employees, but it did count a total of 2,042,783 cotton spindles across the ten Northeastern states. As noted above, throstle tenders in Lowell each monitored one machine of 128 spindles, and Lowell had relatively advanced machinery. If by the 1840s there was, conservatively, one worker (throstle tender, doffer, mule operative, or piecer) for every 100 spindles, then about 20,000 workers may have been employed in cotton spinning. This would have been nearly one-third of all cotton operatives (62,737) in 1840. If spinning was a similar share of total employment in all textile manufacturing, there were about 26,000 spinning employees across cotton, wool, and flax production.[131] This conservative estimate demonstrates the rapid growth of employment in the American textile industry, which had risen more than tenfold in three decades.

Occupational Distribution

Chapter 3 described how technological change in British spinning was male-biased. In the United States, the increased division of labor and reorganization of mechanization also allowed men to claim nearly all of the best jobs as agents, mechanics, and mule operatives, though they were a minority of workers. Gallatin estimated that 88% of cotton factory workers were women and girls in 1809.[132] The Lowell system produced the most detailed information about its workforce, which had an even larger share of women than British continuous mills. In 1819, the Waltham factory employed just 14 men and 286 women and children, and in 1838, 93% of employees at Lowell were women, and the remaining 7% men were all overseers.

[131] 1840 US Census, Compendium of the Sixth Census, 358–364.
[132] Gallatin, *Report on American Manufactures*, 13.

Evidence on the gender composition of continuous mills from the 1810s to the 1830s shows that 80–95% of employees were women.[133] In the early years, nearly all workers in the Lowell system were New Englanders except a few immigrant mechanics.[134] Across wool and cotton manufacturing, mule spinners and mechanics were usually recruited from overseas.[135]

The gender division of mule spinning also mirrored British factories: all of Slater's mule operatives and overseers at the Steam Cotton Manufacturing Company in 1831 were male.[136] Overseers in Slater mills were male, but a few Lowell factories promoted women who were experienced throstle tenders to overseeing in the early years.[137] Family labor and some use of mules in the Slater system meant more child labor. The accounts of the Slater & Tiffany mill from 1829–1830 show about 65% of payments to women and girls, and in 1840, 76% of spinners in Slater's Union Mills in Webster, Massachusetts were children younger than 16, and two-thirds were girls.[138] Pennsylvania mills employed many women, but fewer than the Lowell factories. Their account books rarely survive, but qualitative evidence and the extensive use of mules suggest more male and child labor.[139]

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[133] Abbott, *Women in Industry*, 89–90; Cohen, *American Management and British Labor*, 67.
[134] Dublin, *Women at Work*, 26–28.
[135] Cole, *American Wool Manufacture*, I, 235.
[136] Harvard Business School, Baker Library Special Collections, Slater Family Business Records, Mss 442 1793–1926 S631 Volume R17.
[137] Greenlees, *Female Labour Power*, 102–03.
[138] Harvard Business School, Baker Library Special Collections, Slater Family Business Records, Mss:442 1793-1926 S631, Volume H98. Tucker, *Samuel Slater*, 144–45.
[139] Shelton, *The Mills of Manayunk*.

Conclusion

The First Industrial Revolution in the United States was import-substituting, driven by commercial isolation in the 1800s and 1810s. Americans' reliance on imported textiles before industrialization and irregular work in colonial textile production meant that mechanization destroyed few jobs, although it shifted yarn production from the household to the market. Many aspects of factory conditions were similar to Britain, including 12- and 13-hour workdays, accidents caused by exposed gearing, and low-control employment for most workers.

The American textile industry of the early 19th century had three models that differed in labor recruitment, technical choice, and industrial structure. The Philadelphia model used many mules operated by British immigrants, featured smaller firms, was more competitive, and paid somewhat lower wages than the paternalistic, controlling Lowell system. The large Massachusetts mills established an early corporate form to deal with the expanded task range of spinning work on frames and the task depth of business administration. The Lowell system separated financial, organizational, managerial, maintenance, and operational roles, with more inequality in work-related wellbeing across the factory. The Slater mills began with family labor and a mixture of mules and frames, but by the 1830s managers had begun to claim control over the factory floor. Greater management control that enabled more intense work, along with new productivity-enhancing innovations, were key features of the next period in American textile development.

Table 5.1: Occupational Quality for Hand Spinners, 1760–1840

Year	Daily Wage (d/$)	CN (d/$)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1760	7.93	5.45	2.12	48.00	3.25	2	5	5	5	4	1	3.16	2.79
1770	10.84	6.07	2.24	48.00	3.25	2	5	5	5	4	1	3.16	2.84
1780	0.11	0.12	1.88	48.00	3.25	2	5	5	5	4	1	3.16	2.68
1790	0.10	0.10	1.93	48.00	3.25	2	5	5	5	4	1	3.16	2.71
1800	0.13	0.13	1.92	48.00	3.25	2	5	5	5	4	1	3.16	2.70
1810	0.14	0.14	1.91	48.00	3.25	2	5	5	5	4	1	3.16	2.70
1820	0.14	0.10	2.10	48.00	3.25	2	5	5	5	4	1	3.16	2.78
1830	0.12	0.10	2.04	48.00	3.25	1	5	5	5	4	1	2.82	2.66
1840	0.14	0.09	2.14	48.00	3.25	1	5	5	5	4	1	2.82	2.70

Sources for all tables: Chapters 2, 5, Appendix 1, manuscript sources in the Bibliography, Allen et al (2011), Allen (2015), UC-Davis Global Prices and Incomes Database. Wages and Consumption Needs in Table 5.1 are denominated in d for 1760 and 1770. For Tables 5.1, 5.2, 5.5, 5.8 Consumption Needs are scaled to 85% of an adult male basket (see Appendix 1). Hours/Week figures for factory workers are based on scheduled hours (described in the text) and archival evidence of average days worked per week. Missing decades are those for which there is no wage data.

Table 5.2: Occupational Quality for Continuous Operatives (Massachusetts), 1820–1840

Year	Daily Wage ($)	CN ($)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1820	0.50	0.10	2.88	65.00	2.19	3	3	2	1	3	1	1.94	2.30
1830	0.50	0.10	2.88	65.00	2.19	3	3	2	1	3	1	1.94	2.30
1840	0.45	0.10	2.83	65.00	2.19	3	3	2	1	3	1	1.94	2.29

Table 5.3: Occupational Quality for Continuous Overseers (Massachusetts), 1820–1840

Year	Daily Wage ($)	CN ($)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1820	1.75	0.12	4.40	71.50	1.78	5	4	2	4	4	3	3.53	3.02
1840	2.09	0.11	4.81	71.50	1.78	5	4	2	4	4	3	3.53	3.11

Table 5.4: Occupational Quality for Managers (Massachusetts), 1830–1840

Year	Daily Wage ($)	CN ($)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1830	9.58	0.12	9.31	72.00	1.75	5	5	4	5	4	3	4.26	4.11
1840	15.97	0.11	12.01	72.00	1.75	5	5	4	5	4	3	4.26	4.47

Table 5.5: Occupational Quality for Continuous Operatives (Rhode Island), 1830

Year	Daily Wage ($)	CN ($)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1830	0.33	0.10	2.56	60	2.5	2	3	2	1	3	1	1.82	2.26

Table 5.6: Occupational Quality for Mule Operatives (Rhode Island), 1810–1830

Year	Daily Wage ($)	CN ($)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1810	1.30	0.17	3.35	60.00	2.50	3	4	2	4	2	2	2.70	2.83
1820	1.33	0.11	3.88	60.00	2.50	3	4	2	4	2	2	2.70	2.97
1830	1.55	0.11	4.11	60.00	2.50	3	4	2	4	2	2	2.70	3.03

Table 5.7: Occupational Quality for Managers (Rhode Island), 1830–1840

Year	Daily Wage ($)	CN ($)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1830	2.56	0.11	5.38	72.00	1.75	5	5	4	5	4	3	4.26	3.42
1840	3.19	0.11	6.02	72.00	1.75	5	5	4	5	4	3	4.26	3.55

Table 5.8: Occupational Quality for Continuous Operatives (Pennsylvania), 1840

Year	Daily Wage ($)	CN ($)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1840	0.26	0.07	2.59	62.50	2.34	2	3	2	1	2	1	1.70	2.18

Table 5.9: Occupational Quality for Mule Operatives (Pennsylvania), 1840

Year	Daily Wage ($)	CN ($)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1840	1.13	0.09	4.04	60.00	2.50	3	4	2	4	2	2	2.70	3.01

Chapter 6
American Spinning, 1840–1910

Chapter Abstract

This chapter describes work in the Northeastern American spinning sector from the middle of the 19th century until the First World War. First, it sketches the development of cap and ring spinning in the 1820s and 1830s and shifts in American technical choice. Next, it provides a description of mill design and the American continuous spinning room in the 19th century. The chapter then outlines changes in job quality during this period, especially increasing work intensity (the 'speedup' and 'stretch-out'), and regulation of hours and conditions. Frame spinners' work became more demanding, and overseers claimed shopfloor control from mule spinners. Rising work intensity was one reason that native-born workers left spinning and were replaced by immigrants with fewer outside options. Employment in spinning grew, children were increasingly excluded by regulation, and men became a majority of workers. While work-related wellbeing improved in absolute terms in the final decades of the 19th century, principally because of rising wages and regulation-reduced hours, spinning was less desirable than many alternative occupations.

Introduction

The first 50 years of American machine spinning had produced three heterogenous models of industrialization, as discussed in Chapter 5. The remainder of the 19th century and the first decade of the 20th century saw common trends in yarn production across the Northeast.[1] There were technological improvements that raised productivity, especially to continuous machines. Cap and ring spinning, both invented at the end of the 1820s to replace the throstle, enabled higher spindle speeds. The self-actor was also brought to America, although a large majority of spindles were on ring frames by the late 19th century. While higher-productivity machines could have reduced operatives' workload, from the 1840s American mills reduced unit labor costs by requiring workers to monitor more spindles running at higher speeds. Overseers and managers of intermittent establishments took control of machinery adjustment, discipline, and recruitment, and substituted lower-paid workers or replaced mules with rings. These changes enabled firms to continue increasing productivity after reaping the gains of the ring frame and the self-actor.

The chapter begins by describing the invention of cap and ring spinning and the trajectory of American technical choice. It then presents developments that paralleled the British experience in Chapter 4, describing factory design, power sources, and power transfer, before moving to an outline of work with ring frames. It then describes how manufacturers organized work during the late 19th century and presents evidence on the components of occupational quality, highlighting increased

[1] The Mid-Atlantic industry declined from employing about 20% of cotton workers in the Northeast in 1850 to 15% in 1910, so the analysis in this chapter focuses on New England. 1850 US Census, Part IV, 180. 1910 US Census, Volume 4, Table II, 96–151.

intensity as a key feature of this period. The sections on short-term health risks and working time incorporate discussions of regulation, which was ineffective before factory inspections. As intensity rose and manufacturers took more control of the shopfloor, the spinning workforce became majority immigrant and increasingly male up to the First World War.

Caps, Rings, and Technical Choice

While Richard Roberts was developing the self-acting mule in Lancashire, Americans were building larger continuous machines that could run at higher speeds while producing finer yarn. In the 1820s mechanics installed iron gears on the throstle and added a tin cylinder to drive straps that turned the spindles. On the water frame, spindles were placed in spaced quartets; these improvements enabled the construction of longer throstles with less space between spindles.[2] Rotational speeds were still restricted by the weight of the inverted-U-shaped flyer: about 4000 rpm was the highest possible speed. The first descendant of the throstle was the 'cap' spinner, patented by Charles Danforth in 1830. He replaced the heavy flyer with a lighter sleeve (the 'cap') over the rotating bobbin. The rotation of the bobbin imparted twist as the yarn cycled around the cap and bobbin. To doff, the operative removed the cap and took out the bobbin. At first cap spinning appeared to be a major improvement, but it produced fluffier cotton yarns than the throstle, so its output could not be easily mixed with yarn from other machines. It was used for worsted spinning into the 20th century.[3]

[2] Anna P. Benson, *Textile Machines* (Princes Risborough: Shire, 1983), 14–15, 20.
[3] Harold Catling, *The Spinning Mule* (Newton Abbot: David & Charles, 1970), 183. Anthony F. C. Wallace, *Rockdale: The Growth of an American Village in the Early Industrial Revolution* (New

The second and more successful scion of continuous spinning was the ring frame. John Thorpe, a Rhode Island inventor, removed both the flyer and cap and routed the drafted yarn through a 'traveller' onto the bobbin. The traveller was a small, vertically-aligned metal loop attached to a horizontally-aligned ring placed around the bobbin and spindle. The rotation of the spindle and bobbin dragged the traveller around the ring, and the slightly faster rotation of the spindle than the traveller imparted twist.[4] Lighter components enabled higher rotational speeds, and by the 1850s cap and ring frames could operate at up to 7000 rpm.[5] In the 1870s, machine makers lightened the spindle further, which enabled speeds up to 9000 rpm.[6] Higher speeds demanded more inanimate power, and potentially more piecing, to enable higher productivity.[7] Increased speeds did not change the task range, but they raised intensity.

As discussed in the previous chapter, American manufacturers generally produced lower-quality yarn than British firms and preferred continuous machines that required fewer skilled laborers, but many factories used intermittent machinery: in the mid-19th century almost half of all American spindles were on mules.[8] Self-actors came to the United States after 1840 and by 1850 40% of American spindles were on

York: Norton, 1980), 197. G. Dakin, "A Review of the Development of Cotton Spinning Machinery," *Journal of the Textile Institute Proceedings* 42, no. 8 (1951): 465–66.

[4] Benson, *Textile Machines*, 20.

[5] Wallace, *Rockdale*, 197. Dakin, "Cotton Spinning Machinery," 465.

[6] "Cotton Spinning Machinery," 468.

[7] George Sweet Gibb, *The Saco-Lowell Shops: Textile Machinery Building in New England, 1813–1949* (Cambridge, MA: Harvard University Press, 1950), 211–12.

[8] Gary R. Saxonhouse and Gavin Wright, "National Leadership and Competing Technological Paradigms: The Globalization of Cotton Spinning, 1878–1933," *The Journal of Economic History* 70, no. 3 (2010): 539–40.

self-actors.[9] Self-actors were adopted quickly in part because the lower counts spun by American firms were better suited to the new machinery, as discussed in Chapter 4. Mule spinning was most prominent and concentrated in Fall River, Massachusetts and, by the later 19th century, towns specializing in higher-quality output, like New Bedford, Massachusetts. As late as 1889, 42% of American cotton, woollen, and worsted spindles were on mules.[10] First using mules and, later, improved rings, Northeastern production shifted up the quality spectrum in the late 19th and early 20th century, which helped to resist competition from the American South and overseas.[11]

Preference for continuous machinery returned in the late 19th century as machine-makers improved the quality of frame output.[12] In line with observers in other fields of industry, visiting textile experts from Britain reported that American manufacturers were more willing than British millowners to adopt new labor-saving machines and alter their factory organization.[13] Many American firms stopped using mules for coarse- and medium-quality yarn from the 1890s as the ring frame was more productive than the self-actor in lower counts, it required fewer expensive workers, and it allowed manufacturers to replace militant self-actor minders. By 1909 26.8% of spindles were on mules, and they were only used for the finest output and woollen

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[9] Isaac Cohen, *American Management and British Labor: A Comparative Study of the Cotton Spinning Industry* (New York: Greenwood, 1990), 105, 07–08; Robert H. Baird, *The American Cotton Spinner and Managers' and Carders' Guide: A Practical Treatise on Cotton Spinning* (Massachusetts: Phillips, Sampson & Co., 1856), 19, 171.
[10] Douglas A. Farnie and Michael Huberman, "Cotton Industry," in *The Oxford Encyclopedia of Economic History* (Oxford University Press, 2003). Cohen, *American Management and British Labor*, 2. 1910 US Census, Volume 10, Part 2, 56. This census did not provide spindles by state.
[11] Arthur Harrison Cole, *The American Wool Manufacture*, vol. II (Cambridge, MA: Harvard University Press, 1926), 172–80.
[12] Laurence F. Gross, *The Course of Industrial Decline: The Boott Cotton Mills of Lowell, Massachusetts, 1835–1955* (Baltimore: Johns Hopkins University Press, 1993), 89.
[13] Thomas M. Young, *The American Cotton Industry: A Study of Work and Workers* (New York: Charles Scribner's Sons, 1903), 140–42.

spinning.[14] American manufacturers had established factories with mostly continuous machines in New England during the early 19th century, then entered a phase of substantial, though minority, mule adoption around mid-century to produce higher-quality output, and finally transitioned back to continuous machinery as it was built to run faster and produce finer yarn by the end of the 19th century.

Mill Design & Power Sources

Although the machinery contents fluctuated, the appearance of Northeastern mills changed relatively little. Large mills had been built in the 1820s and 1830s, and the major changes after 1840 aimed to reduce fire risk and reorganize the layout to maximize spindleage per square foot. Ring frames took up less space than throstles, and designers packed more machines into each spinning room.[15] They also added apparatuses to heat, humidify, and in some cases ventilate factories from the last third of the 19th century.[16]

American mills did not have the same fire mitigation that British factories had installed by the later 19th century, in part because of the low cost of wood compared to iron. Factories normally had a brick exterior, but wooden interior beams and columns were common until the end of the 19th century. Fire mitigation was similar to British practices: covering beams and joists with cement, mortar, or asbestos paper, with

[14] Gibb, *The Saco-Lowell Shops*, 261. 1910 US Census, Volume 10 Part 2, 56. The share of mule spindles was even lower (17.7%) in cotton spinning in 1908. Saxonhouse and Wright, "The Globalization of Cotton Spinning," 541.
[15] Richard L. Hills, *Power from Steam: A History of the Stationary Steam Engine* (Cambridge: Cambridge University Press, 1989), 212.
[16] Betsy W. Bahr, "New England Mill Engineering: Rationalization and Reform in Textile Mill Design, 1790–1920" (University of Delaware, 1987), 6–7.

wooden floorboards placed over the top.[17] American mills also began to install sprinklers in the later 19th century, using similar technology to that employed in Britain.[18] While iron construction could have improved structural integrity and fire safety, it was not widely adopted until the 1870s, and reinforced concrete only appeared in manufacturing premises after 1900.[19]

Despite some improvements in fire mitigation practices, many workers did not benefit from new design technologies because a large number of pre-1850 American mills were not renovated.[20] Aging mills included hazards such as old glass panes that fell out and shattered and worn floors full of splinters. Old mills also lacked improved ventilation and operated without toilet facilities for women (or at all) into the 20th century.[21] Factory inspectors stated that unrenovated spinning factories were unpleasant to work in and more dangerous than the factories of new industries and Southern textile mills.[22]

American power sources and transfer systems changed more than factory design. While water power was sometimes inconsistent, wide, fast-flowing rivers like the Merrimack could produce thousands or even tens of thousands of horsepower at

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[17] Joseph Nasmith, *Recent Cotton Mill Construction and Engineering* (Manchester: John Heywood, 1894), 35–38.
[18] *Cotton Mill Construction*, 58–64. Large mills like Lowell had installed water pumps for fire suppression as early as the 1820s. Bahr, "Mill Engineering," 93–4.
[19] Daniel Nelson, *Managers and Workers: Origins of the New Factory System in the United States, 1880–1920* (Madison: University of Wisconsin Press, 1975), 14.
[20] Vera Shlakman, *Economic History of a Factory Town: A Study of Chicopee, Massachusetts* (Northhampton, Mass.: Smith College History Department, 1935), 103–05. Some manufacturers haphazardly added new buildings to mill complexes. Bahr, "Mill Engineering," 267–73.
[21] Gross, *Industrial Decline*, 133–36. Mary H. Blewett, *The Last Generation: Work and Life in the Textile Mills of Lowell, Massachusetts, 1910–1960* (Amherst: University of Massachusetts Press, 1990), 96. Edith Abbott, *Women in Industry: A Study in American Economic History* (New York: D. Appleton and Company, 1910), 125–26.
[22] Nelson, *Managers and Workers*, 25–26. Bahr, "Mill Engineering," 275–85.

Lowell, Lawrence, and Manchester.[23] Continuous spinning required more and steadier power than the mule, and the ring frame was even more demanding.[24] In response, Americans adopted the turbine from the 1850s. More efficient than water wheels, turbines exploited the lateral motion of water rather than its vertical drop, continued to spin with a flooded tail race (the area below the water wheel), and rotated with the watercourse, unlike overshot wheels.[25] The adoption and improvement of turbines enabled mills to run more machines at higher consistent speeds. Turbines also prolonged the use of water power, which allowed inland town-based mills to survive: in 1904, 35% of power in the New England mills was still supplied by water.[26] Efficient water power technology was one factor that mitigated the centripetal forces that affected British spinning.

In part because of the efficiency of turbines, water was cheaper than steam and remained the primary power source until the 1860s. In New England, mills usually supplemented water power with steam from the 1840s and 1850s to allow operation during droughts.[27] Improvements to the steam engine such as George Corliss' mechanism for controlling the entry of steam into a cylinder provided steadier power for ring frames.[28] Coastal cities such as Providence and Fall River shifted to steam earlier than inland mills because of lower transport costs for coal.[29] By the last decades

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[23] Thomas Russell Smith, *The Cotton Textile Industry of Fall River, Massachusetts: A Study of Industrial Localization* (New York: King's Crown Press, 1944), 42.
[24] Hills, *Power from Steam*, 212.
[25] Louis C. Hunter, *A History of Industrial Power in the United States, 1780–1930*, vol. 1 (Charlottesville: University Press of Virginia, 1979), 291–338, 413–15, 503.
[26] Thomas William Uttley, *Cotton Spinning and Manufacturing in the United States of America, a Report* (Manchester: University of Manchester Press, 1905), 5.
[27] Barbara M. Tucker, *Samuel Slater and the Origins of the American Textile Industry, 1790–1860* (Ithaca: Cornell University Press, 1984), 101–02. Hunter, *Industrial Power*, 1, 287.
[28] *Industrial Power*, 1, 483–84.
[29] Smith, *Fall River*, 53–54, 71.

of the 19th century many inland mills reached the limit of their local water power and added steam to expand production and ensure uninterrupted operation.[30]

A main limitation on mill size and output in the 1830s was the inefficiency of power transfer from the wooden water wheel through wooden gears, leather or canvas belts, and wooden ceiling shafts. Wooden gearing and shafts were normally lubricated with tallow, soap, or lard, occasionally mixed with black lead.[31] Substituting metal turbines only improved efficiency in the first link of this chain. As discussed in Chapter 4, cast iron shafts were heavy and could only rotate slowly. Over the middle third of the 1800s, Americans developed better machine tools and casting techniques that allowed factories to replace wooden and cast iron shafts with smaller and lighter components, and some mills adopted belt drives. Mechanics also substituted lighter lubricants, including mineral oils, which did not oxidize, gum up, or thicken with use like animal or vegetable oils.[32] Improved power transfer enabled the construction of larger factory buildings, the use of faster rotating shafts, and spindles running at higher speeds.[33]

American mill design, power generation, and power transfer changed to extract or generate more power to turn more spindles consistently at high speeds, with some improvements in fire mitigation. However, many American textile mills

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[30] Hunter, *Industrial Power*, 1, 520.
[31] Louis C. Hunter and Lynwood Bryant, *A History of Industrial Power in the United States, 1780–1930*, vol. 3 (Cambridge: MIT Press, 1991), 124.
[32] Wallace, *Rockdale*, 131. Hunter and Bryant, *Industrial Power*, 3, 124–26.
[33] Philip Scranton, *Proprietary Capitalism: The Textile Manufacture at Philadelphia, 1800–1885* (Philadelphia: Temple University Press, 1983), 18. Steve Dunwell, *The Run of the Mill: A Pictorial Narrative of the Expansion, Dominion, Decline, and Enduring Impact of the New England Textile Industry* (Boston: D. R. Godine, 1978), 24, 66–68. Hunter, *Industrial Power*, 1, 416–30, 59–71, 78.

continued to use early 19th century premises, which were antiquated and dangerous when compared with newly built factories.

Ring Spinning Rooms

The ring spinning room of the 19th century had much in common with the British mule rooms described in Chapter 4. Spinning was usually on the higher floors of the factory to place the heavy looms below. The room had wooden floorboards soaked with oil and the hot and humid air was full of cotton (or other fiber) dust. As noted, power was usually provided through gears and ceiling line shafts. The rapidly-rotating mechanisms that drove the drafting rollers and spindles produced a steady din that required workers to communicate with hand signals or by reading colleagues' lips.[34] Ring frames were usually about 5.5–6′ high, and workers might be able to see a colleague in the next row through the bobbins of roving at the top of the frame. The frames were usually arranged with only a 2′–3′gap between machines.

Reports about New England factories in the 1840s depict a similar interior environment to British mills. In the winter, the room temperature ranged from 65˚F to 90˚F, and there was very little airflow throughout the year. Ventilation during the colder months would lower the temperature and humidity, resulting in more broken ends. Manufacturers used various means to maintain high humidity, including sprinkling the floors with water and positioning water buckets throughout the rooms. In the 1880s millowners began to install humidifiers that sprayed steam or water droplets.[35] In addition to cotton dust, the air was polluted by oil lamps for work before

[34] Bill Naylor, *Lancashire Leatherneck* (Swinton: N. Richardson, 1985), 8–9.
[35] Smith, *Fall River*, 57–59. Nasmith, *Cotton Mill Construction*, 95–100.

sunrise and after sunset.[36] While many American factories outside of textiles improved lighting in the late 19th century, few New England mills were refurbished.[37] The aging premises were also made more unpleasant by infestations of rats and roaches.[38]

Workers on ring frames were occupied in four tasks: creeling, piecing, cleaning, and doffing. Operatives pieced and cleaned the machinery. Many American mills employed specialized doffers or bobbin boys and girls to creel and doff. Operatives and doffers were monitored and disciplined by overseers (or second and third hands, their assistants). Mechanics maintained, repaired, and adjusted the machinery.[39] To replace empty bobbins at the top of the frame, workers reached over the drafting rollers, lifted the old bobbin up, placed a new one, fed the roving into the rollers, and pieced it to the end of yarn from the old bobbin. When doffing, workers stopped the spindle, split the spun yarn, removed the full bobbin, replaced it with a fresh bobbin, and tied the yarn off around the base of the new bobbin. Cotton threads were thinner and harder to grasp and piece than wool. Some ring frames wound down the bobbin and had to be cranked up following doffing, using a wheel placed on the side.[40] Cleaning was constantly needed as explained previously; doffing similarly required attention to remove full bobbins of yarn expeditiously, and some strength to carry heavy boxes of yarn (later replaced with carts). As in mule spinning, coarse

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[36] Josiah Curtis, *Brief Remarks on the Hygiene of Massachusetts, but More Particularly of the Cities of Boston and Lowell* (Philadelphia: T. K. and P. G. Collins, 1849), 30, 33.
[37] Nelson, *Managers and Workers*, 16–17.
[38] Tamara K. Hareven and Randolph Langenbach, *Amoskeag: Life and Work in an American Factory-City in New England* (London: Methuen, 1979), 197–98. Blewett, *Last Generation*, 96.
[39] John Jewkes and E. M. Gray, *Wages and Labour in the Lancashire Cotton Spinning Industry* (Manchester: Manchester University Press, 1935), 12.
[40] Hareven and Langenbach, *Amoskeag*, 153–55. Blewett, *Last Generation*, 48–49.

production operated at higher speeds, which required more creeling, cleaning, and doffing. Piecing was usually more common in fine spinning.[41]

Ring tending, apart from carrying bobbins, primarily required focus and endurance rather than high-level exertion. If a thread broke and wrapped around the drafting rollers, the rollers could quickly become covered in yarn and fall off the frame, requiring the operative to stop machine, unwind the yarn, and replace the rollers before piecing and restarting the machine. Some operatives kept knives and hooks on hand to remove tangled yarn.[42] Tasks remained similar to those in the early Lowell factories, or even Arkwright's Cromford mills, but workers tended more spindles at higher speeds, requiring ample creeling, piecing, doffing, and cleaning.

Work Organization

The hierarchy and division of labor in continuous spinning changed little in this period. The largest mills employed superintendents to supervise the work of multiple spinning rooms, and overseers, second hands, and third hands to monitor the work of ring tenders, bobbin boys and girls, and doffers. The second and third hands were responsible for part of a spinning room, while the overseer managed recruitment, production, and supplies. Discipline was shared between the second or third hand and

[41] Jewkes and Gray, *Wages and Labour*, 14. Blewett, *Last Generation*, 46, 49. Doffing for coarse spinning could be three to four times as frequent as fine spinning. Ring operatives had to doff more frequently than mule spinners because ring bobbins held less yarn. Melvin T. Copeland, "Technical Development in Cotton Manufacturing since 1860," *The Quarterly Journal of Economics* 24, no. 1 (1909): 126.
[42] Hareven and Langenbach, *Amoskeag*, 55, 186.

the overseer. Smaller mills might have only one overseer or an overseer and a second hand for a single spinning room.[43]

There was more variation in the organization of American mule rooms, and more change. Some employed a self-actor minder or mule operative and one or two piecers for facing pairs of mules, like the British practice. However, others employed multiple overseers, and, instead of piecers, doffers to remove cops and 'back boys' who pieced and cleaned. The tasks of back boys were similar to those of little piecers, but these young workers were sometimes responsible for more than one pair of mules.[44]

The self-actor enabled American firms to shift the distribution of tasks and responsibilities. At first, New England mule mills hired more doffers and scavengers to remove spun yarn and clean the machinery. They also reduced piece rates because the minder was not cleaning.[45] Eventually, the overseer's or foreman's role expanded to incorporate the labor discipline of the British minder. Rather than two piecers for each minder, as in Britain, American firms only employed one back boy, which meant more work for both. By the 1880s, Fall River mills only employed one back boy for two self-actor minders, which meant more piecing for the minders. American overseers or mechanics maintained the machinery, which would have been bitterly resisted by British minders. The American foreman or overseer was paid by the piece, which incentivized him to extract as much output as possible. These changes made the work of American minders like that of British big piecers. They operated machinery and

[43] *Amoskeag*, 116, 49–51.
[44] Gross, *Industrial Decline*, 76.
[45] William Lazonick, *Competitive Advantage on the Shop Floor* (Cambridge: Harvard University Press, 1990), 125.

pieced, but were subordinate to other workers who adjusted the mules and could drive and discipline them.[46] Another staffing system on self-actors was to employ two 'joiners' on each pair of mules. These workers had responsibilities analogous to big piecers and were paid substantially less than American minders. Two joiners pieced, cleaned, and made some machinery adjustments, although these factories usually employed mechanics to make repairs.[47] Employing joiners was suitable for coarser American counts and incurred lower labor costs than paying minders and assistants.

The advent of the self-actor and the threat of replacing mules with rings allowed American managers to replace the earlier, British-derived 'subcontracting' system. The operative or minder had been largely autonomous in the maintenance, adjustment, operation, and supervision of assistants on his pair of mules, but by the late 19th century even self-actor minders in New England were subservient to overseers and subject to their demands for greater production.

Intensity: The Speedup and Stretch-out

The push for higher output from each worker was a defining feature of the period after 1840. The leading section of the New England textile industry, the Lowell system, had originated as a paternalistic, controlling enterprise with some sense of reciprocal obligations between owners and workers. However, external investors displaced the original Boston Associates during the mid-century period. These

[46] Cohen, *American Management and British Labor*, 109–11. "Workers' Control in the Cotton Industry: A Comparative Study of British and American Mule Spinning," *Labor History* 26, no. 1 (1985).
[47] Uttley, *Cotton Spinning in the United States*, 35–36.

stockholders cared about profit maximization rather than social control.[48] Increased capacity and competition across the industry drove down cotton textile prices in the 1830s and 1840s. To restore profit margins, managers at Lowell and across New England adopted labor-cost-saving strategies: the 'speedup', the 'stretch-out', and, in some mills, premiums.

The speedup was self-explanatory: managers increased the rotational speeds of machines to raise output. Using similar-quality cotton but faster-turning spindles generally required more piecing. The stretch-out required operatives to mind additional or longer machines. The Hamilton Manufacturing Company more than doubled spindleage per worker between 1840 and 1854; it operated 129 spindles per worker in 1840 and increased this to 294 per worker in 1854. Across Lowell, spindleage per worker rose by more than 60%. The third element, used in Lowell throstle and ring mills, was to pay overseers who supervised the most productive workers premiums of up to 18% of their annual earnings. This incentive system encouraged overseers to berate less productive workers, a departure from the more conciliatory early years of the Waltham-Lowell system.[49] After implementing the speedup, stretch-out, and premiums, output per worker in the Waltham-Lowell mills analyzed by Robert Layer

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[48] Gross, *Industrial Decline*, 37–38. Scranton, *Proprietary Capitalism*, 21–22. Norman Ware, *The Industrial Worker, 1840–1860: The Reaction of American Industrial Society to the Advance of the Industrial Revolution* (Boston: Houghton Mifflin, 1924), 103–04.

[49] Thomas Dublin, *Women at Work: The Transformation of Work and Community in Lowell, Massachusetts, 1826–1860* (New York: Columbia University Press, 1979), 109–12, 37. Brooke Hindle and Steven D. Lubar, *Engines of Change: The American Industrial Revolution, 1790–1860* (Washington, D.C: Smithsonian Institution Press, 1986), 201–02. Gross, *Industrial Decline*, 14. Tucker, *Samuel Slater*, 227–28. Shlakman, *Factory Town*, 98. Ware, *The Industrial Worker*, 124. Bessen argues that Lowell manufacturers implemented the stretch-out in weaving to take advantage of the higher productivity potential of experienced factory weavers. A permanent factory workforce, discussed further below, allowed for further increases in skill and output. James Bessen, "Technology and Learning by Factory Workers: The Stretch-out at Lowell, 1842," *The Journal of Economic History* 63, no. 1 (2003).

rose by nearly 49%, while daily earnings rose 4%.[50] Exit rates indicate workers' objections to rising intensity: when the Slater mills increased the demands placed on workers during the mid-19th century, turnover rose.[51]

Increasing frame sizes and spindle speeds meant that operatives had to piece more frequently, replace bobbins more quickly and frequently, and mind more spindles. The shift towards finer spinning in this period also contributed to more demands for piecing.[52] As frames expanded and workers were required to tend more spindles, workers lost the brief rest periods of the early Lowell system.[53] American mule mills also increased the size of their machinery. Initially, mule operatives had more assistants to supervise and more exertion from walking along the longer mules.[54] By the late 19th century, American overseers controlled the speed of the mules and pushed operatives and minders to work more draws per minute. At Fall River in the 1880s, four draws per minute was a standard workload.[55] Greater intensity shortened spinners' careers and may have increased absenteeism. Mule spinners walked between twenty and forty miles per day in bare feet piecing and monitoring the machine. Pushing workers to mind machinery with more frequent draws made this more intense work than British self-actor spinning.[56]

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[50] Robert George Layer, *Earnings of Cotton Mill Operatives, 1825–1914* (Cambridge: Harvard University Press, 1955), 24–27.
[51] Tucker, *Samuel Slater*, 229–38.
[52] Gross, *Industrial Decline*, 65.
[53] Dublin, *Women at Work*, 70.
[54] Gross, *Industrial Decline*, 63.
[55] Massachusetts Bureau of Statistics of Labor, "Thirteenth Annual Report," (Boston: Bureau of Statistics of Labor, 1882), 304–05.
[56] Charles Spahr, "The Old Factory Town in New England," *The Outlook*, 4 February 1899, 288.

A British visitor to American mills in 1903–4 provided detailed information on spindles per operative. His observations are summarized in Table 6.1, and show that work had become more intense across New England mills with intermittent and continuous spinning. There was variation in spindles per worker, but most frame tenders were responsible for 8–10 'sides'. The first Arkwright frames had been only 48 spindles, tended by a single operative; the first Lowell frames had 128 spindles for one operative. By the early 20th century, operatives were minding ten times as many spindles. It is not possible to estimate thread breakage rates, but checking on the status of 700 to nearly 3000 threads entailed constantly walking around the frames even if little piecing was required per spindle.[57] Workers could only relieve the stress on their feet by leaning against the walls or the machinery.[58]

Supervision & Control

Frame tenders' work had always been directed by overseers, but the relationship between workers and superiors became more adversarial in the mid-19th century. Stricter control was essential to the speedup, and the premium system established clear incentives to drive workers.[59] Pressure for higher output started with millowners' instructions to the managers and overseers who were accountable for quality of output, maintenance, and labor discipline. Underperforming managers and overseers were verbally abused, and they passed this pressure down to the

[57] Peter Maw et al., "After the Great Inventions: Technological Change in U.K. Cotton Spinning, 1780–1835," *The Economic History Review* Early View (2021): 32; Dublin, *Women at Work*, 63–64, 69; Uttley, *Cotton Spinning in the United States*.
[58] Caroline Manning, "Violations of Health Laws in Women-Employing Industries," in *Labor Laws and Their Enforcement*, ed. Susan M. Kingsbury (New York: Longmans, Green, 1911), 153.
[59] Scranton, *Proprietary Capitalism*, 27.

operatives.[60] Lowell paternalism had disappeared by the late 19th century, but companies still reserved the right to dismiss or discipline workers for conduct outside the factory, including drinking.[61]

Like the organization of work, control changed more in mule spinning than frame spinning. In the first third of the 19th century, American mule operatives exercised a similar amount of control to their British counterparts.[62] However, as outlined above, American managers and overseers changed the organization of mule spinning and directed the pace of work and adjustment of machinery by the late 19th century.[63] In the mid-century period, overseers also took control of recruitment and payment as well as discipline for mule spinning assistants. This began in some of the Slater mills in the 1840s and was copied by other manufacturers.[64] By the 1870s, even mule operatives complained of 'being driven' by American foremen.[65]

Stability of Earnings

The key factors impacting stable incomes for American spinning workers were cyclical depressions and changes to payment frequency. Important downturns occurred in 1848–52, after the Panic of 1857, and during the Civil War, when many mills halted operation entirely.[66] Mirroring British practice, American mills laid off

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[60] Nelson, *Managers and Workers*, 41–44.
[61] Gross, *Industrial Decline*, 87–88.
[62] Cohen, *American Management and British Labor*, 58.
[63] *American Management and British Labor*, 4–5. Gross, *Industrial Decline*, 57–58.
[64] Cohen, *American Management and British Labor*, 109.
[65] Massachusetts Bureau of Statistics of Labor, "Third Annual Report," (Boston: Bureau of Statistics of Labor, 1872), 399.
[66] Robert F. Dalzell, *Enterprising Elite: The Boston Associates and the World They Made* (Cambridge, Mass: Harvard University Press, 1987), 225. Tucker, *Samuel Slater*, 252. Charles Edward Person, "The Early History of Factory Legislation in Massachusetts," in *Labor Laws and Their Enforcement*, ed. Susan M. Kingsbury (New York: Longmans, Green, 1911), 55–56.

workers or operated for fewer days in slow periods.[67] Unlike Britain, though, American spinning had high turnover into the 1910s.[68] Increasing urbanization produced a larger pool of workers who moved into and out of textile employment.[69] American factory work also maintained seasonality into the 20th century: some textile mills halted operations in the summer, and the 1900 Census showed that textiles had a 10.7% variation in the size of the workforce across the year, with the trough in late summer and peak in the fall.[70] Low river levels in late summer reduced output from water-powered mills.

Information on unemployment was collected by the Massachusetts state censuses of 1885 and 1895, and the US Census of 1890.[71] These figures grouped together textile operatives in each section of production (cotton, woollen, and worsted) by gender. 35–39% of male textile operatives experienced unemployment in 1885, with an average duration of three to four months and unemployment rates of more than 10%.[72] Female operatives had unemployment frequencies 4.5 to 10.7 percentage points higher than men, depending on the branch of manufactures.[73] In a more prosperous

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[67] Stanley Edwin Howard, *The Movement of Wages in the Cotton Manufacturing Industry of New England since 1860* (Boston: National Council of American Cotton Manufacturers, 1920), 89.
[68] Gross, *Industrial Decline*, 151. Cole, *American Wool Manufacture*, II, 119.
[69] Alexander Keyssar, *Out of Work: The First Century of Unemployment in Massachusetts* (Cambridge: Cambridge University Press, 1986), 26.
[70] Stanley L. Engerman and Claudia Goldin, "Seasonality in Nineteenth-Century Labor Markets," in *American Economic Development in Historical Perspective*, ed. Thomas Joseph Weiss and Donald Schaefer (Stanford: Stanford University Press, 1994), 114–16. Burnette argues that voluntary absences also reduced earnings stability, although her data is only for weavers. Joyce Burnette, "Missing Work: Absenteeism at Pepperell Manufacturing Co. In 1883," *Cliometrica* 15, no. 3 (2021).
[71] Massachusetts is discussed here as it had the largest spinning workforce, although US Census data is available for other states.
[72] Keyssar, *Out of Work*, Table A.1.
[73] *Out of Work*, Table A.9.

year (1895) 14.6% of male and 16.2% of female operatives experienced unemployment and the unemployment rate was only 3.8%.[74]

The limited figures for specific occupations present a similar picture. Unemployment among unionized mule spinners between 1908–1914 ranged from a low of 8.4% (1912)to a high of 19.6% (1909), and was above 10% for every year but 1912. Within the year, unemployment peaked at 20% in March, June, and December.[75] Seasonal unemployment for textile workers was well below highly cyclical trades like construction, but higher than secure white-collar work.[76] In Fall River in 1895, nearly 90% of women spinning workers experienced unemployment, with a mean duration of 3.2 months. The female woollen and worsted spinning operatives of Lawrence and Lowell experienced 12% and 39.1% unemployment frequencies with mean durations of 4.9 and 3.2 months respectively.[77] Mule spinning may have involved more unstable earnings because its output was more sensitive to changes in demand, as discussed in Chapter 4.

One area of modest improvement was payment frequency. During the 1830s and 1840s, Lowell workers were paid once per month.[78] Strikes pushed a few manufacturers to provide weekly payment, but most workers only received pay at this interval after state regulation in the 1880s and 1890s. The last state to require weekly

[74] *Out of Work*, Table A.2, Table A.10.
[75] *Out of Work*, Table 3.4, Table A.5. Keyssar discusses Massachusetts' representativeness and the comparability of the 1885 data (which asked respondents for unemployment in their principal occupation) and the 1895 data (which asked about unemployment in *any* occupation): *Out of Work*, 299–306, 47–48.
[76] *Out of Work*, Table A.6.
[77] *Out of Work*, Table A.11.
[78] Abbott, *Women in Industry*, 376.

payment was Maine in 1913, and some mills continued to pay fortnightly regardless of the law.[79]

Cyclical unemployment remained a threat for spinners, but state regulation haltingly and belatedly required employers to disburse wages more regularly. There are few reports in this period of payment in non-cash mediums or the use of company stores. Stability of earnings improved modestly, largely because of regulation and strikes that forced employers to pay workers more regularly.

Wages

Most workers saw substantial real income gains after the 1860s, and there was a moderate reduction in earnings inequality across the main operative occupations (frame tenders, doffers, and mule operatives). Wages for ring tenders around midcentury were roughly 45–50¢ per day, while girl doffers were paid about 20¢ and boys around 30¢. In the same period, self-actor minders earned close to $1.40 per day. Over the following decades, the self-actor minder's wage premium fell from three times a ring tender's daily wage in 1840 to about twice the tender's wage by 1900. The threat of ring frames allowed manufacturers to squeeze wages for the senior workers in mule spinning. By contrast, spinning workers on continuous machines saw rapid

[79] Herbert J. Lahne, *The Cotton Mill Worker* (New York: Farrar & Rinehart, 1944), 28. Sarah Scovill Whittelsey and Arthur Twining Hadley, "Massachusetts Labor Legislation, an Historical and Critical Study," *The Annals of the American Academy of Political and Social Science* 17 (1901): 31–32. Pennsylvania courts blocked the state's attempts to require monthly and then twice-monthly payment in 1886 and 1887, but the legislation pushed most manufacturers towards shorter payment intervals. James Lynn Barnard, *Factory Legislation in Pennsylvania: Its History and Administration* (Philadelphia: J.C. Winston, 1907), 40–45.

increases in earnings in the first decade of the 20th century, with ring frame tenders and some doffers earning over $1 per day by 1910.[80]

Short-Term Health Risks

Accidents in spinning have been discussed extensively in Chapters 3, 4, and 5. Belts, straps, and gearing remained the main hazards. Most accidents occurred when cleaning machinery, adjusting machines by hand instead of with tools, or attempting to adjust the machinery without stopping it. Managers consistently blamed workers for accidents, and their insurers agreed. Since most mills used the same machinery and provided little guarding, owners usually saw no reason to change.[81] The Connecticut factory inspector reported in 1888 that machinery installed before c. 1870 rarely had guards over shafts and gearing, 'and the accidents to fingers and hands from being caught in these unprotected gears have been of frequent occurrence'.[82] Packing more frames into spinning rooms gave workers less space to avoid fast-moving belts and gearing.[83]

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[80] Massachusetts Bureau of Statistics of Labor, "Third Annual Report."; "Sixteenth Annual Report: History of Wages and Prices in Massachusetts, 1752–1883," (Boston: Bureau of Statistics of Labor, 1885); "Thirteenth Annual Report."; Bureau of Labor Statistics, *History of Wages in the United States from Colonial Times to 1928* (Washington: Government Printing Office, 1934). Table 6.1 provides some information about pay for mule spinning assistants, but their earnings are rarely recorded in contemporary reports.

[81] Gross, *Industrial Decline*, 68–71, 73–74. In most states employers were rarely found liable for accident compensation, similar to British situation discussed in Chapter 4. Starting with Massachusetts in 1887, states widened the scope for claims, but many accidents remained beyond the scope of a lawsuit. Whittelsey and Hadley, "Massachusetts Labor Legislation," 30–31. Fred Rogers Fairchild, "The Factory Legislation of the State of New York," *Publications of the American Economic Association* 6, no. 4 (1905): 68–69, 91–92. Employer liability for accidents is also discussed in Chapter 8.

[82] *Second Annual Report of the Inspector of Factories of the State of Connecticut for the Year Ending September 30, 1888*, (Hartford: The Case, Lockwood & Brainard Company, 1900), 9.

[83] Mark Aldrich, *Safety First: Technology, Labor, and Business in the Building of American Work Safety, 1870–1939* (Baltimore: Johns Hopkins University Press, 1997), 83.

As described above, fires were the other significant danger to short-term health. Fiber was a potential vector, but so were the floors, which were generally soaked in lubricating oil. By the late 19th century most mills had sprinklers and fire hydrants, although Connecticut factory inspectors in the late 1880s noted that automatic sprinklers were not universal and some factories still did not have fire escapes. To limit fire risks, workers cleaned steam pipes, wiped oil-soaked waste fiber from machinery, and refilled water pails placed around the factory.[84]

Regulation of occupational safety was a minor concern compared to children's work and working time. Several states required protective guards or improved fire egress from the 1870s. Massachusetts required mills to box dangerous machinery and install fire escapes, stairways, and outward-opening doors in 1877.[85] Pennsylvania legislated for external fire escapes on factories with three or more stories in 1879.[86] Compliance was inconsistent at best: in 1899, the Connecticut factory inspectors ordered more than half of textile mills to alter their premises or hygiene practices to comply with regulations. The most common orders were to guard or box belts and gears, and provide sanitary toilet facilities.[87] Even in the 20th century—and contrary to

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[84] Gross, *Industrial Decline*, 67. *Annual Report of the Inspector of Factories for 1888 (Connecticut)*, 7–8. Two other catastrophic risks were mill collapses and boiler explosions. The Pemberton Mill in Lawrence, MA collapsed and burned in 1860, killing 88 workers and injuring 275. The owners had known the mill's iron columns were faulty for years but did not replace them to limit costs. Dalzell, *Enterprising Elite*, 226. Jamie L. Bronstein, *Caught in the Machinery: Workplace Accidents and Injured Workers in Nineteenth-Century Britain* (Stanford: Stanford University Press, 2008), 44–45. Thomas R. Winpenny, *Industrial Progress and Human Welfare: The Rise of the Factory System in 19th Century Lancaster* (Lanham, MD: University Press of America, 1982), 113–14.

[85] Whittelsey and Hadley, "Massachusetts Labor Legislation," 21.

[86] Barnard, *Factory Legislation in Pennsylvania*, 25–34. This law made the property owner responsible for constructing fire escapes; it was revised in the 1880s to make firms renting space liable for compliance.

[87] *Report of the Inspector of Factories of the State of Connecticut*, (Hartford: The Case, Lockwood & Brainard Company, 1889), 10–15.

state law—Lowell spinners reported that power belts were unguarded and caused accidents.[88]

Accident statistics were only collected at the end of this period, and a report from the Bureau of Labor Statistics in 1915 using data from New York and Massachusetts summarized occupational safety in the early 20th century. Textile production had a moderate safety record among factory occupations. It was much less dangerous than the new automobile factories, but more risky than clothing factories and bookmaking. Power transmission mechanisms were still one of the most dangerous elements of factories.[89] In part because of the continued use of old premises and unguarded power transfer machinery, spinning remained a middling occupation for short-term health risks through this period, despite some improvements in fire safety and patchy adoption of boxing.

Long-Term Health Risks

As discussed in Chapter 4, British observers were aware of respiratory damage caused by inhaled fiber (especially cotton) dust in the 19th century, and byssinosis had been identified by the first decade of the 1900s. American doctors commented on the deleterious impacts of poor ventilation as early as the 1840s, but occupational health studies did not recognize byssinosis until the 1960s.[90] Reports throughout the century

[88] Blewett, *Last Generation*, 46–47.
[89] United States Bureau of Labor Statistics, "Industrial Accident Statistics," (Washington: Government Printing Office, 1915), 32, 53. The figures were not disaggregated by textile process.
[90] Jacqueline K. Corn, *Response to Occupational Health Hazards: A Historical Perspective* (New York: Van Nostrand Reinhold, 1992), 147, 53. Janet Greenlees, *Female Labour Power: Women Workers' Influence on Business Practices in the British and American Cotton Industries, 1780–1860* (Aldershot: Ashgate, 2007), 179–80.

suggest that manufacturers did little to improve conditions. In 1882, the Massachusetts Bureau of Labor Statistics inspectors commented that cotton dust 'g[a]ve everyone the appearance of having a cold'.[91] Some states required improved airflow, but even after the advent of factory inspection millowners showed little concern for ventilation.[92] British and American factories used very similar machinery and inputs, and few American mills had superior ventilation practices, so the risk of respiratory disease was probably similar.[93]

There were no large-scale investigations of carcinogenic machine lubricants in the US textile industry. The limited research on 'mule spinners' cancer' (using death records of textile workers who died of cancer) suggests that it may have been less common than in Britain. It is possible that American mills used different oils or American spinners wore more protective clothing, but both explanations are speculative.[94] Alternatively, the smaller number of mule operatives and minders may have reduced interest from public health researchers.

Working Time at Mid-Century

The working hours of American spinning employees had hardly changed from the start of the American factory system until the 1840s. While schedules varied

[91] Massachusetts Bureau of Statistics of Labor, "Thirteenth Annual Report," 224.
[92] Manning, "Violations of Health Laws," 153.
[93] For further discussion, compare Mark Aldrich, "Mortality from Byssinosis among New England Cotton Mill Workers, 1905–1912," *Journal of Occupational Medicine* 24, no. 12 (1982): Chapter 5; Janet Greenlees, *When the Air Became Important: A Social History of the New England and Lancashire Textile Industries* (New Brunswick: Rutgers University Press, 2019).
[94] Frederick L. Hoffman, "Mule Spinners' Cancer in the United States," *Journal of the American Medical Association* 90, no. 1 (1928). Frank M. Castiglione, Jr., Stuart M. Selikowitz, and Robert L. Dimond, "Mule Spinner's Disease," *Archives of Dermatology* 121, no. 3 (1985).

slightly between establishments, most were 11.5–12.5 hours per day. Some mills reduced weekly hours to 66 in the 1840s or 1850s, but raised them in periods of labor weakness, keeping 70–75 hours per week common.[95] Mealtimes were 30–35 minutes, but like British spinning workers, many employees needed to walk home to eat.[96] In the 1860s, of the establishments that reported to a Massachusetts state survey, more than three-quarters still scheduled 11-hour days, with small numbers working either 10.75 or 12 hours per day.[97] Intensification also manifested itself in fewer breaks from the 1850s.[98]

Regulation of Hours and Children's Work

Long hours were one of the main subjects of labor-management conflict in the 19th century. Workers petitioned, lobbied, and struck for shorter hours from the 1840s, aiming their protests at manufacturers and legislators, and demanding a 10-hour day.[99] This movement dovetailed with reformers' interest in factory legislation, which took a similar trajectory to that described in Chapter 4. Factory regulation was weak and ineffective for much of the 19th century: the Constitution's commerce clause kept the federal government from regulating factories and *laissez-faire* doctrine meant that states were reluctant to impose and enforce stringent rules. The first phase of state-level regulation, from the 1830s to the 1870s, aimed to limit children's work, but these

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[95] James P. Hanlan, *The Working Population of Manchester, New Hampshire, 1840–1886*, Studies in American History and Culture (Ann Arbor, Mich.: UMI Research Press, 1981), 67–74. Shlakman, *Factory Town*, 142, 84.
[96] Benita Eisler, *The Lowell Offering: Writings by New England Mill Women (1840–1845)* (Philadelphia: Lippincott, 1977), 40.
[97] Person, "Factory Legislation in Massachusetts," 99.
[98] Tucker, *Samuel Slater*, 251.
[99] Person, "Factory Legislation in Massachusetts," 24–29.

restraints were ineffective until states hired factory inspectors. Later in the 19th century, inspections probably improved compliance with the law, which reduced working hours and children's employment.[100]

Massachusetts, Connecticut, and Rhode Island placed limits on child labor from the 1830s and 1840s, capping hours and requiring that children attend school for part of the year.[101] The Pennsylvania legislature investigated child labor and factory conditions in the 1820s and 1830s, but only enacted a minimum working age and maximum hours for children in 1848.[102] This early legislation was easily evaded or avoided: laws generally allowed employers and workers to opt out of hours limits, many laws only applied to mills owned by corporations, and there were no factory inspectors for enforcement.[103] Moreover, millowners were politically influential, especially in Massachusetts and Rhode Island, and they stymied efforts to enact and enforce regulation.[104]

From the 1870s, states passed enforceable hours limits, although compliance was inconsistent. The first state to pass a 10-hour limit for all workers without the caveats described above was Massachusetts in 1874. The rest of New England followed by 1890, and New York and New Jersey capped hours at 10 per day in 1886 and 1892,

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[100] "Factory Legislation in Massachusetts," xix–xx, 4–5.
[101] Whittelsey and Hadley, "Massachusetts Labor Legislation," 10. Tucker, *Samuel Slater*, 218–21. Alba M. Edwards, "The Labor Legislation of Connecticut," *Publications of the American Economic Association* 8, no. 3 (1907): 7–10, 15–26.
[102] Barnard, *Factory Legislation in Pennsylvania*, 2–3. Some manufacturers in Delaware County flagrantly violated the law until 1853. Wallace, *Rockdale*, 392–94.
[103] John K. Towles, "Factory Legislation of Rhode Island," *American Economic Association Quarterly* 9, no. 3 (1908): 63–70, 78–85, 93–95. Cole, *American Wool Manufacture*, II, 116. Towles, "Factory Legislation of Rhode Island," 19–20, 26–27. Barnard, *Factory Legislation in Pennsylvania*, 19–22.
[104] Gross, *Industrial Decline*, 28.

respectively.[105] Massachusetts later required a half-hour meal break for six hours of work, reduced the overall hours limit to 56 in 1893, and banned night work.[106] A maximum working week of 60 hours was common in most of the Northeast by the 1900s.[107] The minimum age for work in Massachusetts was 14 by the first decade of the 1900s, and most other Northeastern states adopted this limit.[108]

However, these regulations had little effect until state governments employed inspectors to ensure compliance.[109] A 1908 investigation found that a third of New England mills still employed workers younger than the legislated limit.[110] From the 1880s Connecticut, Massachusetts, and New York established factory inspections to monitor compliance with child labor, hours, and safety regulations. At first most inspectorates were short-staffed and several could not require changes in factories or prosecute violators.[111] Enforcement probably improved at the end of the century as states employed more inspectors, and by the 1900s most factories at least complied with working time restrictions.[112] Textile factories continued to operate for relatively long hours and some may have violated working time laws, but most spinners' scheduled hours had fallen to 55–60 per week by 1900.[113]

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[105] Cole, *American Wool Manufacture*, II, 116–17.
[106] Whittelsey and Hadley, "Massachusetts Labor Legislation," 14–15, 115. Gross, *Industrial Decline*, 69. Manning, "Weakness of the Massachusetts Child Labor Laws," 163.
[107] Towles, "Factory Legislation of Rhode Island," 32–36, 42. Barnard, *Factory Legislation in Pennsylvania*, 55–58, 80, 87.
[108] Manning, "Massachusetts Child Labor Laws," 162, 64–65, 212.
[109] Barnard, *Factory Legislation in Pennsylvania*, 107–15. Whittelsey and Hadley, "Massachusetts Labor Legislation," 27–28. Enforcement and compliance were better in areas with more labor organization and public interest in labor issues. Nelson, *Managers and Workers*, 132–33.
[110] Lahne, *The Cotton Mill Worker*, 110–11. Nelson, *Managers and Workers*, 134. Massachusetts had the fewest prohibited child workers, and Maine the most.
[111] Edwards, "Labor Legislation of Connecticut," 254–59. Fairchild, "Factory Legislation of New York," 4–10, 44, 46, 48–52.
[112] Manning, "Violations of Health Laws," 153.
[113] Fairchild, "Factory Legislation of New York," 151.

Hours had remained longer than in Britain and children's employment persisted because states were slower to regulate and fund enforcement. Factory owners almost never willingly shortened hours except in periods of low demand; reductions in hours were either the result of regulation, or in some cases, successful strikes.[114] Reduced hours were an important cause of higher job quality, but improvements lagged British spinning by several decades.

Unions

The United States did not have Combination Acts, but the legal system was unfavorable to collective bargaining. In the same way that regulation was depicted as interference with free contracting, unionization was counter to individualistic American republicanism, and union members were jailed for conspiracy throughout the 19th century, primarily for striking. Some cases such as *Commonwealth v. Hunt* (1842) in Massachusetts permitted legal recognition of unions, but employers fought unions and usually found a favorable audience from judges.[115] Manufacturers responded to strikes and strike threats from the 1840s into the early 20th century by firing workers, locking out operatives before a strike, and hiring strikebreakers, especially immigrants.[116]

The most organized part of American spinning after the decline of the Philadelphia textile district in the midcentury period was in Fall River, which had many intermittent mills. Many militant British minders with an expectation of

[114] Person, "Factory Legislation in Massachusetts," 111.
[115] Christopher L. Tomlins, *Law, Labor, and Ideology in the Early American Republic* (Cambridge: Cambridge University Press, 1993).
[116] Scranton, *Proprietary Capitalism*, 33.

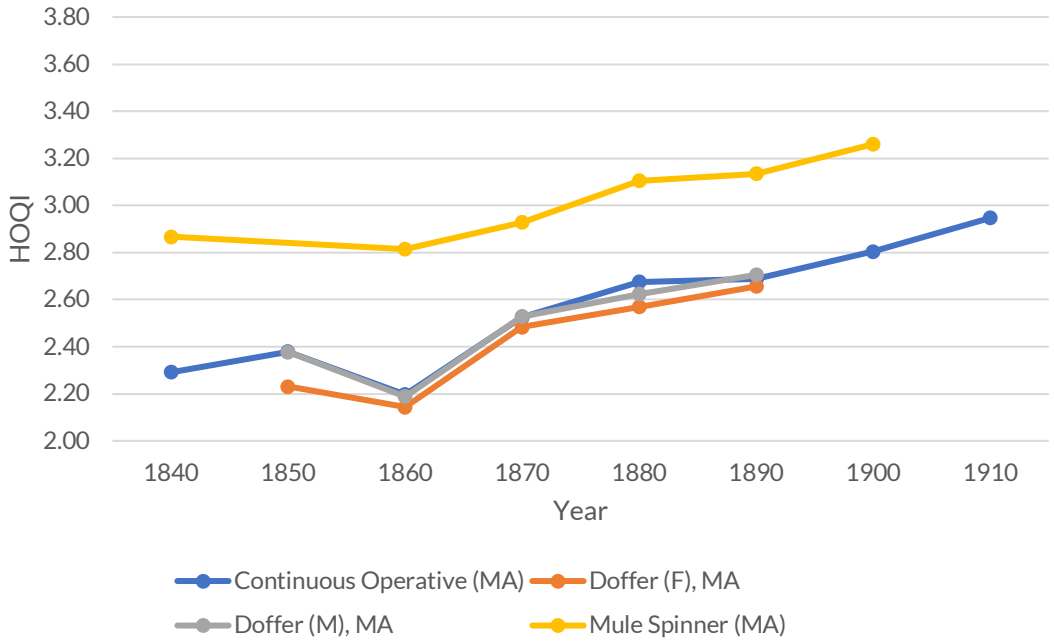
shopfloor control moved there as production expanded in the 1860s and 1870s. When managers attempted to reduce minders' wages and control of operations in the 1870s, workers struck repeatedly, but were defeated.[117] American firms' resistance to unions, including at Fall River, was buttressed by larger and more cohesive combinations. Interlocking directorships provided a stronger basis for cooperation than the smaller, competing firms of Lancashire, and groups of manufacturers generally defeated unions in strikes over wages, recruitment, and control.[118]

The textile unions that survived in the late 19th century were dominated by Irish-Americans and excluded employees from Southern and Eastern Europe.[119] The new immigrants were a large share of continuous spinning room workers because spinning was the entry-level process in most mills. As a result, spinning had low levels of unionization. While there was a general union—the United Textile Workers of America (UTW)—from 1901, it was strongest in loom fixing and weak in spinning.[120] The UTW organized funds to support striking workers in the period up to the First World War, but many industrial actions were unsuccessful, and it was riven by conflict between craft unions. Spinning was not organized enough for labor to have meaningful bargaining power, and the decline of mule spinning meant that there were not enough high-wage operatives who could combine against manufacturers.[121] American workers did not form a durable regional or national union as in Britain, and most strikes were episodic and localized. Relatively weak labor organizing and more

[117] Cohen, *American Management and British Labor*, 114–15. Lahne, *The Cotton Mill Worker*, 176–78.
[118] Cohen, *American Management and British Labor*, 119–24.
[119] Gross, *Industrial Decline*, 89.
[120] Cole, *American Wool Manufacture*, II, 124–25.
[121] Lahne, *The Cotton Mill Worker*, 189–95.

cohesive management resistance to unions is one explanation for the lack of shopfloor control in America.

Figure 6.1: Job Quality in American Spinning, 1840–1910



Sources: See Tables 6.2–6.5

Composite Job Quality

Work in American spinning improved gradually from 1840 to 1910, largely because of rising wages and statutory reductions in working time (See Figure 6.1 and Tables 6.2–6.5). A brief decline in work stability in 1860 because of the Civil War-induced cotton shortage interrupted moderate long-run improvements. However, rising wages for continuous spinning workers and shorter hours only arrived after the war, and well after manufacturers had instituted more intense working practices. Mule spinners saw their relative superiority in job quality somewhat eroded by falling wage premia and reduced control. All spinning workers experienced relatively stable occupational risks; these jobs remained moderately dangerous in the short-term and

had a high probability of respiratory ailments in the long run. Spinning work continued to be highly repetitive, with workers completing only a handful of tasks many times during a shift.

Occupational Availability

The American textile industry continued to expand through the 19th century. Inconsistent census enumeration prevents a precise calculation of employment growth, but there were 47,352 workers enumerated as spinners, bobbin boys, doffers, and carriers in the 1910 census across the 10 Northeastern states.[122] Using the operatives-per-spindle estimate for 1840 (26,000 workers) in the previous chapter would mean that the number of spinning jobs rose by about 82% from 1840 to 1910, although spinning was a much smaller share of the population and the textile workforce. There were 389,866 workers across cotton and all branches of wool manufacturing, making spinning room workers only 12% of the total in 1910. The 1910 census also included a count of machinery in 1909: there were 17,404,378 spindles in the Northeast, meaning one spinner, doffer, or bobbin boy for every 368 spindles in

[122] The 1850 and 1860 censuses collected data on manufacturing establishments and some spinning-related occupations ('manufacturers' and 'spinners'), but there were only 4525 enumerated spinners in 1850 and 7033 in 1860. These were likely counts of mule spinners and excluded most frame tenders. Some enumerators in 1860 counted cotton, woollen, or worsted 'thread' and 'yarn' establishments separately, but many spinning workers were employed in combined mills, enumerated as 'goods' establishments. 1850 US Census, Part IV, 180. 1860 US Census, Population of the United States, Recapitulation, Occupations in the United States, 656–679. There are similar problems up to the 1900 census. 1910 was the first census to enumerate spinning operatives, tenders, bobbin boys, and doffers, although some of the workers who were classified as textile 'operatives' may have been involved in spinning. Linen was a negligible industry throughout this period.

operation (compared to perhaps 100 in 1840).[123] As manufacturers assigned more spindles to each worker, employment grew more slowly than in textiles as a whole.

Occupational Distribution: Locations

New England remained the center of the American textile industry through the later 19th century. Almost 79% of Northeastern cotton workers and 63% of woollen workers were employed in the six states in 1850, and more than 82% of enumerated spinning operatives in cotton, woollen, and worsted worked in New England in 1910.[124] Most American textile production remained in mill towns, using cheap water power from turbines, although there were some challengers along the coast that used steam power to expand rapidly.[125] The most significant example was Fall River, which had more cotton spindles than any other American city by the late 1860s, surpassing Lowell.[126]

In the late 19th century competition for the lowest quality yarn emerged from the South, where there was little regulation and manufacturers could pay lower wages. Southern mills also benefitted from installing the latest equipment, while many New England mills and much of their machinery were antiquated. Some New England millowners invested in new plants in the South rather than refitting or expanding their original operations, but Southern output did not seriously threaten New England, in

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[123] 1910 US Census, Volume 4, Table II, 96–151; Volume 8 Part 6, 582, 645. See the spindles-per-worker discussion in Chapter 5.
[124] See note 122 above about census enumeration. 1850 US Census, Part IV, Tables CXCVI & CXCVII, 180. 1910 US Census, Volume 4, Table II, 96–151. Arthur Harrison Cole, *The American Wool Manufacture*, vol. I (Cambridge, MA: Harvard University Press, 1926), 274–75.
[125] D. A. Farnie, "Cotton, 1780–1914," in *The Cambridge History of Western Textiles*, ed. D. T. Jenkins (Cambridge: Cambridge University Press, 2003), 736.
[126] Smith, *Fall River*, 54.

part because of improved quality in Northeastern spinning, until after the First World War.[127]

Occupational Distribution: Age & Gender

The male share of employment increased in the United States as it had in Britain, despite diverging technical choice. The 1860 Census of Manufactures showed that men were 43% of all workers in cotton, wool, and worsted mills, and by 1910 men were a slight majority (51%) of spinning workers.[128] These trends were common across locations and parts of the textile industry: in Massachusetts, men and boys rose from 32% of workers in 1870 to 47% in 1905.[129] Women dropped from 55.4% of the total worsted workforce in 1869 to 48.1% in 1914. In woollens, adult women's share rose from 35.4% in 1869 to 39.2% in 1889 before dropping to 31.8% at the end of the period (1914).[130] While male workers were commonly employed on mules, immigrant men and boys also worked in continuous spinning.

Children's employment rose and then fell during the mid- to late-19th century. When some Massachusetts mills adopted mules to spin weft in the 1840s and 1850s, they hired more children as piecers and doffers but saved on labor costs by employing fewer adult men.[131] The continuous Waltham-Lowell mills also employed more

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[127] Gross, *Industrial Decline*, 164–65, 239. Smith, *Fall River*, 104–05. Lahne, *The Cotton Mill Worker*, 92–93, 98.
[128] 1860 US Census, Manufactures of the United States, 37–603, 1910 US Census, Volume 4, Table II, 96–151. Cf. note 122.
[129] Gross, *Industrial Decline*, 79.
[130] Cole, *American Wool Manufacture*, II, 103–04.
[131] Dublin, *Women at Work*, 140–41. See also Cole, *American Wool Manufacture*, II, 88–91. John Borden Armstrong, *Factory under the Elms: A History of Harrisville, New Hampshire, 1774–1969* (Cambridge: M.I.T. Press, 1969), 18.

children in the mid-century period to reduce labor costs during the speedup and stretch-out.[132] Factory regulations, eventually supported by inspections, reduced the share of children employed in spinning in the later 19th century. New York's factory inspectors stated that children's employment dropped by 25–30% in the year after a minimum work age of 13 came into effect.[133] Children's employment in woollen plummeted from 12.2% in 1869 to 1.7% in 1914, primarily because of regulation, while in worsted (across all occupations), it fell from 14.7% to just 4.9%. [134] By the 1910 Census, there were almost no children under 14 employed in Northeastern spinning rooms, although Maine and Massachusetts mills still employed many workers under 16 as bobbin boys or girls and doffers (more than 20% of those occupations).[135]

Occupational Distribution: Immigration

The New England mills began by employing native-born operatives, while the mid-Atlantic factories hired British immigrants (especially as mule operatives) and native-born workers.[136] As manufacturers increased intensity and discipline in the mid-19th century, native-born workers increasingly viewed factory work as only fit for desperate immigrants. Accordingly, the New England labor force became dominated by foreign-born workers.[137] New arrivals started in the lowest-paid roles, which meant

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[132] Dublin, *Women at Work*, 176–77.
[133] Fairchild, "Factory Legislation of New York," 116–17.
[134] Cole, *American Wool Manufacture*, II, 103–04.
[135] 1910 US Census, Volume 4, Table VII.
[136] Cynthia J. Shelton, *The Mills of Manayunk: Industrialization and Social Conflict in the Philadelphia Region, 1787–1837* (Baltimore: Johns Hopkins University Press, 1986), 96–99.
[137] Gross, *Industrial Decline*, 24. Scranton, *Proprietary Capitalism*, 27–28. Hanlan, *The Working Population of Manchester*, 119. Shlakman, *Factory Town*, 138–39. Cole, *American Wool Manufacture*, II, 112–15. New England women also had more attractive outside options, such as teaching, by the mid-19th century. Abbott, *Women in Industry*, 139–41, 45. Dublin, *Women at Work*, 139–40. Jonathan Prude, *The Coming of Industrial Order: Town and Factory Life in Rural*

that they became a large share of spinners first. By 1850, the Hamilton Company's spinning rooms were 78% immigrant workers, in comparison to only 24% in the weaving rooms.[138] In the 1850 census, immigrants were more than a third of operatives in the Slater mills of Webster, Massachusetts; by 1860 the figure had risen to two-thirds. In the Slater mills at Blackstone, Massachusetts, 84% of operatives were foreign-born, with 70% from Ireland.[139] There was a foreign-born majority in many New England factories by the end of the 1860s, with the Irish a majority in spinning at Lowell and many French Canadians in Western Massachusetts and Manchester factories.[140] Like the Irish and French Canadians before them, the Greeks and Poles who arrived during the Age of Mass Migration entered the spinning rooms first.[141] Immigrant workers had few alternative opportunities because of smaller local networks and lower levels of education, and reduced outside options were one reason that New England mill workforces became less transient after the 1850s.[142] Many mule operatives and minders were British and Irish immigrants until the last decades of the 1800s.[143] Mechanized yarn production in America began with the immigrant Samuel Slater, and immigrants were the majority of operatives in spinning rooms by the late 19th century.

Massachusetts, 1810–1860 (Cambridge: Cambridge University Press, 1983), 210–13. For the early 20th century, see Hareven and Langenbach, *Amoskeag*, 127–28.

[138] Dublin, *Women at Work*, 147–58.

[139] Tucker, *Samuel Slater*, 239–41.

[140] Person, "Factory Legislation in Massachusetts," 92.

[141] Hareven and Langenbach, *Amoskeag*, 21–22.

[142] Prude, *Industrial Order*, 231–32.

[143] Cohen, *American Management and British Labor*, 102, 28–29.

Conclusion

The American textile industry presented a mixed picture by the beginning of the 20th century. Comparing its origins to its destination suggests pessimism: early 20th century mills had strayed far from the original vision of the Waltham-Lowell system. Francis Cabot Lowell and the Boston Associates had hoped to create a different kind of capitalism that contrasted favorably with Lancashire's 'dark satanic mills'.[144] By the 20th century, American factories employed a permanent working class of immigrants in jobs that native workers spurned. However, these immigrants were earning far better wages than many of them could have dreamed of on the European periphery. The gender and age distribution of the early mills had also changed, as more men worked in spinning, and the age profile of the workforce shifted younger in the mid-19th century before regulation limited children's employment. The women still employed as tenders and doffers had higher wages and shorter hours than earlier generations of women textile workers, but men continued to block their promotion to supervisory roles.

In absolute terms, spinning work quality improved from the introduction of ring spinning and self-actors until the 1910s. Wages rose after the 1860s, and statutory reductions in hours eventually reached the shopfloor once states established factory inspectorates. However, improvements lagged the introduction of superior machinery and rising intensity. After manufacturers had reaped productivity gains from installing new machinery in the first part of the 19th century, they responded to falling cloth and yarn prices by driving workers to raise output, placing job quality in

[144] Gross, *Industrial Decline*, 240; Cole, *American Wool Manufacture*, II.

competition with productivity increases. Overseers and foremen exerted more control over the spinning rooms, even in mule spinning, where operatives and minders became clearly subordinate. Managers set ring tenders to work monitoring and piecing on more spindles running at higher speeds, and doffers were tasked with removing more bobbins more frequently. Substantial wage gains did not arrive for decades after the speedup and stretch-out, and millowners moved slowly to upgrade their premises and make the spinning room a safer workplace. The task range hardly changed, but managers and overseers demanded more work from operatives, which made these jobs increasingly undesirable for workers with better outside options, even though work-related wellbeing rose.

Table 6.1: Machinery per Worker in 1903–1904

Location	Machinery	Frames/Mules per tender or minder	Spindles per tender or minder	Tender or minder wages/week	Spindles per doffer or back boy	Assistants' wages/week
Lawrence, MA	Rings	8–12	640–960	$5.21–7.87	10,736	Doffers: $6.13
Lawrence, MA	Rings	6	800	$6.63	Not stated	Not stated
New Bedford, MA	Rings	Not stated	800	$4.73	Not stated	Not stated
Lowell, MA	Rings	8	832	$5.94	3000	Doffers: $6.35
Lowell, MA	Mules	2	2880	$19.22	17280	Not stated
Burlington, VT	Rings	6–10	720–1200	$5.42–7.41	2230	Doffers: $3–6
Fall River, MA	Rings	8–10	2040–2550	$7.89–9.05	2890–3188	Doffers: $6.08–6.57
Fall River, MA	Rings	10	1360	$6.63	Not stated	Not stated
Fall River, MA	Mules	2	2600	$15.14–17.13	2600 (piecers) 3900 (back boys)	Piecers: $8.07 Back-boys: $5.47
New Bedford, MA	Rings	12–13	2688–2912	$8.07–8.31	Not stated	Not stated
New Bedford, MA	Mules	2	3264	$17.13–18.23	13600 (doffers and back boys)	Back boys: $4.48 Doffers: $4.98
New Bedford, MA	Mules	1 (joiners)	1632 (joiners)	$6.08–$7.07	None (joiners doff, piece, and clean)	N/A
Northern Connecticut	Mules	2	2640	$15.14	2640–5280 (back boys) 15,840 (doffers)	Back-boys: $3–6 Doffers: $6.57 Section hands: $12.15
Northern Connecticut	Rings	8–10	720–900	$4.73	Not stated	Not stated

Source: Uttley, *Cotton spinning and manufacturing in the United States* Note: Section hands replaced power bands & adjusted mules (3 for 64 mules)

Table 6.2: Occupational Quality for Continuous Operatives (Massachusetts), 1840–1910

Year	Daily Wage ($)	CN ($)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1840	0.45	0.10	2.83	65.00	2.19	3	3	2	1	3	1	1.94	2.29
1850	0.47	0.09	2.96	60.00	2.50	3	3	2	1	2	1	1.82	2.38
1860	0.50	0.11	2.80	60.00	2.50	1	3	2	1	2	1	1.51	2.20
1870	0.95	0.15	3.15	55.00	2.81	3	3	2	1	2	1	1.82	2.52
1880	0.89	0.11	3.37	50.00	3.13	3	3	2	1	2	1	1.82	2.68
1890	0.83	0.10	3.42	50.00	3.13	3	3	2	1	2	1	1.82	2.69
1900	0.88	0.09	3.58	48.35	3.23	4	3	2	1	2	1	1.91	2.80
1910	1.36	0.11	4.04	46.85	3.32	4	3	2	1	2	1	1.91	2.95

Sources for all tables: Chapters 2, 5, 6, Appendix 1, manuscript sources in the Bibliography, Allen et al (2011), Allen (2015), UC-Davis Global Prices and Incomes Database. For Ring Tenders, Consumption Needs are scaled to 85% of an adult male basket; for Doffers, Consumption Needs are scaled to 60% (see Appendix 1). Hours/Week figures for factory workers are based on scheduled hours (described in the text) and archival evidence of average days worked per week.

Table 6.3: Occupational Quality for Female Doffers (Massachusetts), 1850–1890

Year	Daily Wage ($)	CN ($)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1850	0.18	0.06	2.44	60.00	2.50	3	3	2	1	2	1	1.82	2.23
1860	0.28	0.08	2.60	60.00	2.50	1	3	2	1	2	1	1.51	2.14
1870	0.58	0.10	3.00	55.00	2.81	3	3	2	1	2	1	1.82	2.48
1880	0.44	0.08	2.98	50.00	3.13	3	3	2	1	2	1	1.82	2.57
1890	0.53	0.07	3.30	50.00	3.13	3	3	2	1	2	1	1.82	2.66

Table 6.4: Occupational Quality for Male Doffers (Massachusetts), 1850–1890

Year	Daily Wage ($)	CN ($)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1850	0.33	0.06	2.96	60.00	2.50	3	3	2	1	2	1	1.82	2.38
1860	0.34	0.08	2.77	60.00	2.50	1	3	2	1	2	1	1.51	2.19
1870	0.68	0.10	3.16	55.00	2.81	3	3	2	1	2	1	1.82	2.53
1880	0.53	0.08	3.18	50.00	3.13	3	3	2	1	2	1	1.82	2.62
1890	0.62	0.07	3.49	50.00	3.13	3	3	2	1	2	1	1.82	2.71

Table 6.5: Occupational Quality for Mule Spinners (Massachusetts), 1840–1900

Year	Daily Wage ($)	CN ($)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1840	1.42	0.11	4.00	65.00	2.19	3	4	2	4	2	2	2.70	2.87
1860	1.60	0.13	3.97	60.00	2.50	1	4	2	4	2	2	2.24	2.81
1870	1.79	0.17	3.72	55.00	2.81	3	4	2	2	2	2	2.40	2.93
1880	1.66	0.13	3.99	50.00	3.13	3	4	2	2	2	2	2.40	3.10
1890	1.61	0.12	4.10	50.00	3.13	3	4	2	2	2	2	2.40	3.13
1900	1.87	0.11	4.47	48.35	3.23	3	4	2	2	2	2	2.40	3.26

Chapter 7
Dirt Roads to the Erie Canal: American Transport, 1750–1830

Chapter Abstract

This chapter examines the impact of the early technological changes of the American Transportation Revolution. Interurban transport in the Northeastern United States improved substantially from 1750 to 1830 as municipal roads were supplemented or replaced by turnpikes and canals, and the network of stagecoach companies expanded. The chapter describes the challenges of late 18th century transport, outlines the organization and work of infrastructure maintenance, and the limited transport services of early America. New infrastructure technologies and growth in services expanded the task range and created new occupations, some of which had high work-related wellbeing. Within occupations, improvements in job quality were largely driven by wage increases as there were few effort-saving innovations and working hours remained long. Improved connectivity, more comfortable journeys, and higher speeds dovetailed with broader economic growth to raise demand for transport services and increase transport employment.

Introduction

The low population density of the North American colonies in the mid-18th century shaped transport as well as textile production. In the 1750s, small groups of laborers and teamsters maintained rough dirt roads. Transport services for goods, mail, and passengers were rare and journeys were difficult: the few couriers and coachmen rode for long hours along rutted routes, avoiding stumps and boulders. By 1830 graveled turnpikes smoothed the way for a growing number of stagecoach companies, and canals carried millions of tons of bulk goods and thousands of passengers on more placid journeys. Travelers benefited from higher speeds and more connections, and freight rates collapsed.[1] Improved transport transformed the economic geography of the American continent and laid the groundwork for global leadership in manufacturing productivity by the end of the 19th century.[2]

Underlying these macroeconomic transformations were changes in work: the range and repetition of tasks to maintain infrastructure and operate services increased, which produced a greater division of labor. With specialization came larger differences in remuneration, work intensity, and other components of job quality. The early transport macroinventions caused little qualitative change within the same or similar occupations, and the work-related wellbeing of laborers and carpenters rose

[1] Albert Fishlow, "Internal Transportation in the Nineteenth and Early Twentieth Centuries," in *The Cambridge Economic History of the United States, Volume 2*, ed. Robert E. Gallman and Stanley L. Engerman (Cambridge: Cambridge University Press, 2000), 563–65.
[2] S. N. Broadberry, *The Productivity Race: British Manufacturing in International Perspective, 1850–1990* (Cambridge: Cambridge University Press, 1997). Gavin Wright, "The Origins of American Industrial Success, 1879–1940," *The American Economic Review* 80, no. 4 (1990). Paul David and Gavin Wright, "Increasing Returns and the Genesis of American Resource Abundance," *Industrial and Corporate Change* 6, no. 2 (1997).

because of rising wages. However, the new supervisory roles were better occupations, which produced job stratification.

American economic historians have taken an intensive interest in transportation technology, particularly its contribution to growth.[3] Wages have also attracted scholarly attention.[4] Social and labor historians have focused on other aspects, including the structure of work and unions, both with a focus on railroads.[5] Earlier technologies have received far less discussion, but their effects on wellbeing underline two key features of the relationship between technological change and jobs. First, by expanding the task range and increasing task depth, turnpikes and canals both stratified work-related wellbeing, though their effects were less dramatic than railroads. Second, these technologies present a different outcome for the race between macroinvention-enhanced productivity and demand than Chapter 3. In transportation, innovation paved the way for employment growth.

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[3] The classic debates on canals and railroads include: Carter Goodrich, *Canals and American Economic Development* (New York: Columbia University Press, 1961); Leland H. Jenks, "Railroads as an Economic Force in American Development," *The Journal of Economic History* 4, no. 1 (1944); Robert William Fogel, *Railroads and American Economic Growth: Essays in Econometric History* (Baltimore: Johns Hopkins University Press, 1964); Marc Nerlove, "Railroads and American Economic Growth," *The Journal of Economic History* 26, no. 1 (1966); Paul A. David, "Transport Innovation and Economic Growth: Professor Fogel on and Off the Rails," *The Economic History Review* 22, no. 3 (1969); Stanley Lebergott, "United States Transport Advance and Externalities," *The Journal of Economic History* 26, no. 4 (1966).

[4] Walter B. Smith, "Wage Rates on the Erie Canal, 1828–1881," *The Journal of Economic History* 23, no. 3 (1963); Mark Aldrich, "Earnings of American Civil Engineers 1820–1859," *The Journal of Economic History* 31, no. 2 (1971).

[5] Shelton Stromquist, *A Generation of Boomers: The Pattern of Railroad Labor Conflict in Nineteenth-Century America* (Urbana: University of Illinois Press, 1987). Walter Licht, *Working for the Railroad: The Organization of Work in the Nineteenth Century* (Princeton, New Jersey: Princeton University Press, 1983). Other contributions include discussions of transport's social impacts, e.g. Carol Sheriff, *The Artificial River: The Erie Canal and the Paradox of Progress, 1817–1862* (New York: Hill and Wang, 1996).

This chapter discusses the first part of the macroinventions phase of technological change in Northeastern American transport. It analyzes maintenance and service provision on roads, turnpikes, and canals from the mid-18th century to the early years of the Erie Canal. The first section describes the colonial and early republic systems for road maintenance and the development of turnpikes. The second section discusses work in road and turnpike maintenance and land transport operation. The third section outlines the history of the Northeastern canal network, and the fourth section analyzes work in canal boating and maintenance. The following chapter analyzes the most important transport macroinvention—the railroad—and its effects up to the Civil War. Chapter 9 analyzes a wide array of smaller technological changes on railroads and their impacts from 1860 to 1910.

Early American Transport

Native Americans traversed the Northeastern part of what became the United States on foot or by canoe before Europeans arrived. Canoes were normally dugouts made from a hard wood such as oak, and about 20 feet in length, although there were longer and shorter craft.[6] Many paths followed natural courses through a challenging landscape, such as alongside creeks or rivers.[7] Native American paths, on water and on land, shaped the early colonists' transport routes.

The low population density and limited market-facing economic activity of colonial North America discussed in Chapter 5 also constrained demand for

[6] Richard DeLuca, *Post Roads & Iron Horses: Transportation in Connecticut from Colonial Times to the Age of Steam* (Middletown, CT: Wesleyan University Press, 2011), 8–9.
[7] George W. Roach, "Colonial Highways in the Upper Hudson Valley," *New York History* 40, no. 2 (1959): 94.

transportation infrastructure and services. Europeans first settled along the coast and on rivers, and only moved inland after populating areas with easy water access. Colonists traveled by foot, horse, and canoe or boat, with portages to avoid waterfalls and rapids. Long-distance journeys were difficult and unpleasant, and merchants avoided moving goods overland.[8] One writer pithily commented that American roads 'furnished all the facilities for discomfort.'[9] Irregular postal service was the main means of communication in the mid-18th century. Much travel was ad hoc and non-market-facing, with travelers using their own animals and carts. There were sporadic attempts to improve internal connectivity, principally by linking the major cities—Boston, New York, and Philadelphia—with stagecoaches. Difficult land journeys along unimproved trails encouraged the use of coastal or river shipping.[10]

Early Roads

Dirt roads were the main infrastructure for early American internal transportation. These routes varied substantially in size and surface quality. Many

[8] Jane Louise Mesick, *The English Traveller in America, 1785–1835* (New York: Columbia University Press, 1922), 50. Foreign visitors were scathing about American roads in comparison with their home routes. Roger Parks, "The Roads of New England, 1790–1840" (Michigan State University, 1966), 6–7.
[9] "Roads of New England," 7–8.
[10] DeLuca, *Transportation in Connecticut*, 17. George Rogers Taylor, *The Transportation Revolution, 1815–1860* (New York: Rinehart, 1951), 56. There has been little research on colonial and early republic shipping by water, and there are hardly any primary sources that recount shipping work in this period. General secondary works include: William E. Verplanck and Moses W. Collyer, *The Sloops of the Hudson* (New York: G. P. Putnam's Sons, 1908); Augustine A. Heard, "Carriers of the Lake," *Proceedings of the New York State Historical Association* 10 (1911); John S. Curtiss, "The Sloops of the Hudson, 1800–1850," *New York History* 14, no. 1 (1933); Marvin A. Rapp, "New York's Trade on the Great Lakes, 1800–1840," *New York History* 39, no. 1 (1958). K. J. Bauer's *Maritime History of the United States* (Columbia: University of South Carolina Press, 1988) provides an overview of sectoral development and technologies, but little information about work.

roads followed old Native American paths that wound between hills and along streams or climbed steep gradients to avoid soft riverbank soil. In lightly settled areas, twisting traditional ways covered far longer distances than necessary.[11] Many 'roads' were narrow bridlepaths in the mid-18th century, even along important routes such as between New York and Boston. Surfaces with a gravel coating were 'artificial roads', and nearly all other routes were dirt roads, even the 'King's Highways' planned by colonial surveyors.[12] Dirt surfaces meant that roads were rutted at the best of times, and frequently impassible in winter or wet weather. Without graveling, carriages could sink up to their hubs in mud.[13] 'Corduroy' roads crossed swamps or low-lying areas, with logs placed perpendicular to the route and gaps filled with sand.[14] These bumpy causeways were generally just wider than a carriage, which gave the drivers little margin for error.[15] In the winter, sleds or sleighs provided smoother and more regular transport, and snowshoes were used in North America, but the ski did not arrive until the mid-19th century.[16] Land transport infrastructure was minimal, cheap, and its poor state impeded connectivity.

To build and maintain these rudimentary surfaces, the Northeastern colonies and then states used the English statute labor system (sometimes referred to in

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[11] Parks, "Roads of New England," 9–10.
[12] Charles I. Landis, "History of the Philadelphia and Lancaster Turnpike: The First Long Turnpike in the United States," *The Pennsylvania Magazine of History and Biography* 42, no. 1 (1918): 2. Oliver W. Holmes, "Levi Pease, the Father of New England Stage-Coaching," *Journal of Economic and Business History* 3, no. 2 (1931): 243.
[13] Parks, "Roads of New England," 3.
[14] DeLuca, *Transportation in Connecticut*, 23.
[15] Philip Taylor, "The Turnpike Era in New England" (Yale University, 1934), 50. Swampy conditions were common in Rhode Island.
[16] The absence of skiing is partly explained by the deep, powdery snow of North America, which was poorly suited to skis by comparison with packed Eurasian snow. Roland Huntford, *Two Planks and a Passion: The Dramatic History of Skiing* (London: Bloomsbury Continuum, 2008), 4–5, 305–07.

America as 'conscription'). It required adult male residents of a town or county to work for a specified number of days each year on the public roads under the direction of elected (and almost invariably unqualified) surveyors.[17] Compulsory work was unpopular but most Americans also disliked paying taxes for road maintenance.[18] In the mid-18th century some English parishes began to pay road laborers from local taxation, and a few American states followed in the late 1700s.[19] Residents who did not perform required labor were fined; in time, paying the fine became a way to buy oneself out of service.[20] The quality of the roads matched the amateurism of the bureaucracy and the disinterest of the workers. In addition to mud and puddles caused by poor drainage, stubborn stumps dotted the routes.[21] Colonists did not want to spend time and money improving roads for through travelers or even maintaining connections with the next town. The colonial and state governments repeatedly ordered towns to improve roads and bridges, but there was little enforcement of laws regarding road maintenance.[22]

Crossings: Ferries and Bridges

Long journeys were usually intermodal, using roads, boats, and coastal ships. Travelers crossed the many rivers in the Northeast by bridge, boat, or found a passable ford.[23] Where waterways were too wide to bridge with the technology and minimal

[17] Taylor, "Turnpike Era," 35.
[18] "Turnpike Era," 73–74.
[19] "Turnpike Era," 75.
[20] DeLuca, *Transportation in Connecticut*, 23.
[21] Taylor, *Transportation Revolution*, 15.
[22] Parks, "Roads of New England," 45–46, 48–49.
[23] Roach, "Colonial Highways," 96.

capital of the time, or where bridges could be swept away by high water, enterprising locals established ferry services. Most ferries were rafts or flat-bottom boats propelled by pole, sail, cable, oars, or a horse team.[24]

Ferries were subject to the vicissitudes of the weather, like all transport. Strong winds or currents swept them off course and ice floes crushed small craft. Most ferrymen were farmers who used boat traffic to supplement their income. Low demand meant ferries, like most colonial transport services, were itinerant. The lone ferry across the Delaware River in the mid-18th century only crossed every few days.[25] Bridges began to replace ferries from the 1760s, and ferrying shifted to wide rivers that separated major settlements such as Manhattan and Brooklyn.[26]

Bridges were rare, short, and maintained by the proximate municipality, sometimes partly funded by the colonial or state government. Early bridges had floors of loose logs or planks with a rail on one side, and were just wide enough for a single horse.[27] A common colonial bridge design used stone piers on each bank connected by two long parallel logs. It was supported by a wooden center post, and workers laid

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[24] John Perry, *American Ferryboats* (New York: W. Funk, 1957), 8–10. Taylor, "Turnpike Era," 55.
[25] Oliver W. Holmes, "The Turnpike Era," in *History of the State of New York, Vol. V*, ed. Alexander Clarence Flick (New York: Columbia University Press, 1933), 274.
[26] Taylor, "Turnpike Era," 55. Steam ferries were used around New York from 1807, although much of their traffic was intraurban and therefore excluded from this analysis. Steamboats and ferries incorporated many of the tradeoffs of steam railroads discussed in Chapter 8: higher speeds, larger hauling capacity, an expanded task range and division of labor, but also a greater risk of accidents. Kevin James Crisman and Arthur B. Cohn, *When Horses Walked on Water: Horse-Powered Ferries in Nineteenth-Century America* (Washington: Smithsonian Institution Press, 1998), 28–29. Ogden J. Ross, *The Steamboats of Lake Champlain, 1809–1930* (New York Champlain Transportation Company, 1930), 33, 47. Oliver W. Holmes, "Stagecoach Travel and Some Aspects of the Staging Business in New England, 1800–1850," *Proceedings of the Massachusetts Historical Society* 85 (1973): 41.
[27] Taylor, "Turnpike Era," 58–59.

floor planks across the two logs.[28] Many of these flimsy wooden bridges were poorly constructed and dangerous. They were swept away by heavy rains, winter ice, or buckled under the weight of a pulled load. Wood was the primary construction material because of its abundance and cheapness. Covering bridges with a roof and sides improved durability, and the availability of lumber made this option much cheaper than stone.[29] Covered bridges were floored with loose boards laid perpendicularly over long logs that stretched across the river or stream. The dark interior was lit by lamplight and some side openings.[30] Well-built covered bridges could span over 100 feet by the early 19th century, at far lower cost than a stone bridge.[31]

Travel in the Stagecoach Era

The travelers journeying bumpily over these rudimentary roads and splashing across fords were generally horse-bound or in horse-pulled coaches. Poorer travelers had to walk. Most colonial transport was itinerant and regular schedules only began in the mid-18th century. The most consistent service was the mail, although even this essential line of communication was frequently interrupted by poor road or weather conditions. While some inter-city post routes were traversed regularly, newspaper publishers and statesmen who needed communication services sometimes hired couriers individually.[32]

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[28] DeLuca, *Transportation in Connecticut*, 27. This design was suitable for rivers up to 40 feet wide.
[29] Holmes, "The Turnpike Era," 260, 74–75.
[30] Clara E. Wagemann, *Covered Bridges of New England* (Vermont: C.E. Tuttle, 1952), 12–13.
[31] E.g. *Covered Bridges*, 29.
[32] Wesley Everett Rich, *The History of the United States Post Office to the Year 1829* (Cambridge, MA: Harvard University Press, 1924), 23–25, 33–34.

Population growth and dispersion increased demand for transportation services.[33] There were several abortive attempts to establish scheduled stagecoaches along the Post Road between New York and Boston and parts of the route between New York and Philadelphia in the mid-18th century.[34] More lines appeared after the Revolution: there was a regular New York-Boston coach from 1784, a route between New York City and Albany began in 1785, and others connected Boston and Philadelphia to their hinterlands.[35] Early long-distance routes were a challenging commercial and practical proposition. The first coaching line that eventually became a sustainable business from Boston to New York frequently had no passengers in its early months.[36] Stagecoach lines were commonly associated with taverns and inns or formed by their proprietors. The coaching business brought travelers to drink or stay overnight and attracted locals to pick up mail.[37] Coaches carried passengers, luggage, some packages, newspapers, and post, although the latter two only unofficially at first as doing so competed with the colonial and then federal mail service.[38]

Throughout the Northeast the population of inland counties grew in the late 18th and early 19th century, and these new settlements stimulated demand for more and better-quality transport infrastructure. However, Americans lacked private

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[33] DeLuca, *Transportation in Connecticut*, 32–34.
[34] Eric Jaffe, *The King's Best Highway: The Lost History of the Boston Post Road, the Route That Made America* (New York: Scribner, 2010), 20–23, 29–30, 38–43, 54. William H. Benedict, "Travel across New Jersey in the Eighteenth Century and Later," *Proceedings of the New Jersey Historical Society* VII, no. 2 (1922): 100–04.
[35] Holmes, "New England Stage-Coaching," 241–42. "The Stage-Coach Business in the Hudson Valley," *The Quarterly Journal of the New York State Historical Association* 12, no. 3 (1931): 232–34.
[36] "New England Stage-Coaching," 244.
[37] Jaffe, *King's Best Highway*, 85.
[38] Oliver W. Holmes, "Shall Stagecoaches Carry the Mail? A Debate of the Confederation Period," *The William and Mary Quarterly* 20, no. 4 (1963): 557–59, 62–63.

capital for major infrastructure projects, and there was little state or federal support. The increasing volume of through traffic also generated complaints about road quality to state governments.[39] The federal government designated certain routes for the mail, but provided no funding for maintenance of these roads or enforcement of rules about surface quality.[40]

Privatization: The Turnpike Boom

An apparent solution to the transportation infrastructure problem arrived in the form of another technology and institution adopted from abroad. There were quasi-private turnpike trusts in Britain from the late 17th century, and after a 'turnpike boom' in the 1760s and 1770s, Americans followed the British example.[41] The first tolled road in the Northeast was the Philadelphia and Lancaster Turnpike, constructed in the 1790s.[42] This well-built thoroughfare connected a major city with its settled hinterland and attracted substantial traffic. As later happened on railroads, Americans adapted the turnpike to their political economy and high labor costs. A private corporation rather than a trust and lower maintenance standards were features of American turnpikes.[43]

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[39] Parks, "Roads of New England," 14, 17–19, 42. Holmes, "The Turnpike Era," 258.
[40] Parks, "Roads of New England," 44.
[41] Taylor, "Turnpike Era," 79–80. English turnpike trusts did not take profits; receipts were supposed to be reinvested in road maintenance. However, like private American turnpikes, many did not break even.
[42] There was one earlier, much shorter tolled road in the South, connecting Georgetown and Alexandria in Virginia. Frederic J. Wood, *The Turnpikes of New England and Evolution of the Same through England, Virginia, and Maryland* (Boston: Marshall Jones Company, 1919), 7. The Philadelphia and Lancaster Turnpike covered roughly ten times the distance of this road.
[43] Landis, "Philadelphia and Lancaster Turnpike " 131–32.

Turnpikes had lower construction costs per distance than canals, and enthusiasm about the financial success of the Philadelphia and Lancaster produced roughly twenty years of private road-building in New England and the Mid-Atlantic. Most tolled roads were of middling distance (15–50 miles) and raised capital from local savers.[44]

The technological and organizational development of the turnpike was modest but had remarkable results. The right-of-way was cleared, cambered (or 'crowned') for drainage, and graveled. Workers dug side ditches to keep the roadbed dry, and in some cases built stone sluices to divert water from one ditch, under the road, to another.[45] The company then constructed toll-bars and gatehouses to prevent free-riding.[46] However, high labor costs meant some turnpikes were not well-constructed and included steep gradients or poor surfaces. A few were simply claims to popular thoroughfares, and produced toll-dodging and 'shunpikes', which diverted traffic around tollgates.[47]

In addition to toll avoidance, turnpike revenues were limited by extensive toll exemptions and regulations on toll rates and gate locations. Poor construction could

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[44] Daniel B. Klein and John Majewski, "Economy, Community, and Law: The Turnpike Movement in New York, 1797–1845," *Law & Society Review* 26, no. 3 (1992): 500. Fishlow, "Internal Transportation," 550.

[45] Klein and Majewski, "Turnpike Movement," 481.

[46] Tolls and the private, profit-seeking status of turnpikes prompted opposition, see "Turnpike Movement," 486–91. Parks, "Roads of New England," 176–77, 83–84. Taylor, "Turnpike Era," 115–18.

[47] Jaffe, *King's Best Highway*, 94–95. Taylor, *Transportation Revolution*, 28. Many turnpikes were only partially completed, and because of the short distance built they were not permitted to construct a tollgate. In New York State the minimum usable distance to permit tolls was ten miles, and 60–65% of projects did not meet this threshold. Klein and Majewski, "Turnpike Movement," 481–82. For detail on shunpiking, see "Turnpike Movement," 496–98.

also make maintenance expensive.[48] A common way to reduce construction and short-term maintenance costs was to use less gravel, with predictable results for durability.[49] Companies had three incentives for maintenance: state oversight (state commissioners could prevent the company from taking tolls if the road was in poor condition), attractiveness to toll-paying travelers, and an enduringly American encouragement—the risk of lawsuits resulting from accidents.[50] Revenue constraints and shunpiking in particular made most turnpikes unprofitable, and they usually suffered financial difficulty well before competition from railroads.[51]

Despite inconsistent construction and financial troubles, American roads had improved enough by 1826 that one optimistic commentator claimed '[a]n astonishing revolution has been wrought in navigation and all modes of traveling. We now have good roads in every direction'.[52] Even turnpike skeptics acknowledged by the 1820s that road travel was far easier and faster.[53] While observers in the era of the automobile would hardly consider turnpikes good quality road surfaces, they were wider, smoother, more direct, and safer than the municipal roads they replaced.[54] Turnpike

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[48] Daniel B. Klein, "The Voluntary Provision of Public Goods? The Turnpike Companies of Early America," *Economic Inquiry* 28, no. 4 (1990): 791–94. Also Klein and Majewski, "Turnpike Movement," 499–500. Parks, "Roads of New England," 137–39.
[49] American road builders considered 'madadamizing' too costly before the invention of a stone crusher in 1858. "Roads of New England," 94, 193.
[50] Harry F. Jackson, "The Utica Turnpike Road Company," *New York History* 40, no. 1 (1959): 27.
[51] Most Northeastern turnpikes did not compete with canals. Parks, "Roads of New England," 1–2, 132–34, 50, 63–64.
[52] *American Traveller*, 5 July 1825 quoted in Holmes, "Stage-Coach Business," 256. More glowing comments are in Parks, "Roads of New England," 186–87.
[53] Klein and Majewski, "Turnpike Movement," 501–02.
[54] Taylor, "Turnpike Era," 185.

mileage declined from the 1830s, primarily because unprofitable companies ceded their routes, but some public roads were built with turnpike methods.[55]

Good turnpikes raised the speed, reliability, and comfort of passenger travel, which aided providers of transport services. The 1810s and 1820s were the heyday of stagecoaches in the Northeast. Before canals reached far into the interior, coaches were the best option for overland journeys. The growing turnpike network allowed higher speeds and improved service reliability. By the 1810s coaches operated on a schedule, and wealthy travelers could secure chartered services.[56] In Boston alone (then a city of just over 43,000), probably 60,000 people arrived or departed by stagecoach in 1820.[57]

Road connectivity improved in the early decades of the republic, but progress was fitful. The challenges of securing sufficient capital for investments in a network of good quality thoroughfares held back American transport until the first decades of the 1800s. Turnpikes provided meaningful improvements over poorly-maintained, narrow town roads and treacherous fords. Most transport services were for passenger traffic and high-value or time-sensitive items. However, the difficulty and expense of building and maintaining a smooth surface and powering journeys held back road transportation until the late 19th century, when bicycles and automobiles revolutionized personal transit.

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[55] Parks, "Roads of New England," 166–68, 74–75. More detail on low profitability is available in Taylor, "Turnpike Era," 266–80.
[56] Holmes, "Stage-Coach Business," 243–45.
[57] 1820 US Census, Return for Suffolk County, Massachusetts, 33. "Stagecoach Travel," 37.

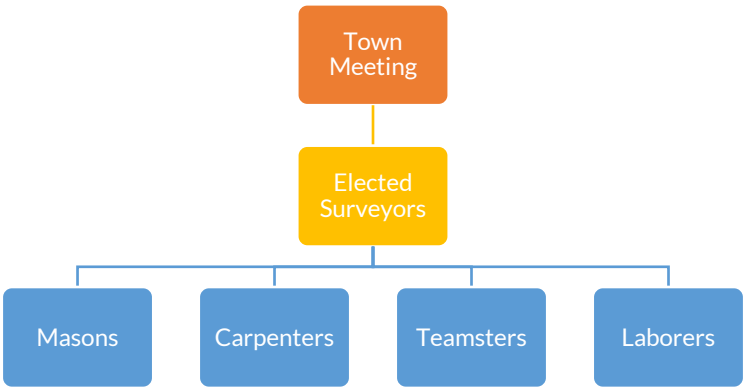
Road and Turnpike Work

There was a limited task range and division of labor in road maintenance. Most surviving payments for workers in municipal accounts were to laborers and teamsters, with some for skilled craftsmen. There was no meaningful change in the tasks or surroundings of road work across the period, and only modest change with the advent of toll roads. While good turnpikes were a major improvement over dirt roads, dramatic shifts in the content of road maintenance work only arrived with road grading machines and asphalt surfaces.

To maintain roads workers felled trees, removed large stones, cut back overgrown brush or branches, and filled in ruts or washouts. Americans patched roads with clay or saplings rather than gravel, which would have improved drainage but took time to gather.[58] Masons and carpenters primarily repaired bridges, but also some culverts. On the rare occasions that roads were graded, workers used heavy wooden plows. The plow was held down by a strong man to press it into the road surface, while another drove the animal team.[59] Unlike later transportation infrastructure work, jovial disorder—including rum consumption—was noted by some contemporaries as a part of town road maintenance.[60] Overall, work was repetitive, irregular, and sometimes tiring, but involved few occupational risks.

[58] Roach, "Colonial Highways," 101–04; Mesick, *English Traveller*, 50.
[59] Taylor, "Turnpike Era," 41.
[60] Parks, "Roads of New England," 52.

Figure 7.1: Organizational Chart of Town Road Maintenance, c. 1750



Sources: Author's elaboration.

As shown in Figure 7.1, there were few occupations required for road maintenance. Work was supervised by the surveyors, sometimes overseen by county commissioners.[61] Statute labor was usually a week per year, with modest variations over time and place.[62] Most workers were white men, although there were some children, very rarely women, and a few instances of African-American enslaved people working on roads.[63]

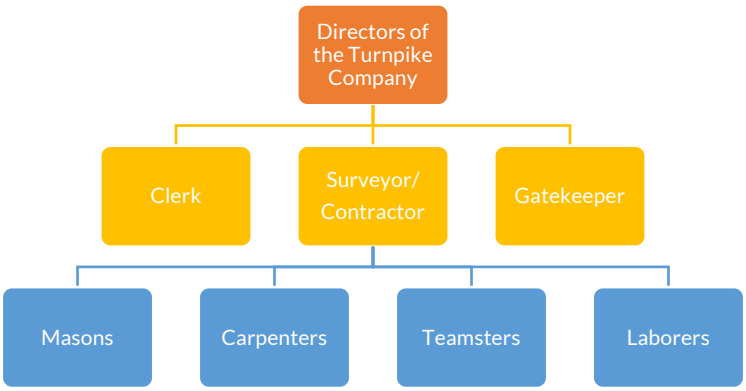
Turnpike companies, like municipalities, were required to maintain their road 'in good order', although this was poorly defined.[64] Typical tasks included 'graveling the turnpike', 'carting gravel', and 'clearing away the timber', using shovels, rakes, hoes, axes, and plows.[65] In road and turnpike maintenance, most work took place between May and October. Some turnpikes hired many workers for short stints, and others employed few workers for several months at a time. Seasons disrupted turnpike maintenance as well as transport services.[66]

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[61] DeLuca, *Transportation in Connecticut*, 21.
[62] Roach, "Colonial Highways," 99–102.
[63] Taylor, "Turnpike Era," 39.
[64] Klein and Majewski, "Turnpike Movement," 492.
[65] New Jersey State Archives, Joshua Wright Papers, PWRIG001 Box 5. Jackson, "Utica Turnpike," 21.
[66] Landis, "Philadelphia and Lancaster Turnpike," 241.

Turnpikes expanded the division of labor through a wider task range and greater task depth (repetition). To carry out the new tasks of monitoring a gate during daylight hours and collecting tolls, turnpikes hired gatekeepers. These workers opened and closed the gate, and accounted for traveler numbers and receipts on a printed account sheet or in an account book. The gate was normally a latticework barrier or a single long pole, raised by hand.[67] Scattered records of traffic suggest that gatekeepers were busiest in the summer.[68]

Figure 7.2: Organizational Chart of a Turnpike Company, c. 1800



Sources: Author's elaboration, primarily from Yale Manuscripts and Archives, Turnpikes Collection, MS 1063.

The gatekeeper lived in a structure that adjoined the road, in a purpose-built tollhouse, or sometimes the company hired the resident closest to the gate.[69] Vehicles or travelers might only appear a few times a day on poorly-trafficked routes, so it was a stable though tedious occupation with intermittent activity. There were three payment systems: commission from receipts, renting the tolls, and salaries. Surviving records are almost all for salaries, and they show low pay for gatekeepers. In recompense, turnpike companies sometimes provided land for subsistence along with

[67] Taylor, "Turnpike Era," 195.
[68] "Turnpike Era," 261, 63.
[69] "Turnpike Era," 196. To incorporate free housing, Table 7.4 reduces the gatekeeper's basket cost by 5% in line with Allen's rent share of basket cost.

the tollhouse.[70] Gatekeepers needed to watch for counterfeit and bad notes as they could be liable for the company's loss on such instruments.[71] Deficiencies in the accounts might also be deducted from their salary.[72] Almost all gatekeepers were men, but there are a few records of women taking tolls.[73] High turnover suggests that it was an undesirable occupation.[74]

Municipal surveyors usually compiled a few pages of accounts each year, listing residents who had performed required labor, fines levied, and payments to laborers or craftsmen. Turnpike administration had greater task depth in the form of repeated accounting duties. Companies had to calculate toll receipts, payments for more frequent maintenance, and disbursements to shareholders. For these tasks turnpikes hired a part-time clerk, paid a member of the board as Treasurer, or both. More frequent administrative decisions meant that most boards met monthly or bi-monthly, which was more common than town discussions of road maintenance, and directors were compensated for their time and travel.[75]

Figure 7.2 and Tables 7.1–7.3 summarize the organization and quality of work in turnpike construction and maintenance.[76] Privatization slightly increased the task range and task depth, which created new occupations. Gatekeeping was a low-quality

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[70] Parks, "Roads of New England," 142–43.
[71] Jackson, "Utica Turnpike," 26.
[72] E.g. New York Public Library, Fairchild Collection, MssCol 969, Box 6, "Rules and Regulations for the Gate Keepers of the Third Great Western Turnpike Company"
[73] For one example, see J. Orin Oliphant and Merrill W. Linn, "The Lewisburg and Mifflinburg Turnpike Company," *Pennsylvania History* 15, no. 2 (1948): note 34.
[74] Parks, "Roads of New England," 147.
[75] Taylor, "Turnpike Era," 153–54. There are few records of clerks' and directors' pay and as a result they are not included in the job quality tables. However, manuscript sources listed in the bibliography show earnings from $1/day to as much as $4/day in the early 19th century.
[76] Teamsters are excluded from the job quality analysis because payments to them frequently appear to include maintenance or rental costs of draught animals.

job, but clerks probably had moderate work-related wellbeing. For maintenance workers, tasks and job quality were little different from municipal road maintenance.

Service Providers: Post Riders and Stagecoach Drivers

Post riders ventured along paths and roads laden with letters or packages, and they were preferred to small wagons for particularly bad road conditions. Many were young men, although the title 'post boy' did not circumscribe their age.[77] Income could be irregular: newspaper subscribers were supposed to pay the rider half of the subscription price, but many subscribers paid late or not at all. The work was lonely and required long hours exposed to the elements on poor and winding roads, and riders could be victims of highway robbery. One of the few formal work rules was to announce one's arrival in a town with a horn.[78] The return to commerce after the Revolution increased package and mail volume to the limits of post riders' carrying capacity.[79] Stagecoaches began to take over deliveries when they demonstrated consistent service; they could also carry more mail and packages. Stagecoaches were at a lower risk of thefts, probably because passengers provided safety in numbers. Chapter 5 discussed how hand spinning was pushed to rural, peripheral areas after the development of factories and this phenomenon also occurred in transport: post

[77] John H. Selkreg, *Landmarks of Tompkins County, New York Including a History of Cornell University* (Syracuse: D. Mason & Co., 1894), 123.
[78] Vincent DiGirolamo, "In Franklin's Footsteps: News Carriers and Postboys in the Revolution and Early Republic," in *Children and Youth in a New Nation*, ed. James Marten (New York: NYU Press, 2009), 50, 58, 60–61.
[79] Holmes, "Shall Stagecoaches Carry the Mail?," 561.

riders were relegated to the less-trafficked inland routes when coaches displaced them on main routes.[80]

The late 18th and early 19th century coach was built of wood with some iron fittings, holding a light roof over several benches or seats, with the driver's bench at the front. Passengers entered from the front, climbing over the driver's bench, or, on later coaches, the side, and placed their luggage under the benches, at the back of the coach, or on the roof. Large wheels maintained momentum over difficult terrain. Coaching services could be faster in winter using sleighs and traveling over frozen rivers and lakes, which were smoother than roads.[81] Sleighs did not have a uniform design but were readily built by carpenters. Wagons frequently had a concave interior to prevent goods falling out, and a strong team could carry several tons.[82]

Coach drivers frequently worked for 14–18 hours a day to reach their promised destination. This meant very early starts—at least 4–6 AM for long distance routes, and sometimes earlier.[83] On the front bench of the coach, the driver was exposed to the elements no matter the season. He endured snow, sleet, and freezing cold in winter, or baking heat while beset by insects in summer.[84] Higher American labor costs meant that drivers frequently worked alone, while in Britain drivers were accompanied by a guard. This meant that drivers had to remain close to the coach to monitor the security of mail, packages, and luggage.[85]

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[80] "New England Stage-Coaching," 247.
[81] "Stage-Coach Business," 238–39.
[82] Wood, *The Turnpikes of New England*, 47–50.
[83] Holmes, "Stagecoach Travel," 54.
[84] There is an engaging description of New England drivers in John Bernard, *Retrospections of America* (New York: Harper & Brothers, 1887): 34–37.
[85] Holmes, "Shall Stagecoaches Carry the Mail?," 564. The scarcity of service personnel around American transportation enterprises was noted by Habakkuk. H. J. Habakkuk, *American and*

American drivers also did not accept tips, which appears to have produced disinterest in passenger comfort and a focus on the state of the horses and equipment. They were nonetheless expected to help women passengers into and out of the coach, while men had to climb in unaided. For a time, drivers had to announce their arrival in a town (and the arrival of the mail) by blowing a horn, which they also used when passing vehicles and calling passengers back to the coach at stops.[86] Some coaches operated in relays of 10–15 miles with drivers traveling outbound and then returning home; mail drivers continued for three or four legs. Passenger drivers were responsible for their horse teams: feeding them, maintaining harnesses, and treating minor injuries.[87] Coachmen and passengers took meals (usually breakfast, after the early start, and lunch, with dinner at the destination) at the scheduled tavern stops.[88]

Driving a coach was exhausting and required focus over bumpy roads, in the early days usually on an unsprung carriage.[89] Drivers had some administrative tasks, such as completing waybills with arrival and departure times at taverns; the driver submitted them to the proprietor to demonstrate punctuality.[90] As shown in Figure 7.3, staging involved few occupations, and usually only drivers and perhaps an agent who sold tickets were employed by the company. Most tasks—operating the carriage, loading and unloading luggage, completing paperwork—were done by the driver, who also took fares when the company did not have an agent. Blacksmiths were paid

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British Technology in the Nineteenth Century: The Search for Labour-Saving Inventions (Cambridge: Cambridge University Press, 1962), 46–47.

[86] Holmes, "Stagecoach Travel," 52–53. "New England Stage-Coaching," 270.

[87] "Stagecoach Travel," 54.

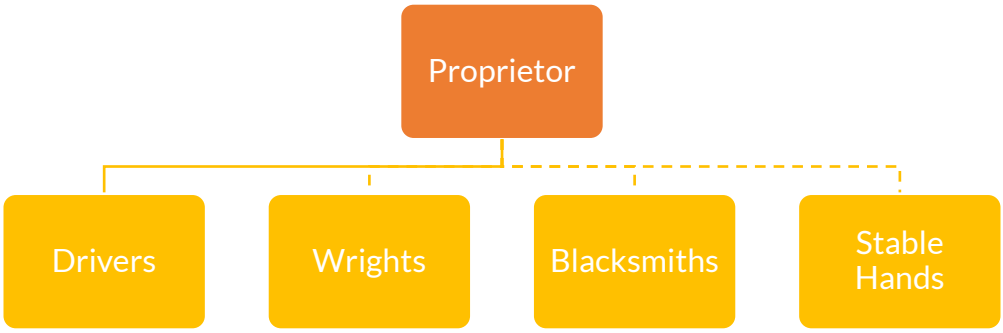
[88] "Stagecoach Travel," 56; "New England Stage-Coaching," 244–45.

[89] Carriages and wagons without suspension were less likely to overturn on bad roads. "New England Stage-Coaching," 250.

[90] "New England Stage-Coaching," 260.

piece rates for tasks such as shoeing horses, wainwrights or wheelwrights repaired coaches, and stable hands tended to the horses.

Figure 7.3: Organizational Chart of a Stagecoach Company, c. 1800



Source: Author's elaboration, primarily from Princeton University Rare Books and Special Collections, Gulick Family Papers, Box 2. (Dashed lines are for occasional piece rate workers)

There were also wagon teamsters carrying freight loads in pre-canal days. They were frequently farmers or storekeepers conveying their own goods, but there were also some dedicated waggoners, although no records of their business survive. Their work was similar to that of coach drivers, but they did not have the same rigid timetables.[91]

The risks of traveling by road may seem quaint, and evidence of accidents is not systematic, but there were dangers. Travelers might be overwhelmed while fording a high river, and vehicles could overturn after running into a stray stump. Travel became more dangerous in winter, as ruts could fill with water and freeze.[92] There were other hazards, too, such as cattle or other animals in the road. These would not be the last encounters between American vehicles and livestock.[93]

The turnpikes provided benefits to road users, but most of all to long-distance operators. Good roads and bridges made the roads and river crossings safer, enabling

[91] "The Turnpike Era," 277.
[92] Jackson, "Utica Turnpike."
[93] Holmes, "The Turnpike Era," 278–79.

higher speeds and more travel at night and throughout the year.[94] Coaches could be made lighter and sit higher above the road (instead of sturdier with a lower center of gravity), which eased the work of coachmen. Coach technology itself improved over the 1820s and 1830s, improving suspension for a smoother ride.[95] Microinventions and better infrastructure combined to make driving somewhat safer, less taxing, and, with rising demand, a more consistent employment, though drivers still worked long hours in all weather conditions.

The inchoate organization of town road maintenance and turnpike work makes estimating occupational availability difficult. However, there are records of peak turnpike mileage. By 1808 in New England 162 companies had built 2919 miles of turnpike; this grew modestly to 3764 miles owned by 242 companies in 1840, and there was little construction thereafter.[96] By roughly the same point (1807), 28 companies in New York had constructed 900 miles of turnpike; turnpiking in New York peaked in 1821, with roughly 4000 miles in operation across 270 companies. There were also 56 chartered bridge companies.[97] If each turnpike or bridge company employed one part-time clerk and a gatekeeper for every ten miles of road or a single bridge, the private road infrastructure of the Northeast would have employed more than 200 clerks and 400 gatekeepers in 1810. Tollkeepers for roads and bridges were first enumerated in the 1850 census, and there were 828 counted across the Northeast.

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[94] One drawback of higher speeds was increasing speed competition, which led to accidents. Alvin F. Harlow, *Old Towpaths: The Story of the American Canal Era* (New York and London: D. Appleton and Company, 1926), 79–80.

[95] In the 1820s and 1830s coaches used leather strap suspension because springs could not survive American roads. Holmes, "Stagecoach Travel," 41, 50–51.

[96] Parks, "Roads of New England," 68.

[97] Holmes, "The Turnpike Era," 267–68. Pennsylvania's turnpike mileage peaked much later, in 1830, but turnpiked milage was declining in other states by this point.

The 1860 and 1870 censuses reported similar numbers of toll takers (895 and 817); 1880, the final census in which they were enumerated, reported a slight decline to 647.[98] Drivers were also enumerated in 1850 and 1860, although their large number (6746 in 1850 and 11886) probably included short-distance operators on intraurban routes. All of these figures were a substantial advance over the minimal operative and administrative personnel employed in colonial transportation.

Accurately estimating the number of maintenance workers is impossible as repair demands varied widely between roads, and companies' accounts may be incomplete. At one extreme, the 10th Massachusetts Turnpike, which stretched about 35 miles from Sandisfield to Canaan, recorded payments for 230 days of maintenance in 1811 and 290 days in 1812. At the other extreme, records of the Mohawk Turnpike & Bridge Company in New York show 34.5 days of maintenance in 1802, 5.5 days in 1803, and 5.5 in 1804 on its road, which covered nearly 13 miles.[99]

New infrastructure and services increased the task range and division of labor (see Tables 8.1–8.3), albeit only modestly. Later, microinventions enabled by better infrastructure slightly improved work for transport operators. In line with broader

[98] 1850 US Census, Table L, lxvii—lxxix. 1860 US Census, Occupations in the United States, 656–679. 1870 US Census, Volume 3, Table XVIII, 812–823. 1880 US Census, Volume 1, Table XXXIII. Clerks working in transport were not enumerated until 1870, and then only railroad clerks were specifically counted. The plank road boom of the late 1840s and 1850s may explain the much higher number of gatekeepers counted in 1850 than the 1810 estimate. See Daniel B. Klein and John Majewski, "Plank Road Fever in Antebellum America: New York State Origins," *New York History* 75, no. 1 (1994).

[99] Yale University Manuscripts & Archives, Account books collection, MS 29 Series I Box 77 Folders 404–413. New-York Historical Society, Mohawk Turnpike & Bridge Co. Collection, AHMC - Mohawk Turnpike and Bridge Company. The Mohawk Turnpike & Bridge Company's distance is not stated in its records, but it paid for work at two locations 12.8 miles apart (near Hirkimer and St. Johnsville, NY).

economic growth, increasing transport connections benefitted from and spurred greater demand to move products and people, increasing job availability.[100]

Canals and River Navigations

The principal limitation of road transport was friction from the surface, and the power constraints of draught animals kept loads small. Water transport at low speeds required less power for the same weight. There had been proposals for canal construction and even a few surveys in the 17th and 18th centuries, but there was no substantial construction until after the Revolution.[101] Americans recognized the value of inland waterways during the British canal building era of the late 18th century.

Early American Canals

In the first decades of the American republic there was much interest in internal improvements at the state and federal levels. Canals, like roads, could bind state markets together and promote unified American republicanism.[102] The most ambitious expression of this movement was the Gallatin Report of 1808, which proposed several trans-Appalachian water routes and coastal canals to protect shipping.[103] By the mid-1790s there were 30 canal companies in eight states, but construction was slow, and these projects were short-distance, narrow canals. Like

[100] There is a discussion of turnpikes' contribution to growth in Parks, "Roads of New England," 84–87.
[101] Harlow, *Old Towpaths*, 6–7.
[102] Ronald E. Shaw, *Canals for a Nation: The Canal Era in the United States, 1790–1860* (Lexington: University Press of Kentucky, 1990), 18–23, 28–29.
[103] *Canals for a Nation*, 23–24. Harlow, *Old Towpaths*, 40–42.

turnpikes, many were abandoned before completion.[104] Most early canal projects linked or improved the main rivers of the Northeast, including the Susquehanna, the Delaware, the Hudson, and the Connecticut River. Further south, there was a quixotic project to build a canal from the Potomac to the Ohio River.[105]

The most successful early route was the Middlesex Canal, which connected the Mystic and Merrimack Rivers in Massachusetts. It was chartered in 1793 and, after spurts of construction, finally opened in 1803.[106] It carried traffic between Boston and developing towns to the north, including Lowell and Nashua, New Hampshire, and generated particularly high revenue in the late 1820s and 1830s.[107] Nonetheless, it was exceptional. A more typical example was the attempt to canalize New York's Mohawk River. The State of New York permitted the Western Inland Lock Navigation Company to build a canal on the Mohawk in 1792, but it was poorly capitalized for the task. The company cleared channels on placid parts of the river and built locks around waterfalls, but its components, particularly the wooden locks, were flimsy.[108] There were also complaints about high tolls and travel was frequently hampered by inconsistent water levels, which were also partly caused by cheap construction. The company never completed its original plan and failed in the 1790s.[109]

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[104] Shaw, *Canals for a Nation*, 3; Christopher Roberts, *The Middlesex Canal, 1793–1860* (Cambridge: Harvard University Press, 1938), 3.
[105] Shaw, *Canals for a Nation*, 3–9.
[106] *Canals for a Nation*, 11–13.
[107] Roberts, *Middlesex Canal*, 169–70.
[108] The Middlesex Canal experienced problems with wooden locks but persisted with them until 1825 despite the need for frequent repairs. Shaw, *Canals for a Nation*, 13. Roberts, *Middlesex Canal*, 110–11, 84.
[109] Julius Rubin, "An Innovating Public Improvement: The Erie Canal," in *Canals and American Economic Development*, ed. Carter Goodrich (New York: Columbia University Press, 1961), 21–23. Elkanah Watson, *History of the Rise, Progress, and Existing Condition of the Western Canals in the State of New-York* (Albany, 1820), 63.

More extensive and higher-quality infrastructure was only built after the first decade of the 19th century. As in the textile industry, the War of 1812 was a crucial juncture. The Non-Importation Act, Embargo, and War stimulated the development of a mechanized textile industry, and the difficulty of east-west transport during the conflict emphasized the importance of trans-Appalachian infrastructure. High transport costs and slow services were a national security issue as well as a constraint on growth.[110]

The Erie Canal

The transformational leap of the first phase of transport development in the antebellum period was a political achievement as much as a technological one. The standalone canal was not a new development. Building one for more than 360 miles across lightly populated central and western New York—the longest artificial waterway outside of China—was a remarkable feat.[111] The major challenge for east-west American transport was topography. At every point bar one between Maine and Georgia, travel from the East Coast to the interior required crossing the Appalachian Mountains. The single gap lay on the Hudson-Mohawk River route, which had been discussed as the potential course for an artificial waterway since the first half of the 18th century.[112] New York was drawn into a long-distance canal project in part by the

[110] Harlow, *Old Towpaths*, 42–43.
[111] Despite the settlement efforts of the Military Tract, central and western New York remained lightly populated in 1820. See Ronald E. Shaw, *Erie Water West: A History of the Erie Canal, 1792–1854* (Lexington: University Press of Kentucky, 1966), 5–6.
[112] Rubin, "An Innovating Public Improvement: The Erie Canal," 17.

promise of federal support in the Gallatin Report. When constitutional and sectional objections blocked a federal subsidy, the state chose to build the canal alone.[113]

The Erie Canal was constructed between 1817 and 1825, and sections were opened for traffic before the full canal was complete.[114] It proved a spectacular success even before it was finished, and this route to the interior established New York City's ascendency among the East Coast cities.[115] The Erie and a network of state-constructed branch canals soon put many turnpike companies, especially longer ones that connected central and western New York to the Hudson, out of business.[116] Surviving turnpikes connected peripheral locations to the canals, much like post riders had been pushed to marginal routes by stagecoaches.[117] However, coaches continued to operate in Central and Western New York when speed or all-season transport was needed before the advance of railroads.[118]

Work in Water Transport

Workers moving goods and occasionally people on American waterways experienced some similar conditions to their land-based counterparts, including exposure to the elements and long hours. On natural waterways, goods traveled in boats, rafts, and arks. From the 1750s, long, narrow 'Durham' boats carried freight on

[113] "An Innovating Public Improvement: The Erie Canal," 35–36, 42–51
[114] Shaw, *Erie Water West*, 101–03. Harlow, *Old Towpaths*, 57–58.
[115] Shaw, *Canals for a Nation*, 45.
[116] Holmes, "The Turnpike Era," 268.
[117] Klein and Majewski, "Turnpike Movement," 504.
[118] Holmes, "Stage-Coach Business," 246. See also the amusing (if occasionally fanciful) account of the Erie in Jacob Abbott, *Marco Paul's Voyages & Travels, Erie Canal* (New York: Harper, 1852).

the Delaware River, propelled by sails, poles, and oars.[119] Rafts were sometimes lashed together and arks were linked and hinged to provide safety in groups. Raftmen steered using long oars. At the end of a journey, the wooden craft were broken up and sold as lumber. Makeshift vessels were displaced in the 1830s by permanent canal-type boats that travelled up and down slack water navigations or canals.[120]

Artificial waterways saw a similar technological trajectory: early boats were frequently not specialized, poorly built, and took on water, but in time boating became professionalized with dedicated canal boats and boat companies.[121] By the 1820s, some companies owned multiple boats, though individual ownership continued. For example, there were 512 individually-owned boats and 68 boats owned by three boat companies on the Schuylkill Navigation in 1833.[122] Early boats were cramped, with the Middlesex Canal limiting boats to 75 feet long by 9½ feet wide.[123] The Erie was much wider and allowed for bigger boats; the largest of them just fit inside the 90′ x 15′ lock dimensions.[124]

Boatmen were paid on a time-rate basis (more common for boat companies), or per trip completed (more common on individual boats).[125] However, wages were not necessarily paid monthly, and could be paid only at the end of the season—or not

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[119] Brooke Hindle and Steven D. Lubar, *Engines of Change: The American Industrial Revolution, 1790–1860* (Washington, D.C: Smithsonian Institution Press, 1986), 111.
[120] Chester Lloyd Jones, *The Economic History of the Anthracite-Tidewater Canals* (Pennsylvania: University of Pennsylvania Press, 1908), 13–14.
[121] Harlow, *Old Towpaths*, 327. Almost no records of boat companies have survived.
[122] Jones, *Anthracite-Tidewater Canals*, 131.
[123] Roberts, *Middlesex Canal*, 136. Canal widths, and most importantly lock sizes, generally increased on new or expanded canals in the 18th and 19th centuries.
[124] Shaw, *Erie Water West*, 201–02.
[125] Jones, *Anthracite-Tidewater Canals*, 82.

at all.[126] In New York and much of the Northeast the boating season began in March or April and ended in November, sometimes later on more southerly routes.[127] Boatmen pushed their luck in the early winter, taking as many journeys as possible until an overnight freeze halted progress, which could come partway through a trip. Some canals were drained in the winter, so the crew had to unload the remaining cargo.[128]

Most canal boats carried freight, with variations in goods consignments by route. Agricultural products, coal, stone, lumber, and some high-bulk or fragile manufactured goods were standard coastbound shipments. Traffic headed inland was more difficult to obtain.[129] Boats also transported many passengers, including westward immigrants, in the early 19th century.[130] Passenger traffic in 'packet' boats was most common over long routes such as the Erie, which had more demand for travel to the interior. A journey from Albany to Buffalo took four to six days, and packets accommodated 40–100 passengers.[131]

Freight boatmen loaded and unloaded their bulky products at harbors along the route before casting off and moving away under animal power. Boats might have to enter a weigh lock near a terminus, where canal employees measured the boat's laden weight and compared this to its empty weight to compute the freight embarked and fees due. Toll offices checked boat paperwork periodically to ensure that the toll

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[126] Harlow, *Old Towpaths*, 328. There are reports of canal boatmen abandoning their boats because of low pay in the 1820s and 1830s. Jones, *Anthracite-Tidewater Canals*, 82–83.
[127] Princeton University Special Collections, Robert Anderson Family Papers, C1230 Box 3.
[128] Harlow, *Old Towpaths*, 308–09.
[129] Roberts, *Middlesex Canal*, 138, 41.
[130] Harlow, *Old Towpaths*, 117–20.
[131] Shaw, *Canals for a Nation*, 48, 178. *Erie Water West*, 206–10.

had been paid and the contents were as described.[132] The boat captain navigated through traffic and kept the vessel under the speed limit, which was commonly four miles an hour to prevent wakes from eroding the banks.[133]

The slow pace of canalling meant that boaters worked long, monotonous hours, and frequently had to cook meals and eat in motion. On boats with only two hands, the steersman and driver alternated roles. At mealtimes, the former scrambled back and forward between a stove in the middle of the craft and the tiller at the stern to adjust the course. Monotony and endurance of mind and legs were the main challenges, although bursts of strength and activity were needed to avoid collisions and when loading or unloading.[134] When canal boats were delayed by breaches in the artificial waterway, boatmen waited behind a temporary dam or carried goods and baggage to wagons that transported passengers, luggage, and merchandise to the other side of the damaged section.[135]

Draught animals were the main sources of propulsion, though sails and poles were sometimes used on early boats.[136] After horses or mules had become ubiquitous for power, boats generally kept a long pole on hand to push the craft away from obstacles and to negotiate lock entrances.[137] Inventors tested steam power, horse treadmills, and other methods to achieve higher speeds than usual (which for freight was only 1–2 mph). However, mules and horses remained the primary power source

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[132] Sheriff, *Artificial River*, 140–41.
[133] Harlow, *Old Towpaths*, 58. Speed regulation was prompted by packet boats tearing down canals at the breakneck rate of five miles per hour.
[134] *Old Towpaths*.
[135] Peter L. Bernstein, *Wedding of the Waters: The Erie Canal and the Making of a Great Nation* (New York: W.W. Norton, 2005), 333.
[136] Shaw, *Canals for a Nation*, 15, 188.
[137] Harlow, *Old Towpaths*, 315.

as their modest pace prevented damage to the banks. The inexpensive earth base of a canal limited speeds and prevented innovation.[138]

The main occupational risk for boatmen was being thrown overboard by striking a bridge as the boat passed under it. Bridges were built so low on the Erie that the crew and passengers had to lay down on the deck or go below. Unlike passengers, the crew were used to bridge drills and gave signals when approaching an obstacle. Towropes could also pose a risk, but again these were more likely to catch out passengers than crew. Canals were channels of disease, carrying smallpox and cholera to workers along their length. Still water in the canal or in adjoining feeder reservoirs also provided breeding grounds for mosquitoes. Boating was repetitive, especially on the two 'long level' sections of the Erie Canal, which stretched more than fifty miles without a lock.[139]

When a boat needed to descend, boatmen brought the boat into the lock, the lock tender closed the rear doors, and opened the sluices to release water. This occurred with the boat a few inches from each side of the stone lock walls, and damage to the gates could result in fines for boatmen. Upward boats carried out the opposite operation, entering before the lock tender closed the gates and opened the sluices on the higher end of the lock.[140] To pass a boat traveling in the opposite direction, one boat's team slowed to drop its towrope into the water and allowed the other boat to

[138] *Old Towpaths*, 321–26. Different propulsion systems are discussed in H. Boynton, *History of Steam on the Erie Canal* (New York: Evening Post Steam Presses, 1873).
[139] Shaw, *Canals for a Nation*, 178–80, 92. *Erie Water West*, 223–24.
[140] Harlow, *Old Towpaths*, 315.

pass, with the latter's rope held above the first boat. In case of emergency, boats were eventually required to keep a knife on board to cut towropes.[141]

The fierce American religiosity of the 19th century intruded on canal work: Sabbatarians attempted (sometimes successfully) to prevent lock operation on Sundays.[142] Safety was also a consideration for limits on operation: the Middlesex Canal restricted locking to daylight hours and moonlit nights, and canals generally limited nighttime mooring to designated basins. However, on the busier Erie, traffic continued through the night if lock tenders kept opening and closing the gates.[143] Some boats placed a light on the bow, but not all, and collisions were a risk when traveling at night.[144] Specialized boats rarely sank on canals, but packet boats occasionally caught fire from lamps used to light the interior.

Sinkings or swampings were most common where canals intersected with rivers. There were usually 'guard locks' on each side of the natural watercourse to prevent water overflowing into a canal, but high water levels and fast currents in the river could hold up boats. If a canal boat with an anxious captain trying to avoid a costly delay attempted to cross the fast-flowing natural water section, only expert piloting and a strong (perhaps doubled) team could prevent the boat from being swept away down the river to disaster, as sometimes happened on the Erie's intersection

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[141] Shaw, *Canals for a Nation*, 187. *Erie Water West*, 236.

[142] Harlow, *Old Towpaths*, 334–35; Shaw, *Canals for a Nation*, 194–96. Following pressure from temperance advocates, in 1833 the New York Canal Commissioners prohibited contractors and land-based workers from consuming spirits, but this restriction was impossible to enforce. *Erie Water West*, 225–28.

[143] Roberts, *Middlesex Canal*, 137. Harlow, *Old Towpaths*, 318.

[144] A night collision is described in Cornell University Rare Books and Manuscripts, Stevens vs. Gilbert legal documents, MS 1129m. One boat was traveling on the wrong side of the canal without a light around dusk and it collided with another boat, which sank.

with the Mohawk River. Rapids and currents were a danger for any boatmen using slack water navigations.[145]

Canal boating expanded the division of labor (Figure 7.4): Erie passenger boats had a captain, steward, helmsman, bowsman, cook, cabin boy, and driver, with several boats overseen by a superintendent.[146] The crew of a packet boat slept in a small compartment in the bow that was separated from the passengers' sections. On a passenger boat, the cook served the evening meal from the kitchen at the stern, and the steward or cabin boy prepared the cabin beds, generally stacked three or four high.[147] While some of these roles, such as that of the cook, brought tasks that had previously been performed by stationary workers (in taverns for stagecoaches) into the canal boat, boat operations required more hands. Even the smallest craft had at least two boatmen, and freight boats could have five or six hands: two drivers, two men on the tiller ('helmsmen'), a cook, and a deckhand or 'bowsman'.[148] This division of labor was much greater than the stagecoach businesses that relied on a single driver to direct the carriage.

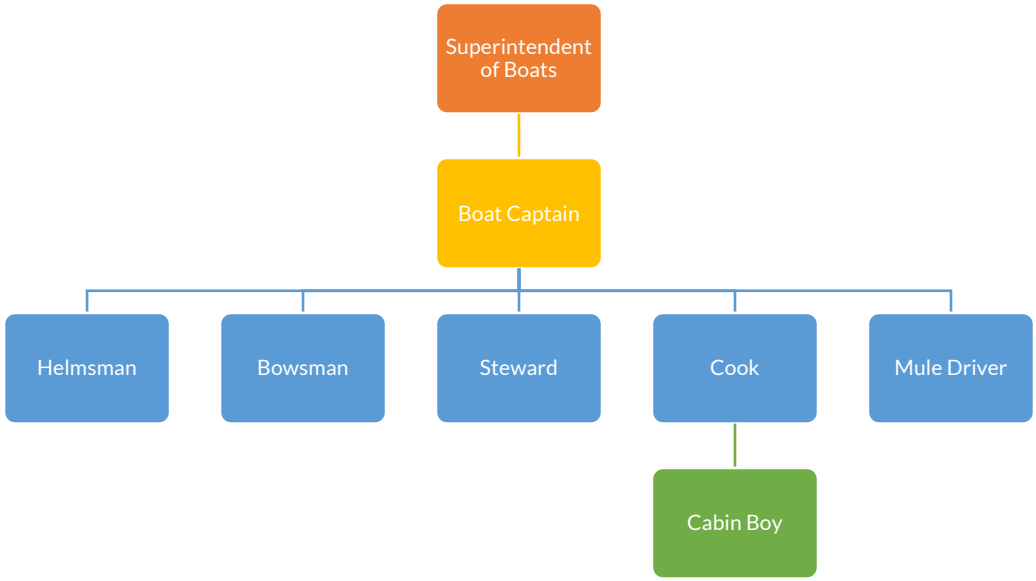
While earlier transport employees were almost exclusively adults, thousands of boys and a few girls, frequently runaways, found employment on canals, primarily as drivers for draught animals. The animals they monitored were usually mules; oxen were powerful but too slow even for canals.[149] Drivers were well-paid for child workers but did not receive education and captains frequently abused them.[150]

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[145] Harlow, *Old Towpaths*, 141, 312–13.
[146] Shaw, *Erie Water West*, 197–98.
[147] Harlow, *Old Towpaths*, 345–46.
[148] *Old Towpaths*.
[149] *Old Towpaths*, 321. Sheriff, *Artificial River*, 141.
[150] Shaw, *Erie Water West*, 229. *Canals for a Nation*, 187.

Violence also occurred between boat crews, particularly if they were competing for a place in line at a lock. Fighting skills were prized by captains, and battles between crews could cause serious injuries.[151] Pugnacity was likely increased by the tendency for boatmen to indulge in liquor. Cheap whiskey, applejack, rum mixed with molasses (called 'blackstrap'), and other strong beverages were readily available.[152]

Figure 7.4: Organizational Chart of the Erie Canal Navigation Company, c. 1820



Source: Elaboration from Cornell University Rare and Manuscript Collections, Simon Newton Dexter Papers, 753.

Canal Maintenance

Land-based workers were responsible for the constant endeavor of keeping the canal in functioning condition. The worse the original construction, the more immediate and frequent remediation was needed. Poor design, such as low banks for fear of insufficient water, led to canals overtopping the towpath in heavy rains.[153]

[151] Harlow, *Old Towpaths*, 318–19.
[152] *Old Towpaths*, 330. The culture of work on the Erie Canal is discussed in Lionel D. Wyld, *Low Bridge! Folklore and the Erie Canal* (Syracuse: Syracuse University Press, 1962).
[153] Charles Rufus Harte, *Connecticut's Canals* (New Haven: Connecticut Society of Civil Engineers, 1938), 22.

Locks were particularly troublesome, as wooden doors or dry masonry joints demanded regular repairs.[154]

Climate was as important in canal repairs as other parts of transport work. At the end of the season on canals that were drained to avoid ice damage, workers stopped feeders and left open gates or sluices to release water. To prepare for reopening in the spring, they cleaned the dry canal, removing debris, digging out sandbars, relining the canal walls with clay (although this became less important as the walls hardened), while masons repaired locks and aqueducts.[155] The start of the season also required repairs to towpaths and embankments eroded by winter weather. Freshets were a particular problem: they could produce weeks or months of work and delay journeys or destroy boats.[156] Spring was usually the most disrupted season because of snowmelt and accumulated damage from the winter. Burrowing animals could also perforate embankments, and the Middlesex Canal offered rewards for catching rodents near the canal.[157]

The risks to a canal of a breach—destroyed embankments and a cessation of traffic, possibly for weeks—were much greater than common road damage. As a result, canals employed workers to monitor the waterway's condition. While government officials had occasionally inspected roads, towpath walkers were permanent employees. They checked that sluices let out the right amount of water, viewed locks, dams, and aqueducts for weakness or damage, and noted eroded banks

[154] *Connecticut's Canals*, 28.
[155] Harlow, *Old Towpaths*, 309.
[156] Shaw, *Erie Water West*, 238.
[157] Harlow, *Old Towpaths*, 310.

for repair. Towpath walkers' sections could be up to ten miles long, and inspections were required every operational day.[158]

When a towpath walker or boatman found a breach, the canal company sent a party for rapid repairs. First, workers blocked off the water on each side by driving tall tongue-and-grooved planks perpendicular to the bed as a primitive coffer dam. With the water flow reduced, workers then drove pairs of stakes into the area of the breach, parallel to the canal, tied the stakes with rope, and filled the area with straw. Once this barrier had been secured, the workers added more planking and soil or stone to rebuild the bank.[159]

Like turnpike gatekeepers, lock-tenders were frequently provided with accommodation.[160] Their work was also dull and repetitive, but more taxing. Opening and closing lock doors and sluices was more strenuous than working a turnpike gate. Hours were longer, particularly on busy routes: lock tenders could work for up to eighteen hours when boats needed locking during the night, and return to work just before dawn.[161] On the Erie, they were expected to pay an assistant out of their wages to ensure that locking could continue round the clock.[162]

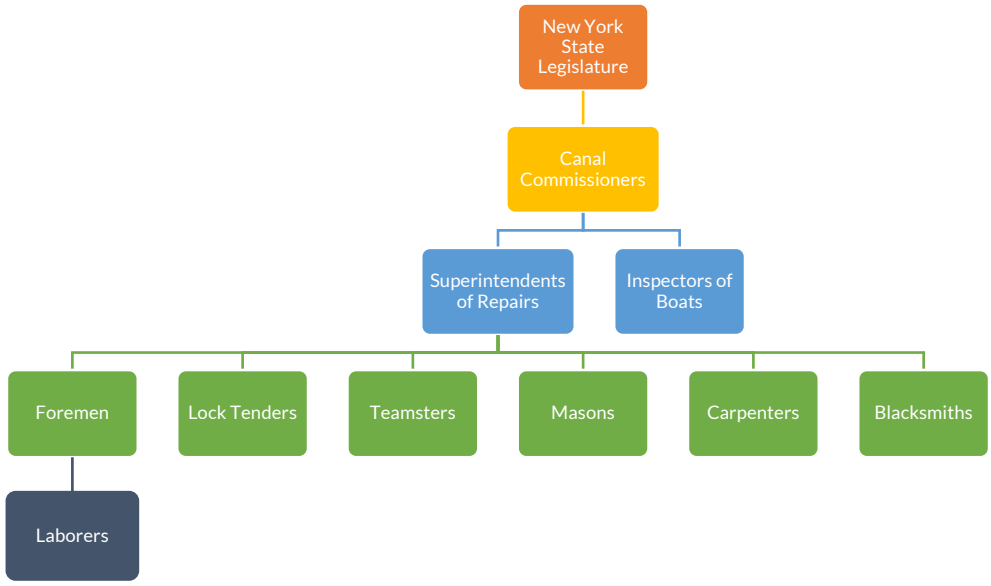
The Erie's payrolls record payments to many laborers, but also craftsmen, teamsters, and supervisory workers such as foremen and the men with general responsibility for upkeep on specified sections of canal, the superintendents. Superintendents oversaw maintenance for 25-mile sections and helped boats that

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[158] *Old Towpaths*, 310–11.
[159] *Old Towpaths*, 311.
[160] Table 7.7 follows the procedure explained above in note 69 for adjusting the Lock Tender's basket.
[161] Harlow, *Old Towpaths*, 315–16.
[162] Shaw, *Erie Water West*, 247.

confronted ice floes or other impediments. They were supposed to monitor the canal's status and direct operations in case of a break. Foremen hired laborers, directed work, and compiled labor accounts for the superintendent's approval.[163]

Figure 7.5: Organizational Chart of the Erie Canal, c. 1830



Source: Elaboration from New York State Archives, Comptroller's Office Abstracts for Canal Expenditures, A0013 and Shaw, *Erie Water West*.

For most employees, canal work was hard labor, and on the Erie, ten-hour days were standard until 1870.[164] The scale of canals meant that more supervisory employees were required to oversee the construction and maintenance of this infrastructure, and these workers enjoyed higher pay and safer, less strenuous conditions, as summarized in Tables 7.5–7.9 and Figure 7.5. Real wages were modestly higher than in turnpike work, but this was balanced by slightly greater health risks and lower control.

Canals' advantages for hauling bulk goods rapidly drew in workers. By the completion of the Erie Canal in 1825, it already employed 8000 people.[165] The American

[163] *Erie Water West*, 238. Smith, "Wages on the Erie Canal," 299.
[164] "Wages on the Erie Canal," 300.
[165] Shaw, *Erie Water West*, 182.

Bethel Society claimed that 30,000 people were working on the Erie in 1846, including 8000 children, but they may have exaggerated to emphasize the problem of child canal labor. State registrations of canal boats show about 3400 vessels in 1853, which could have employed at least 10,000 workers in service provision alone.[166] More reliable statistics are available in the Census, which counted 17,892 'persons in navigation of canals, lakes, and rivers' across the Northeast in 1840, and 19,783 'boatmen' in 1850.[167] The 1860 census counted 16,928 boatmen and 2316 'canalmen', and 14,520 and 3242 in the analogous categories for 1880.[168] While some boatmen may have been employed outside of canals, canal maintenance and boating provided far more employment than road transport. Occupational segregation in the transport sector continued through the canal age: these roles were almost invariably filled by white men.[169]

Conclusion

The first phase of transport innovation in the United States saw generally modest investments to connect cities and regions. Slowly expanding networks for land and water transport supported growth and development, and, in the realm of work,

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166 Sheriff, *Artificial River*, 139. There were 10,982 enumerated 'boatmen' in New York in the 1850 Census. 1850 US Census, Table L, lxvii—lxxix.

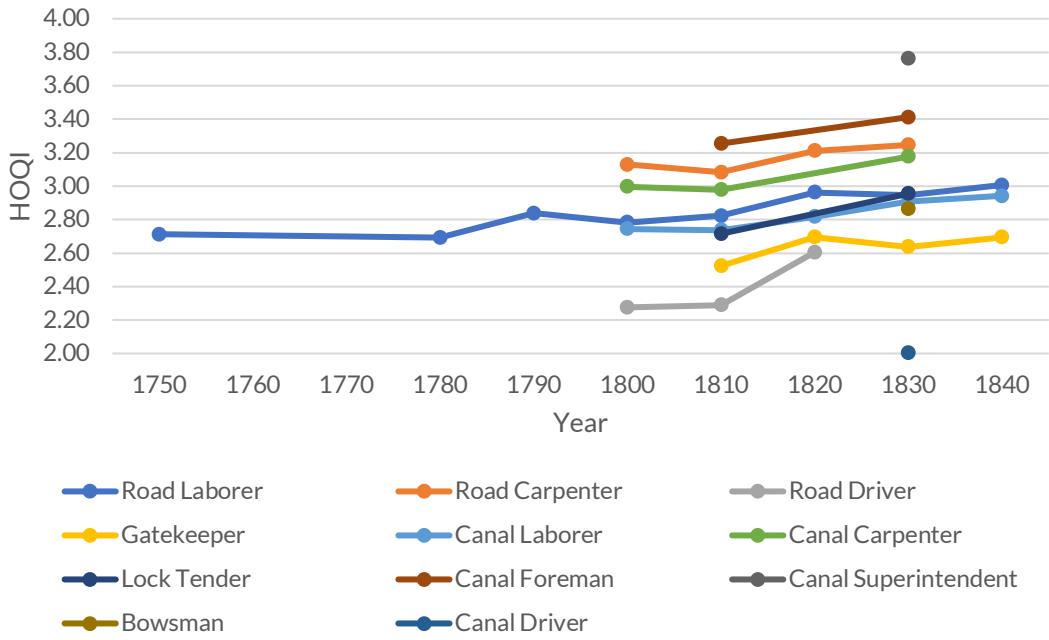
167 1840 US Census, Compendium of the Sixth Census, 6–31, 360. 1850 US Census, Table L, lxvii—lxxix.

168 1860 US Census, Occupations in the United States, 656–679. 1880 US Census, Volume 1, Table XXXIII. The 1870 census inexplicably recorded five times as many 'canalmen' in Pennsylvania as the 1860 or 1880 Census. No other states showed similar variation.

169 New York State Archives, New York State Comptroller's Office Abstracts, Check Rolls, and Vouchers for Canal Expenditures, A0013 Box 9. There were some women employed on canals, but they were exceedingly rare. In 1812, Elizabeth McNeel was paid $50 for six months' service in as a toll taker on the Morris Canal in New Jersey. Princeton University Special Collections, Samuel L. Southard Papers, Box 135, Folder 13. Only 1.5% of 'Boatmen, Canalmen, pilots and sailors' in New York were enumerated as 'Colored' in 1890. 1890 US Census, Volume 1, Table 116.

they began to stratify job quality, as shown in Figure 7.6. New technologies expanded the task range and in some cases task depth (Tables 8.1–8.3), which led employers to increase the division of labor. Turnpike companies collected revenue and required more accounting, so they hired gatekeepers and clerks. Canal maintenance demanded more craftsmen to repair locks, foremen to oversee more workers, new roles such as towpath walkers to inspect infrastructure, and superintendents to coordinate maintenance across long stretches of artificial waterway. Canal boats needed workers to drive the animal team, man the helm, assist with loading and unloading, and tend to passengers' needs.

Figure 7.6: Job Quality in American Transport, 1750–1840



Sources: See Tables 7.1–7.10

Some occupations remained low-quality, such as driving a canal animal team or manning a turnpike gate. Most improvements in job quality were driven by rising wages, rather than effort-saving technology or shorter hours. A few new occupations were well-paid, secure, and safe, such as canal superintendents, but most of the

workers in canal maintenance were laborers until late in the 19th century. Along with a widening variety of occupations there were substantial increases in job availability in the transport sector, although nearly all occupations were limited to white men. Moderate employment growth, some new roles, and incipient stratification in the early 19th century were only the first job transformations wrought by the industrialization of transport in the United States. The next phase introduced the key general-purpose technology of the Industrial Revolution, steam power, to land transport.

Table 7.1: Occupational Quality for Road Laborers, 1750–1840

Year	Daily Wage (d/$)	CN (d/$)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1750	20.00	4.74	2.65	45.00	3.44	1	4	4	2	3	1	2.14	2.71
1780	0.49	0.12	2.65	45.00	3.44	1	4	4	2	3	1	2.14	2.69
1790	0.66	0.10	3.11	45.00	3.44	1	4	4	2	3	1	2.14	2.84
1800	0.61	0.12	2.79	45.00	3.44	2	4	4	2	2	1	2.24	2.78
1810	0.77	0.13	2.92	45.00	3.44	2	4	4	2	2	1	2.24	2.82
1820	0.80	0.09	3.37	45.00	3.44	2	4	4	2	2	1	2.24	2.96
1830	0.76	0.09	3.31	45.00	3.44	2	4	4	2	2	1	2.24	2.94
1840	0.86	0.09	3.52	45.00	3.44	2	4	4	2	2	1	2.24	3.01

Sources for all tables: Chapters 2, 7, Appendix 1, manuscript sources in the Bibliography, Allen et al (2011), Allen (2015), Smith (1963), UC-Davis Global Prices and Incomes Database. Notes: Wages and Consumption Needs in Table 5.1 are denominated in d for 1750. Hours/Week figures for infrastructure maintenance use 10-hour days and estimates or archival evidence of average days worked per week. Hours/Week figures for service providers are described in the text. Missing decades are those for which there is no wage data. The Driver's Consumption Needs for Table 7.10 are scaled to 60% of an adult male basket.

Table 7.2: Occupational Quality for Road Carpenters, 1800–1830

Year	Daily Wage ($)	CN ($)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1800	1.19	0.12	3.64	50.00	3.13	2	4	4	3	2	2	2.70	3.13
1810	1.16	0.13	3.48	50.00	3.13	2	4	4	3	2	2	2.70	3.08
1820	1.10	0.09	3.93	50.00	3.13	2	4	4	3	2	2	2.70	3.21
1830	1.20	0.09	4.06	50.00	3.13	2	4	4	3	2	2	2.70	3.25

Table 7.3: Occupational Quality for Coach Drivers, 1800–1820

Year	Daily Wage ($)	CN ($)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1800	0.38	0.12	2.62	72.00	1.75	2	3	4	3	2	2	2.57	2.28
1810	0.44	0.13	2.67	72.00	1.75	2	3	4	3	2	2	2.57	2.29
1820	0.63	0.09	3.43	72.00	1.75	3	3	4	3	3	2	2.94	2.61

Table 7.4: Occupational Quality for Gatekeepers, 1810–1840

Year	Daily Wage ($)	CN ($)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1810	0.34	0.13	2.51	72.00	1.75	4	5	5	3	4	2	3.66	2.52
1820	0.43	0.09	3.06	72.00	1.75	4	5	5	3	4	2	3.66	2.69
1830	0.35	0.09	2.86	72.00	1.75	4	5	5	3	4	2	3.66	2.64
1840	0.41	0.08	3.06	72.00	1.75	4	5	5	3	4	2	3.66	2.69

Table 7.5: Occupational Quality for Canal Laborers, 1800–1840

Year	Daily Wage ($)	CN ($)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1800	0.68	0.12	3.04	52.50	2.97	3	3	4	2	2	1	2.29	2.74
1810	0.73	0.13	3.01	52.50	2.97	3	3	4	2	2	1	2.29	2.74
1820	0.64	0.09	3.29	52.50	2.97	3	3	4	2	2	1	2.29	2.82
1830	0.84	0.09	3.62	52.50	2.97	3	3	4	2	2	1	2.29	2.91
1840	0.88	0.09	3.75	52.50	2.97	3	3	4	2	2	1	2.29	2.94

Table 7.6: Occupational Quality for Canal Carpenters, 1800–1830

Year	Daily Wage ($)	CN ($)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1800	1.04	0.12	3.52	52.50	2.97	3	3	4	2	2	2	2.57	3.00
1810	1.09	0.13	3.46	52.50	2.97	3	3	4	2	2	2	2.57	2.98
1830	1.25	0.09	4.20	52.50	2.97	3	3	4	2	2	2	2.57	3.18

Table 7.7: Occupational Quality for Lock Tenders, 1810–1830

Year	Daily Wage ($)	CN ($)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1810	0.96	0.13	3.53	72.00	1.75	4	4	4	3	3	2	3.24	2.72
1830	1.28	0.09	4.55	72.00	1.75	4	4	4	3	3	2	3.24	2.95

Table 7.8: Occupational Quality for Canal Foremen, 1810–1830

Year	Daily Wage ($)	CN ($)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1810	1.00	0.13	3.52	60.00	2.50	4	5	5	4	3	3	3.91	3.25
1830	1.00	0.09	4.06	60.00	2.50	4	5	5	4	3	3	3.91	3.41

Table 7.9: Occupational Quality for Canal Superintendents, 1830

Year	Daily Wage ($)	CN ($)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1830	1.92	0.09	5.24	60.00	2.50	5	5	5	4	3	3	4.06	3.76

Table 7.10: Occupational Quality for Canal Boatmen, 1830

Occupation	Daily Wage ($)	CN ($)	*w*	Hours/ Week	Wkg. Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
Bowsman	0.77	0.09	3.90	84.00	1.00	3	4	5	2	2	2	2.80	2.87
Driver	0.38	0.05	3.63	84.00	1.00	3	4	5	1	2	1	2.22	2.01

Chapter 8
Transport Under Steam:
American Railroads, 1830–1860

Chapter Abstract

This chapter analyzes the introduction and development of railroads, which became the main mode of interurban transport in the 19th century. It describes the key elements of railroad technology, workplaces, and the main occupations available in railroading. Steam traction over iron rails increased the range of tasks involved in maintaining infrastructure and providing transport services. To carry out this wider range of tasks spread across hundreds of miles of track, railroads further increased the division of labor, which raised the inequality of work. This extends an element of the Chandler (1977) analysis of the firm to occupational quality, as many of the new jobs were for white-collar workers who earned higher salaries in safer employment. The chapter also outlines how Americans adapted railroad technology to their local conditions and illustrates innovation's role in the race between productivity and job quality.

Introduction

By 1830, Americans had begun to link together the vast expanse of their country with transportation infrastructure. As the first boats headed along the Erie Canal, inventors were experimenting with horse-pulled railroads, and Americans soon heard of the success of Britain's Stockton & Darlington Railway. Just as they had adopted turnpikes and canals, American inventors and entrepreneurs seized the opportunity to increase the speed and carrying capacity of land transport using steam traction. While canals required a greater division of labor than road and turnpike maintenance and operation, the railroad increased the task range and specialization far more. Railroads demanded more skilled manual workers to repair and operate locomotives and cars. Train control to keep services on time and prevent accidents required men to communicate orders and set switches. Maintaining rails, roadbeds, and structures required laborers and craftsmen. Increased task depth in accounting, financial management, and strategic decision-making demanded a corporate bureaucracy. Railroads were the fundamental organizational break that produced the impersonal corporation.[1]

Despite specialization to mitigate inefficiency and accidents, railroading was dangerous. These new risks were not equally distributed across the growing workforce: managers enjoyed high pay and safe work, but enginemen, firemen, and above all brakemen worked in some of the most dangerous jobs in 19th century America. Not only were jobs in the 'running trades'—the railroaders' term for the men

[1] Alfred D. Chandler, *The Visible Hand: The Managerial Revolution in American Business* (Cambridge: Harvard University Press, 1977). Glenn Porter, *The Rise of Big Business, 1860–1910* (Crowell: New York, 1973).

who operated the trains—dangerous, but some of the most dangerous occupations had the lowest pay and worst conditions.

The first two sections outline the development of railroading in mid-century America and elements of railroad technology. The railroad was a macroinvention with many constituent parts: the roadbed, rails, rolling stock and its components, power and braking mechanisms, and train control systems were all shaped by microinventions. Railroads developed systems for determining which innovations suited their conditions and adopted differing technologies.[2] The middle sections outline railroad premises and key groups of railroad occupations. Several thematic sections then set out common elements of job quality on the railroad, highlighting the many hazards faced by railroaders and discussing pay, working time, and supervision. The final sections synthesize railroad job quality and discuss the increasing availability but continuing segregation of transport work.

Early American Railroading

The forerunners of steam railroads were systems for transporting coal from the pithead to rivers in Northeast England. By the 17th century, coal wagons on flanged wheels were pulled by workers and animals on raised wood or stone rails. In the 1700s gravity, animals, and stationary steam engines pulled wooden or metal-wheeled wagons over rails that were increasingly topped with cast iron. These short routes were known variously as 'plateways', 'railways', and 'tramways', with slow service

[2] Steven W. Usselman, *Regulating Railroad Innovation: Business, Technology, and Politics in America, 1840–1920* (Cambridge: Cambridge University Press, 2002), 63–75. This chapter and Chapter 9 necessarily compress heterogeneity between railroads.

and modest hauling capacity. Rail-based transport was transformed spectacularly in the 19th century with the application of steam power. George and Robert Stephenson's success in locomotive building and on the Stockton & Darlington and Liverpool & Manchester Railways showed that steam traction on metal rails was technically feasible and commercially viable.[3]

Americans followed the progress of the British railroad pioneers and adopted British methods quickly in the 1820s and 1830s. Inventors like John Stevens experimented with metal rails and steam traction. American miners built railroads that used animal-pulled wagons and inclined planes driven by stationary engines to move stone and coal. Other mine railroads used gravity power, with filled wagons moving downhill attached to a rope that pulled empty wagons upward.[4] The first project with extant work records is the Mine Hill & Schuylkill Haven Railroad in eastern Pennsylvania, built between 1828 and 1831 to carry coal 13.5 miles to the Schuylkill Canal. It was cheaply constructed, which soon became common practice on American railroads, with sharp curves and untrussed stringer bridges.[5]

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[3] Darwin H. Stapleton, *The Transfer of Early Industrial Technologies to America* (Philadelphia: American Philosophical Society, 1987), 123–24. James E. Vance, *The North American Railroad: Its Origin, Evolution, and Geography* (Baltimore: Johns Hopkins University Press, 1995), 5. A more detailed description is James D. Dilts, *The Great Road: The Building of the Baltimore and Ohio, the Nation's First Railroad, 1828–1853* (Stanford: Stanford University Press, 1993), 81–90.
[4] John F. Stover, *American Railroads* (Chicago: University of Chicago Press, 1961), 3. Chester Lloyd Jones, *The Economic History of the Anthracite-Tidewater Canals* (Pennsylvania: University of Pennsylvania Press, 1908), 15–16. *The First Railroad in America: A History of the Origin and Development of the Granite Railway at Quincy, Massachusetts*, (Boston: Walton Advertising & Print Co., 1926).
[5] Jules I. Bogen, *The Anthracite Railroads: A Study in American Railroad Enterprise* (New York: The Ronald Press Company, 1927), 12–13. Douglas J. Puffert, *Tracks across Continents, Paths through History: The Economic Dynamics of Standardization in Railway Gauge* (Chicago: University of Chicago Press, 2009), 98. Hagley Library & Museum, Reading Company Records, 1520 B-809.

The first interurban railroad in America was the Baltimore & Ohio, which began construction in 1828. Railroads proliferated in the early 1830s and rail links, most of which were 80 miles or shorter, were constructed between cities across New York, New England, and Pennsylvania. Railroad construction responded to economic conditions, and the regional focus shifted over time. The contraction of 1839–1843 curtailed new construction and halted building on the 'trunk' routes that would link the eastern seaboard to the Midwest, with all short of their final termini on Western waters. When construction resumed in the 1840s, New England was the center of building.[6] In the 1850s, Americans built new railroads in the more peripheral states of Maine, New Hampshire, and Vermont, and the east-west routes finally crossed the Appalachians. The Pennsylvania Railroad connected Philadelphia to Pittsburgh when the spectacular Horseshoe Curve at Altoona was completed in 1855, and Cornelius Vanderbilt consolidated several small lines into the New York Central to link New York with Chicago in the 1850s. Further south, the Baltimore & Ohio reached the Ohio River at Wheeling, West Virginia in 1853.[7] Most long journeys still required changing trains or shifting freight between cars of different railroads, and travelers or shippers had to cross some rivers by ferry, but by the eve of the Civil War there were multiple routes from the eastern seaboard to the growing cities of the Midwest.

[6] Albert Fishlow, *American Railroads and the Transformation of the Antebellum Economy* (Cambridge: Harvard University Press, 1966), 6–8.
[7] Stover, *American Railroads*, 38–43.

Rails and Roadbeds

American railroad building appeared cheap by comparison with the British model. British railroads made the roadbed as straight and level as possible, hiring hundreds or thousands of laborers to excavate and embank soil. On top of the roadbed, workers placed stone blocks and metal brackets ('chairs') to hold the iron rails in position.[8] A few early American railroads followed British practices, but they faced very different conditions. Low population density meant lower traffic volumes, and the terrain was more challenging. Labor, especially skilled labor, and capital were more expensive, but, as noted in Chapter 7, wood was very cheap, so it was used extensively for bridges, stations, and parts of rolling stock. Double-tracking through thinly-settled areas was unprofitable, so most railroads used single track. Since extensive grading required heavy expenditure on labor, American railroads had sharper corners that followed the terrain and steeper gradients.[9] Railroads also economized on supports under the rails: they adopted a flexible substructure of light gravel ballast to cushion the rails under cheap wooden ties, which were less expensive than metal chairs and stone blocks.[10] However, low-quality American roadbeds caused

[8] Colleen A. Dunlavy, *Politics and Industrialization: Early Railroads in the United States and Prussia* (Princeton: Princeton University Press, 1994), 208. Vance, *North American Railroad*, 52–53. Brooke Hindle and Steven D. Lubar, *Engines of Change: The American Industrial Revolution, 1790–1860* (Washington, D.C: Smithsonian Institution Press, 1986), 136–37.
[9] Albert J. Churella, *The Pennsylvania Railroad* (Philadelphia: University of Pennsylvania Press, 2013), 114; Mark Aldrich, *Safety First: Technology, Labor, and Business in the Building of American Work Safety, 1870–1939* (Baltimore: Johns Hopkins University Press, 1997), 17–20. Ellis L. Armstrong, Michael C. Robinson, and Suellen M. Hoy, *History of Public Works in the United States, 1776–1976* (Chicago: American Public Works Association, 1976), 108–09; H. J. Habakkuk, *American and British Technology in the Nineteenth Century: The Search for Labour-Saving Inventions* (Cambridge: Cambridge University Press, 1962).
[10] Vance, *North American Railroad*, 46–47.

rails to sink during the spring melt, and frozen ground in winter damaged rolling stock and rails.[11]

Another design to reduce construction costs replaced all-iron rails with wooden rails topped by strap iron, 2.5 inches wide and a little more than half an inch thick, with the two elements linked by spikes.[12] At joints, the ends of straps could curl up under heavy rolling stock, punching a hole through the bottom of a railcar. Engineers quickly realized that an all-iron rail in a T-shape was a superior design and rolled iron rails were common for new construction by the second decade of American railroading, but strap rail remained in use in the Northeast until at least the 1840s.[13] Low-quality American iron manufacturing meant that early all-iron rails were produced in short sections, which increased the chances of derailment because every meeting point between rails could throw rolling stock off the tracks if the joint was not smooth.[14] The weight of rails gradually increased to provide a more stable and durable platform over the 1840s and 1850s, although there were continuing problems with poor iron and stress from heavy traffic.[15] Heavier rails meant harder work for maintenance crews, but, with good quality iron, less frequent repairs and fewer accidents. Wooden ties exposed to all-season weather deteriorated rapidly, which allowed the rails to flex, causing derailments and accidents. Railroads preferred locust,

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[11] John H. White, *Introduction of the Locomotive Safety Truck* (Washington: Smithsonian Institution, 1961), 118.
[12] Fishlow, *American Railroads*, 5. John B. Jervis, "A Memoir of American Engineering," *Transactions of the American Society of Civil Engineers* VI (1877): 50.
[13] Stover, *American Railroads*, 21–24. Vance, *North American Railroad*, 54.
[14] Michael Duffy, "Rail Stresses, Impact Loading and Steam Locomotive Design," *History of Technology* 9 (1984): 43–47.
[15] Thomas Weber, *The Northern Railroads in the Civil War, 1861–1865* (New York: King's Crown Press, 1952), 6. Ann Marie Scanlon, "The Beginnings of the New York Central Railroad: A Study of Men, Money, and Materials" (Ph.D., Syracuse University, 1981), 56–57.

cedar, oak and pine for their durability, but used whatever wood they could find. There was no treated wood in the mid-19th century, but railroads experimented with chemical processes, such as infusing wood with zinc chloride, to lengthen the life of ties.[16]

Bridge construction remained crudely empirical: until the 1850s, few engineers calculated the loads that these structures could tolerate.[17] Wooden bridges saved on expensive iron or stone as well as skilled labor, and railroad builders used timber as a key building material for bridges until the 1860s even though wooden bridges could rot and fail.[18] As in other aspects of railroad technology, American managers frequently preferred low-cost, higher-risk approaches.[19] Reform only arrived after a campaign by civil engineers that will be discussed in the next chapter.

Rolling Stock

Locomotives and cars on American railroads rapidly departed from British practice to handle lower-quality rails and roadbeds. Each component was extensively developed by railroad engineers and outside inventors across the 19th century to increase speeds, reduce derailments, and enable railroads to carry more traffic. Some changes, like the addition of the locomotive cab or the leading truck, improved conditions for workers by providing shelter or preventing accidents, but others simply

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[16] Weber, *Northern Railroads*, 6. Stapleton, *Early Industrial Technologies*, 147–48.
[17] Churella, *Pennsylvania Railroad*, 123.
[18] Armstrong, Robinson, and Hoy, *Public Works*, 108–09. On the ubiquity of wood in 19th century America, see Nathan Rosenberg, *Technology and American Economic Growth* (New York: Harper & Row, 1972), 27–31.
[19] Mark Aldrich, *Death Rode the Rails: American Railroad Accidents and Safety, 1828–1965* (Baltimore: Johns Hopkins University Press, 2006).

enabled faster running or required longer stopping distances, which negated safety improvements. The race between productivity-enhancing technology and job quality was a constant feature of work on American railroads.

Locomotives

The first power sources for railroads were horses and stationary engines on inclined planes, but horses had a low maximum power and stationary engines were inflexible and too expensive for a long railroad. After British inventors proved that steam traction could operate on a moving platform it became the primary motive power of railroads for more than a century. A fire contained in a metal-lined 'firebox' heated water in an adjoining or overlapping boiler, producing steam that was piped into cylinders. Valves let steam into the cylinders, and the steam pushed a piston connected to the driving wheels of the locomotive, causing the wheels to rotate. Each part of this system was an engineering challenge, from the tube-shaped flues of the boiler to the connecting rods that linked the piston to the driver, and every component required cleaning and maintenance to keep the engine running. Failure of a part could cause slow running, a stopped train, or a deadly boiler explosion.

The first American locomotives were steam engines placed on flat platforms about 10–15' long, with no cover for the crew. The engineman and fireman operated the locomotive from the rear of the platform.[20] Economizing on grading required American railroads to purchase more powerful locomotives that used high-pressure

[20] See examples in Edwin P. Alexander, *Iron Horses: American Locomotives, 1829–1900* (New York: Bonanza Books, 1941).

steam and more fuel, but wood abundance made this a satisfactory tradeoff.[21] Imported English engines designed for good roadbeds and gentle curves derailed or were damaged by the American track. To guide locomotives around sharp corners and over rough track sections, builders attached one or two pairs of wheels in a rotating metal frame ('truck') under the front of the locomotive. The leading safety (or 'bogie') truck also distributed the vehicle's weight more evenly.[22] Railroads did not want to fence hundreds of miles of track to keep out livestock, so locomotive builders added the 'cow catcher' to reduce damage from collisions.[23] Locomotives rarely had brakes for the driving wheels before the late 1870s. Instead, to check the motion of a locomotive, enginemen reversed the driving wheels and applied the tender brakes.[24]

The first steam locomotives belched smoke, steam, and wood sparks directly over the engine crew and cars. In the 1830s locomotives received larger boilers and taller, conical smokestacks with spark arrestors to mitigate fire risk and direct exhaust away from the crew and train, but the crew remained exposed to the elements.[25] The engineman and fireman were somewhat protected in a cab by the late 1830s, which probably originated in upstate New York. Cabs were initially plain wood boxes with a single window on each side, but eventually they were embellished and locomotive builders added forward-facing windows. Not all roads provided cabs—there were no

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[21] Hindle and Lubar, *Engines of Change*, 140. Rosenberg, *Technology and American Economic Growth*, 74.
[22] White, *Locomotive Safety Truck*, 118–23. Pin placement and stabilizing devices improved the truck in the 1850s and enabled the classic 4-4-0 design.
[23] Fishlow, *American Railroads*, 5.
[24] John H. White, *American Locomotives: An Engineering History, 1830–1880* (Baltimore: Johns Hopkins University Press, 1997), 184.
[25] Alexander, *Iron Horses*, 23–31. August Mencken, *The Railroad Passenger Car: An Illustrated History of the First Hundred Years, with Accounts by Contemporary Passengers* (Baltimore: Johns Hopkins Press, 1957), 43. On spark arrestors, see White, *American Locomotives*, 114–24.

cabs on Reading Railroad locomotives until 1846 and Erie Railroad locomotives until 1847. Indeed, locomotive builders considered them optional until 1855.[26]

Monitoring the water level in the boiler was one of the engineman's key responsibilities. If there was too little water (not enough to cover the top of the firebox, which was called the crown sheet) the firebox could melt or deform, leading to a deadly boiler explosion. American locomotives had a vertical row of 'cocks' (usually three) that showed whether there was water or steam at specified heights in the boiler. If the top cock, when opened, blew out water, the boiler was overfilled; if the bottom cock emitted steam, then the crown sheet was not covered in water and the boiler was at risk of exploding. Glass-tube gauges that showed the precise water level (when properly maintained) were common in Britain by the 1850s, but Americans considered them extravagant and they were rare before the 1860s.[27] The engineman also had a lever to release grit from the sandbox onto the rails ahead of the driving wheels when traveling over track covered in water or oil. It was invented in the 1840s and in common use by the mid-1850s.[28]

On early locomotives, the frame (the platform under the boiler) was made from wood. This component was under high stress and iron soon replaced wood, though its cheapness meant that cabs and the upper part of tenders were built from wood until the 1880s. The boiler was iron until the late 19th century, but iron used for locomotives was as inconsistent in quality as iron for rails. Cast iron was cheap and could be shaped

[26] *American Locomotives*, 46–47, 221–23.
[27] *American Locomotives*, 132–33. By contrast, Americans were relatively quick to adopt steam gauges in the 1850s, probably in part because they used high-pressure steam. *American Locomotives*, 133–36.
[28] *American Locomotives*, 234–35.

easily, but brittle unless it was reinforced. Reinforcement made it excessively heavy, and locomotive builders soon realized that unreinforced cast iron was unsuitable for parts of a locomotive under heavy strain. Cast iron was used on parts subject to fewer lateral or twisting forces through the end of the 1800s. More expensive wrought iron was used for some components under high stress such as the frame, boiler, axles, and rods. However, large components of wrought iron sometimes had catastrophic defects that produced boiler explosions or other calamities.[29]

Wood abundance made it the obvious fuel. The first locomotives had little space for wood storage and water barrels, which limited their range. To run longer distances, railroads added a linked car behind the locomotive, called a tender, that contained a water reservoir and fuel bunker. Water was always the predominant part of the tender's weight on account of the greater demand for water than fuel. In the 1850s, a locomotive could consume a cord of wood and about 1000 gallons of water in a 25-mile journey. The tender's variable weight from full to empty made it difficult to design an appropriate wheel arrangement, and it could ride roughly over the rails.[30] Experiments in the 1850s with coal were fitful and left some locomotives stranded between stations.[31]

By 1850, new locomotives were usually built in a 4-4-0 configuration, with a leading bogie truck behind the cow-catcher and two pairs of linked driving wheels

[29] *American Locomotives*, 29–32. *James Millholland and Early Railroad Engineering* (Washington: Smithsonian Press, 1967), 6.
[30] *American Locomotives*, 223–33. Reed C. Richardson, *The Locomotive Engineer, 1863–1963: A Century of Railway Labor Relations and Work Rules* (Ann Arbor: University of Michigan, 1963), 95.
[31] Weber, *Northern Railroads*, 55–56.

under the boiler and cab.[32] To signal and warn travelers at grade crossings, locomotives had a bell and a steam whistle, and there was an oil-lamp headlight at the front.[33] The 4-4-0 was the most common style for 19th century American locomotives. Railroaders appreciated its relative simplicity, adaptability, and ruggedness.[34]

Passenger Cars

The first passenger cars were small (15′ long) wood constructions that looked like stagecoaches and held up to 20 passengers. A more common, longer type of 1830s car had separated compartments with side doors and two fixed axles that produced a bumpy ride and caused frequent derailments, and these cars broke apart in accidents. The conductor had to traverse a compartmented car on an exterior running board, which exposed him to the elements and put him at serious risk of falling or being crushed between the train and platforms, tunnels, and buildings.[35]

As railroads sought to accommodate more passengers, they found that longer cars 'see-sawed' if two fixed axles were placed toward the center, and cars derailed on curves if fixed axles were placed at the ends. To solve this problem, builders substituted a rotating four-wheel truck placed at each end by the late 1830s; cars were then up to 35′ long and could hold 50 passengers.[36] Two swiveling trucks tolerated

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[32] Hindle and Lubar, *Engines of Change*, 140. Whyte notation classifies engines by wheel arrangement: a 4-4-0 had four leading wheels, four driving wheels, and no trailing wheels under the cab.
[33] Brian Solomon, *American Steam Locomotive* (Osceola, WI: MBI Publishing, 1998), 28–29. White, *American Locomotives*, 211–17. Electricity replaced oil in headlights around 1900.
[34] John K. Brown, *The Baldwin Locomotive Works, 1831–1915: A Study in American Industrial Practice* (Baltimore: Johns Hopkins University Press, 1995), 66.
[35] John H. White, *The American Railroad Passenger Car* (Baltimore: Johns Hopkins University Press, 1978), 3–18. Mencken, *Railroad Passenger Car*, 11–12.
[36] *Railroad Passenger Car*, 11–13.

rough roadbeds better than two fixed axles. By about 1840 compartments and running boards had been replaced by seats arranged along a central walkway with doors at each end.[37]

Throughout the 19th century most passenger cars were 'day coaches': unspecialized rolling stock that accommodated travelers for moderate distances. There were few sleeping or eating cars or compartments, so in this period conductors sometimes took meal orders that were telegraphed ahead to a trackside 'eating house'.[38] The first passenger cars were unheated, but by the late 1830s most had wood or coal stoves. They were poorly ventilated and insulated, giving only moderate protection to the conductor when he ducked inside. Ventilation came through windows, when they were opened, or the car doors at stopping points, but admitting outside air introduced locomotive smoke and dust, which made cleaning cars laborious.[39] In the late 1850s, car builders added a central clerestory to improve lighting and ventilation, and it became widely used in the 1860s.[40] Cars were lit by candles, then oil lamps, but lighting remained poor until the 1880s, and lamp flames or stoves could set crashed cars alight.[41] Even in the 1840s and 1850s most cars lacked suspension and poor-quality springs provided a jarring ride.[42] Throughout most of the 19th century they had no toilet facilities.[43]

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[37] White, *American Passenger Car*, 8–23. Mencken, *Railroad Passenger Car*, 11.
[38] Eric Arnesen, *Brotherhoods of Color: Black Railroad Workers and the Struggle for Equality* (Cambridge: Harvard University Press, 2001), 14–16. Mencken, *Railroad Passenger Car*, 26–27. White, *American Passenger Car*, 204.
[39] Mencken, *Railroad Passenger Car*, 42–43. White, *American Passenger Car*, 380–85.
[40] *American Passenger Car*, 26–29. Anthony J. Bianculli, *Trains and Technology: The American Railroad in the Nineteenth Century*, vol. 2 (Newark, DE: University of Delaware Press, 2001), 29–31.
[41] White, *American Passenger Car*, 413–14.
[42] Mencken, *Railroad Passenger Car*, 18.
[43] Arnesen, *Brotherhoods of Color*, 14.

By 1860, the longest cars were 60′ long, 10′–11′ wide, and held 60–70 passengers.[44] A few cars incorporated iron frames, but wood remained the predominant material. Wooden cars crumpled, splintered, and burned in crashes, but in addition to its cheapness and abundance, wood was light. Midcentury motive power could not pull heavier cars, and even with wooden cars, most passenger services were short.[45]

Freight Cars

The initial euphoria around railroads focused on their potential for personal transportation, but freight became the main business of American railroads.[46] The first freight cars were expanded versions of mining coal cars with four wheels under a wooden frame. Goods were also carried in a 'gondola', a longer platform with short walls that became the most common early freight car. The boxcar came into use in 1833, and railroads adopted it through the 1830s to protect freight from the elements.[47] Boxcars were the common conveyors of miscellaneous bulk goods. Their sliding doors had a latch, not a lock, covered with a tin-plated strap or seal.[48] Nearly all freight cars were made from wood in the antebellum period. Like passenger cars, car builders constructed longer models and by the 1840s most of them had eight wheels in two trucks.

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[44] Mencken, *Railroad Passenger Car*, 18–19.
[45] White, *American Passenger Car*, 8–23, 117.
[46] Stover, *American Railroads*, 32.
[47] John H. White, *The American Railroad Freight Car: From the Wood-Car Era to the Coming of Steel* (Baltimore: Johns Hopkins University Press, 1993), 155–66.
[48] *American Freight Car*, 75–76.

While British railroads reduced speeds using brakes in the locomotive and a tailing brake car, heavier American freight cars needed their own brakes.[49] At first brakemen had to set the brakes separately for each truck, but in the 1850s 'double-acting' brakes enabled brakemen to set the brakes for both trucks on a car using one brake wheel. Double-acting brakes should have improved safety by allowing brakemen to apply all brakes faster, but they also allowed railroads to employ fewer brakemen per car and run trains more quickly.[50]

By 1860, freight trains were generally 20 cars or fewer in length, carrying 5–10 tons per car and traveling 10–20 miles per hour. Passenger trains were usually 5–10 cars and traveled more quickly: 25 miles per hour for local trains, and about 30 miles per hour on express service.[51]

Maintenance Cars

There was a variety of specialized rolling stock for maintenance, most of which were small cars with four wheels and no rotating trucks. The oldest and most common was the hand car, which track laborers and other maintenance workers used to move along the railroad with tools. At first hand cars were a four-wheeled platform that workers pushed by sitting on the back and kicking the ties, or by poling along the side. The crank- or lever-powered hand car probably emerged in the 1850s. Hopper cars carried ballast or other heavy supplies and usually had a mechanism to tip contents to the side of the tracks by pushing or turning a crank. Flatcars or gondolas with hinged

[49] Aldrich, *Safety First*, 21–22. British freight cars had brakes, but these were operated by yard workers from ground level and not in line service.
[50] Usselman, *Regulating Railroad Innovation*, 108.
[51] Weber, *Northern Railroads*, 12.

metal wings to level ballast to the side of the tracks were referred to as grader cars. In winter railroads used hand-shoveling labor crews and locomotive-pushed plows to clear snow. The wedge-shaped snowplow came into use from the 1840s, at first built of wood and eventually iron and steel. From the 1880s the rotary snowplow placed a 10–15′ diameter propellor-shaped rotor enclosed in a box or cylinder at the front of a steam-powered rectangular car. Railroads also purchased steam shovels and rolling pile drivers for excavation and bridge construction or repair, as well as cranes and derricks affixed to flat platform cars. These cars allowed workers to lift heavy implements when carrying out repairs. Early cranes were hand-powered, but eventually some used steam engines.[52] Maintenance cars made track laborers' work easier, or in some cases like rotary snow plows, replaced them entirely.

Railroad Premises

Workers who were not employed on trains spent their hours in one of a variety of railroad sites. Like the development of specialized railcars, the novelty of railroad technology meant that the first depots and maintenance shops were repurposed buildings before engineers and architects designed railroad-specific structures. Most employees in stationary occupations moved between indoor and outdoor premises and mingled with other workers in shops or with the public in depots.

[52] Bianculli, *Trains and Technology*, 2, 149–55. John H. White, "A History of the Railroad Hand Car," *Railroad History*, no. 127 (1972).

Stations and Depots

The first railroad depots were ticket booths in shops or hotels adjacent to the railroad line, or existing houses acquired by the railroad. Most had no specified areas for passengers to wait or employees to congregate indoors. Dedicated stations in the early years looked like large gabled barns.[53] Growing traffic encouraged railroads to construct specialized depots, which were an advance over the stagecoach companies' use of inns or taverns. Although traffic was bi-directional, most stations had a single depot building and platform for the single-tracked railroad. Stations usually had at least five parts: platforms for passenger boarding and freight loading (eventually covered by the depot eaves), an indoor waiting area for passengers and packages, a ticket and information desk, staff work areas, and toilets.[54] The platform and depot were usually built from wood, or sometimes brick.[55] The agent's office usually contained a desk, telegraph equipment, cash boxes or drawers, writing implements (later a typewriter), a clock, and railroad paperwork.[56]

Engine Houses, Roundhouses, Machine and Car Shops

Along with large urban depots, the most substantial railroad workplaces were engine houses, roundhouses, and machine and car shops. The first indoor storage for locomotives was a box-shaped engine house that locomotives entered through a series of switches. The turntable was introduced in the 1830s in Britain to turn locomotives

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[53] Jeffrey Richards and John M. MacKenzie, *The Railway Station: A Social History* (Oxford: Oxford University Press, 1986), 39–40.
[54] *Railway Station*, 19–20.
[55] Carroll L. V. Meeks, *The Railroad Station: An Architectural History* (New York: Dover Publications, 1995), 48–49.
[56] Janet Greenstein Potter, *Great American Railroad Stations* (New York: Wiley, 1996), 24.

at the end of a run. The roundhouse, which was more common in America than the engine house, developed shortly afterward to provide space for covered locomotive storage and maintenance, and was built around a turntable. To service locomotives, engine houses and roundhouses had hoists and drop pits (trenches between the tracks where machinists could view and repair the underside of a locomotive). Ventilation was important in the roundhouse, as engines were put under steam to move them out. The combination of many locomotives and a large volume of wood or coal and machine oil made fires a serious risk in roundhouses, so railroads placed water barrels and fire buckets at intervals. The machine shop and car shop were usually rectangular buildings with several tracks, drop pits, and a variety of tools, lathes, and sometimes forges to make parts and repair rolling stock. Maintenance buildings had poor lighting, were hot in the summer and cold in the winter, and were smoky and steamy environments with the risk of falling machinery and scalding steam.[57]

Yards

When railroads expanded beyond a handful of passenger and freight cars, they needed locations to store rolling stock and compose trains away from a station platform. Yards were large open areas with many parallel tracks accessed through switches. The first railroad cars were light enough that they could be sorted and moved by manpower, without the need for switching engines. To turn locomotives and move cars between tracks, railroads used small turntables and traversers (a short

[57] Hans Halberstadt and April Halberstadt, *The American Train Depot & Roundhouse* (Osceola, WI: Motorbooks International, 1995), 145–58; Walter G. Berg, *Buildings and Structures of American Railroads* (New York: J. Wiley & Sons, 1900), 168.

section of track that could be shifted laterally to move rolling stock between tracks without switches).[58] Soon these hand-powered elements were replaced by switching engines to shunt and compose trains. Some yards were built on a gentle slope so that workers could uncouple cars and let gravity pull them down the slope to the correct siding. Yards usually had small structures that held tools for laborers and brakemen, and an office for the yardmaster. There were also small shanties for watchmen who prevented thefts of railroad property or freight. Later in the 19th century, two-storey signal towers provided a better view of the yard for watchmen, switchmen, and signalmen.[59]

Railroad Hierarchies and Jobs

The railroads required a vast array of occupations, almost all of which were new job titles, to handle the increasingly diverse task range (Figure 8.3, Tables 8.1–8.3). This section summarizes railroad hierarchies and then describes groups of occupations on railroads, starting with executives and proceeding through jobs in the 'running trades', stationary workers, shopmen, maintenance of way, and station employees.

There were some commonalities across groups of railroad jobs. Men in the running trades had to perform tasks while moving, sometimes at high speed, over uneven tracks. They were also at the mercy of their locomotive's status, especially the engineman and fireman. Mechanical issues could delay or strand workers and force them to work longer than scheduled. Stationary employees who toiled around track

[58] Meeks, *Railroad Station*, 29.
[59] Berg, *Structures of Railroads*, 1, 6–7, 39, 43–45.

had to be alert for oncoming traffic to avoid accidents, and keep track of which train had passed most recently and in which direction.

To mitigate some risks, trainmen and yard workers communicated with hand signals; some were adopted from sailing and others developed on the railroads. Individual railroads also created their own systems of hand communications, and some used flags of different colors. At night, they substituted lantern signals for hand signals. The engineman also had his whistle and bell to send signals. Differing signal practices across railroads could cause confusion, leading to accidents and injury.[60] Another shared task for blue-collar workers was cleaning locomotives and rolling stock. The engine crew usually cleaned their locomotive when it was in service, and shopmen did so when rolling stock was in their possession. Cleanliness was more than an aesthetic concern: gauges crusted with dirt were difficult to read, headlamps covered in dust provided insufficient illumination, and grimy locomotive cab windows impeded visibility.[61]

Railroad Hierarchies

While some tasks and responsibilities were shared, their allocation was the result of organizational hierarchy, set up by railroad directors and managers. The first key feature of the railroads that shaped organization was their size, in employees and geographical scope. By the 1850s, the Erie Railroad employed over 4000 people—more than the largest of the Lowell mills—along hundreds of miles of track. Distance made

[60] White, *American Freight Car*, 87–89.
[61] John W. Orr, *Set up Running: The Life of a Pennsylvania Railroad Engineman, 1904–1949* (University Park, PA: Pennsylvania State University Press, 2001), 60.

key elements of management, such as information gathering, oversight, and coordination, far more difficult than walking through a factory. The second key feature was the heterogeneity of tasks. Railroads needed workers who could operate locomotives, sell tickets to passengers, account for cost centers, operate the brakes on railcars, repair bridges, and set switches in the yards. Although early railroad workers sometimes completed tasks outside of their job description, specialization was essential to ensure timely service and reduce accidents. The agency problems and variety of railroad work tasks were key reasons for the increased division of labor. The physical separation of workers necessitated duplication of occupations across the line, with hierarchical organization for coordination.[62]

Dispersed and highly varied activity led to the creation of two organizational models. The first organized a railroad by functional unit, or 'department', such as track maintenance or motive power. The second model prioritized geographic area or 'division'. Divisional management emerged in Northeastern railroads in the late 1840s and early 1850s, first on the Western Railroad of Massachusetts. The system relied on passing information up a chain of command to a central office and led to the creation of the organizational chart, of which Figure 8.3 is a stylized example. Most major railroads eventually preferred a divisional system, although each division contained departments.[63] The Erie Canal and other waterways used a divisional structure, but they did not have multiple departments within divisions.

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[62] Alfred D. Chandler, *The Railroads: The Nation's First Big Business* (New York: Harcourt, Brace & World, 1965), 97–99.
[63] Churella, *Pennsylvania Railroad*, 195–96. Chandler, *The Railroads*, 97–100. *Visible Hand*.

Managers

At the top of the divisional hierarchies were the executives, the first of whom were usually engineers who demonstrated organizational competence in railroad building and understood the science and logistics of railroading. These men, and those who followed them by ascending within a firm, were the early salaried managers of the mid-century period.[64] Railroads slowly developed internal promotion systems for executives. These men learned about operations and coordination of the new enterprises on the job and received promotions to higher office based on success and experience within the firm.[65] Managerial expertise was usually gained on the job through many attempts to streamline organization, maximize the efficient use of infrastructure and rolling stock, avoid accidents, and ensure implementation of orders or instructions.[66]

The working life of a railroad executive was increasingly removed from that of his employees. Executives tried to spend time on the road, but their hours were primarily occupied by correspondence and meetings. Directors' and board committee meetings usually took place in a major city such as Philadelphia or New York. Executives used internal reports, outside auditors' statements, newspaper articles, and company gossip to understand their railroad's activities. Correspondence shows that much of their time was occupied by information-gathering about the actions of their own railroad and competitors. They used this knowledge to shape decision-making

[64] Churella, *Pennsylvania Railroad*, 105–10.
[65] Thomas C. Cochran, *Railroad Leaders, 1845–1890* (Cambridge: Harvard University Press, 1953), 79–81.
[66] Churella, *Pennsylvania Railroad*, 131.

and strategy for pricing, recruitment, technological acquisition, marketing, and lobbying.[67]

Executives faced very different challenges from the rest of the workforce. They were generously compensated and many had long tenures. However, they frequently worked long hours, and the stress of overseeing large, complex organizations could shorten their lives. Four of the first eight presidents of the Pennsylvania Railroad died in post, and a further two within a year of retirement.[68]

Enginemen

Far from railroad offices and boardrooms were the men of the running trades. At the head of a train, the engineman (or locomotive engineer) operated the locomotive and supervised the fireman. He was nominally under the authority of the conductor, who was responsible for ensuring on-time service, but the engineman effectively controlled a moving train.[69] At the start of a run, the engineman inspected the locomotive for problems or defects out of professional responsibility and concern for his safety. When running, the engineman controlled the locomotive's speed using the throttle (which allowed steam from the boiler into the cylinders), the Johnson bar (which controlled the timing of steam entry into the cylinders, and therefore the direction of driving wheel rotation and the power delivered to the drivers), and the brakes. Throughout the first century of railroading, enginemen were trained on the

[67] Cochran, *Railroad Leaders*, 54–61 and Appendix.
[68] Churella, *Pennsylvania Railroad*, ix.
[69] Shelton Stromquist, *A Generation of Boomers: The Pattern of Railroad Labor Conflict in Nineteenth-Century America* (Urbana: University of Illinois Press, 1987), 107.

job, usually by gaining experience as firemen.[70] By convention, the engineman rode on the right side of the cab, and the fireman's seat was on the left.[71] Most crews had their 'own' engine and did not switch between locomotives unless workers were absent for a run.[72] However, when enginemen or crews switched to different locomotives, variations in design or gauges could cause problems.

Not all trips or 'runs' were equal: grades, corners, single track, and grade crossings made the engineman's job more difficult. Before steep gradients, the engineman took on fuel and water. Hard running uphill required more steam, and therefore more water and wood. Corners limited visibility and required deceleration and acceleration, while single tracking entailed time in sidings and also more accelerations and braking. It also made running off-orders or trying to make up time more dangerous. The engineman had to use the locomotive bell or whistle ahead of grade crossings, and the latter expended steam from the boiler.[73]

Until the introduction of telegraphy in the 1850s, all train movements were controlled by paper orders and timetables. Timetables were set to ensure that trains did not collide, and updates to the schedule (fresh orders) were provided at stations, usually handed over to the crew or held on a stick for the engineman or fireman to grab while moving. Orders specified the time that the train should reach the next stations, numbers of other trains traveling in the opposite direction, and required stopping points. Dispatchers, station agents, telegraphers, and trainmen could miscommunicate, incorrectly transcribe, or misunderstand orders, causing a collision.

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[70] Orr, *Set up Running*, 2.
[71] *Set up Running*, 37.
[72] *Set up Running*, 4.
[73] *Set up Running*, 22–23, 31–32.

Engine crews also made errors in timekeeping. Even after the invention of the telegraph, train control methods changed little on most railroads until the late 19th century.[74]

Firemen

The fireman's chief responsibility was stoking the fire to generate steam in the boiler. This required him to add wood, later coal, supplied from the tender, while the locomotive oscillated laterally at speed.[75] Firemen were frequently promoted from the ranks of young low-skilled shopmen, gaining experience when a normal fireman was absent for a day before a permanent promotion. Shop work provided basic knowledge of engines—at least enough for a single run. Firemen and enginemen started on irregular service or less desirable routes, and worked their way up to better routes and promotion (sometimes as a 'hostler' or engineman in the yard and shops) through a mixture of seniority and demonstrated competence.[76] Fueling locomotives was tiring and tedious, especially on routes with stiff grades, but workers tolerated it because of the chance of promotion to the other side of the cab.

Conductors

Conductors were not as well-paid as enginemen, but they had authority over the operation of trains and supervised the complement of two to four brakemen.

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[74] White, *American Freight Car*, 83. Robert B. Shaw, *Down Brakes: A History of Railroad Accidents, Safety Precautions and Operating Practices in the United States of America* (London: P. R. Macmillan, 1961), 149–51. American telegraphers were reputedly less experienced and more mistake-prone than British telegraphers. Aldrich, *Safety First*, 24.
[75] Orr, *Set up Running*, 2.
[76] Stromquist, *Generation of Boomers*, 109–10.

Unlike most other trainmen, their work was organizational, interpersonal, and supervisory rather than physical. Freight conductors monitored the condition of their train and signaled to passing conductors if they saw anything amiss with another train. They also kept a manifest of cars in the train and their destination, including the details of the consignments, and checked the tin 'seals' on boxcars to prevent theft. The content of their work changed relatively little as technology improved, and they were closely associated with railroad management.[77]

On passenger trains, conductors were also responsible for the safety of travelers. Conductors could be disciplined, dismissed, or even criminally charged for negligence that resulted in injury to passengers.[78] The career ladder normally required six years as a brakeman before a worker could advance to being a conductor on a freight train, and a further six years before rising to work in passenger service.[79]

Brakemen

The brakeman was the most intrepid of workers in the running trades, and his job was the most dangerous. His responsibilities varied with the size of the crew and type of train, but the two main tasks were coupling cars and operating the brakes, which were the two most dangerous mundane operations on railroads. To couple, he had to stand between two cars and risk being crushed or having his fingers or hand taken off by the couplers. Braking required him to climb over and jump between moving cars to pull or crank the heavy hand brakes. To engage the brakes, workers at

[77] *Generation of Boomers*, 108–09. White, *American Freight Car*, 74–76.
[78] E. C. Robbins, *Railway Conductors, a Study in Organized Labor* (New York: Longmans, Green & co., 1914), 85.
[79] *Railway Conductors*, 86.

first pulled a brake lever. From around 1850, this was replaced by a wheel-cranked braking system. Brakemen needed to apply the brakes enough to reduce speed, but not so much as to lock the wheels and cause skidding.[80] Standing atop or between freight cars for an entire journey left a brakeman at the mercy of the elements in the smoke and dust of the train, and crashes sent him flying. He sometimes clung to a car by a brake lever, a ladder, or a grab iron, which was hopefully well secured to the car.[81] Brakemen also set switches for trains approaching sidings that did not have designated switchmen.[82]

On passenger trains, brakemen sat inside a coach, swept the cars, stoked the stove, called out stations, carried baggage, and waited for the whistle to signal braking. At this sound, like his freight counterpart, he stepped out onto the platform at the end of the car to twist the brake wheel into position. He then stepped across to the wheel on the next platform, set that brake, and perhaps returned to the first to tighten further and equalize the braking force.[83] Passenger braking was easier than freight braking, but coupling, switching, and stepping outside to set the brakes were still dangerous tasks.

When trains broke down, brakemen doubled as flagmen, walking down the track to signal to oncoming or trailing traffic. They had to be ready for the sound of the engineer's whistle when the engine restarted to jump onto the moving train. There are no accident reports for the early decades of railroading, but work practices changed little before the 1890s and safety-improving devices were adopted slowly (see

[80] White, *American Freight Car*, 527–28. *American Passenger Car*, 558.
[81] *American Freight Car*, 71–73.
[82] Orr, *Set up Running*, 69.
[83] White, *American Passenger Car*, 541.

Chapter 9), so brakemen probably faced serious risks of debilitating injury or death throughout the century, theirs was likely the most dangerous railroad job. Indeed, braking was so perilous that there was no insurance available for brakemen.[84] Brakemen were usually the most inexperienced workers on railroads, and their turnover was high because of injuries and limited opportunities for promotion to conductor (there was only one conductor for every three or four brakemen).[85] The number of cars per brakeman varied widely, with as few as one per passenger car, and as many as one for four passenger cars. Freight trains had fewer brakemen per car, sometimes as few as two for a 50-car train, although freights traveled at lower speeds.[86]

Switchmen

Switchmen worked in a fixed location, setting (opening or closing) the switches with hand-powered levers to direct trains as required, and monitoring the progress of passing trains. They were paid by time rather than trips, and although their hours were long (12-hour shifts were common), schedules were less erratic than for trainmen. Switchmen were more closely supervised than some workers in the running trades, as there was usually a foreman for yard switchmen. There were few foremen relative to switchmen and the potential to rise through the ranks was very limited. Their work was probably almost as dangerous as that of brakemen because most worked around

[84] Aldrich, *Safety First*, 22–23. White, *American Passenger Car*, 541.
[85] Stromquist, *Generation of Boomers*, 109.
[86] White, *American Passenger Car*, 541–42.

moving cars in marshalling yards. They were also easily identified as culprits for accidents and frequently dismissed or suspended for a single error.[87]

Shopmen

In the railroad shops and roundhouses there were workers with varying responsibilities and skill levels, from unskilled laborers to carpenters and machinists or boilermakers. They were the most closely supervised railroad employees as they worked in an enclosed space, and they were also the most concentrated, unlike most railroad occupations that were spread along the line. The heterogeneity or idiosyncrasy of rolling stock required them to remedy a range of locomotive and car issues, although there was usually separation between workers maintaining motive power and those who repaired cars. Cleaning was an essential part of maintenance, and 'Wipers' had some of the dirtiest and most tedious jobs. Shopmen were generally paid by the day, and master mechanics could earn three times the wages of low-skilled workers or more.[88]

Trackmen and Maintenance of Way

Trainmen's jobs were dangerous and tiring, but they were at least exciting. Maintenance of way workers were responsible for replacing broken rails or ties, re-

[87] Zerah Colburn, *Reminiscences in the Life of a Locomotive Engineer* (Columbus: Follet Foster, 1861), 147. University of Connecticut Special Collections, Providence & Worcester Railroad Records, 1997.012 Box 43. Hagley Museum & Library, Reading Company Records, 1520 V-437.
[88] Stromquist, *Generation of Boomers*, 112–13. James Ducker, "Men of the Steel Rails: Workers on the Atchison, Topeka & Santa Fe Railroad, 1869–1900" (Ph.D., University of Illinois at Urbana-Champaign, 1980), 4–5.

setting spikes, refilling ballast after washouts, and checking switching mechanisms. They worked in small teams and traveled on railcars (with the risk of being thrown off in an accident) or handcars. Most railroads separated their routes into sections that were assigned to a group of laborers and a foreman, which gave rise to their title as 'section laborers'. The foreman was usually responsible for inspecting his section each day. When at work trackside, section laborers might have to jump out of the way or quickly pull a handcar off the tracks to avoid an oncoming locomotive.[89]

Station Personnel

The station master or agent was a manager, record-keeper, and customer service representative. He sold tickets and collected fees for freight shipments, kept records of incoming goods and passenger numbers, and calculated payroll. Sometimes he recorded the weather and reported it to superiors if heavy rain or snow caused washouts or drifts. Station agents, or in larger stations, their assistants, announced train arrivals and maintained the depot buildings. Clerks recorded and accounted for consignments and revenues over long, tedious hours. Larger stations had more service workers to communicate with passengers, keep records, and maintain the premises.[90] Politeness and extensive knowledge of timetables, train facilities, and connections were essential.[91] Public-facing workers were also required to dress in a clean railroad uniform and cap.[92] Porters or baggage men were responsible for heavy lifting; large

[89] White, "A History of the Railroad Hand Car," 68. Ducker, "Men of the Steel Rails," 5.
[90] Richards and MacKenzie, *Railway Station*, 232–34. Potter, *American Railroad Stations*, 7–8. Halberstadt and Halberstadt, *American Depot & Roundhouse*, 35.
[91] Richards and MacKenzie, *Railway Station*, 225–26.
[92] Halberstadt and Halberstadt, *American Depot & Roundhouse*, 46.

stations had a team of workers under a head porter. Long operating hours meant city station porters were split into two or three shifts, including some night shifts. If traffic was light in the evening, they helped to clean the station.[93] Early station staff were frequently hired from competing industries such as stagecoaching, shipping, and freight wagons.[94]

Railroad Pay

Payment rates and bases were almost as heterogenous as railroad work. Managers, white collar workers, and supervisory employees were salaried by the month or year; other stationary workers were commonly paid day rates; and from around 1860, workers in the running trades were increasingly paid by trip or distance. Agents were sometimes paid a partial salary, topped up by commission from ticket sales or freight rates. Passenger employees were generally paid more than freight workers, and yard employees received the lowest trainmen's wages.[95] As is well-known, there were large differences in pay between occupations. The lowest-paid track laborers could earn as little as 75¢ per day, while managers in the mid-century period earned more than $5 per day. Earnings for managers and executives are less well-documented but appear in some memorandum books, letters, and account books. Overall, railroaders earned relatively high wages compared to other occupations that were considered to have similar skill requirements. In addition to perceived skill, experienced workers could receive higher wages, which later developed into a

[93] Richards and MacKenzie, *Railway Station*, 235.
[94] *Railway Station*, 225.
[95] Robbins, *Railway Conductors*, 58, 73, 76–80.

seniority-based pay system.[96] On the other hand, overtime was rare despite long hours, and varying difficulty between routes (such steep gradients) was rarely reflected in pay.[97]

Working Time

At first railroads only operated during the day, which limited hours for men in the running trades. Daylight similarly curtailed most maintenance activities, and daytime operation meant that station employees also had nights off. The development of kerosene headlamps in the 1840s enabled nighttime operation and increased the potential working hours of railroaders.[98] From this point working time could be very long. Precise shift lengths were a function of the local supervisor's scheduling and, for trainmen and cabmen, whether they had the ability (and fortune) to run on time. Hours were usually 10–12 per day in a six-day week in section gangs or on trains, although work in the running trades could easily stretch to 16–20 hours in a shift. Shop workers generally had slightly shorter hours, 10–11 per day. Clerks in railroad offices generally worked 12-hour days, though some could leave an hour or two early on Saturdays.[99]

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[96] Walter Licht, *Working for the Railroad: The Organization of Work in the Nineteenth Century* (Princeton, New Jersey: Princeton University Press, 1983), 125–32. Licht cites an 1878 Illinois survey that showed larger railroads paid higher compensation to managers, but not other occupations.
[97] Stromquist, *Generation of Boomers*, 115–20.
[98] Stover, *American Railroads*, 26.
[99] Licht, *Working for the Railroad*, 174–76.

Stability of Earnings

Payroll sheets and railroaders' memoirs state that workers were usually paid once per month.[100] However, some railroads required that workers had to present themselves at a set location on a specific date each month to collect their pay. If the workers did not show up, they were not paid until the next month.[101] At other times, railroads experienced the same shortages of hard currency discussed in previous chapters, and managers could defer wages for weeks or months at a time.[102]

While railroads operated year-round, that did not mean an equal amount of work from month to month. The demand for services and maintenance fluctuated seasonally, and workers, particularly in the running trades and maintenance of way, experienced variation in earnings.[103] Freight service and pay for freight workers was more volatile than passenger traffic. Since pay for trainmen depended on trips completed, some employees worked extra hours (for example, carrying coal to cities before winter) to save for periods when there was less work available.[104] While there are no unemployment statistics for the mid-19th century, later evidence suggests that unemployment on railroads was less common than it had been in road or canal transportation. Data from the late 19th century will be discussed in more detail in Chapter 9.

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[100] Orr, *Set up Running*, 4. See also Manuscript sources in the Bibliography.
[101] *Set up Running*, 10–11.
[102] Licht, *Working for the Railroad*, 135–36.
[103] Stromquist, *Generation of Boomers*, 132–33.
[104] Orr, *Set up Running*, 5.

Accidents

Railroad accidents attracted public interest because they were spectacular and produced appalling death tolls.[105] The most-discussed risks on early railroads were boiler explosions and catastrophic crashes. Derailments were common, but most were not deadly and the result of poor roadbeds, rails, or badly-built rolling stock. Cheap infrastructure also caused less common but very deadly bridge collapses. Collisions were common because of weak brakes and single-track operation with primitive train control. While railroads built passing loops, enginemen did not always use them because of incorrect scheduling, poor communication, incorrect orders, or an insistence on running to 'smoke orders': only stopping when the engineman saw smoke from an oncoming train. When railroads developed hand and lamp signals, they differed widely between roads, which was deadly in an era when workers switched employers frequently.[106]

Many worker deaths occurred when trainmen were thrown or fell from moving rolling stock, or were crushed between railcars, but these incidents attracted less public interest. 28% of railroad fatalities in 1851–52 were caused by falls. The two tasks most likely to cause injury and death were braking, the dangers of which were discussed above, and coupling, which was another technologically-produced danger.[107] The main coupling system used from the 1830s to the 1890s was the link-

[105] Many accidents are described in Shaw, *Down Brakes*. The first decade of railroading was not exceptionally deadly because of low speeds. There are accounts of early accidents in S. A. Howland, *Steamboat Disasters and Railroad Accidents in the United States* (Massachusetts: Dorr, Howland & Co., 1840), 245–64.
[106] Aldrich, *Safety First*, 10–15. Stephen Salsbury, *The State, the Investor, and the Railroad: The Boston & Albany, 1825–1867* (Cambridge: Harvard University Press, 1967), 114–15, 83–84.
[107] Aldrich, *Safety First*, 10–15.

and-pin. At each end of a car there was a rectangular metal tube with a hollow center called a 'drawbar'. A metal pin placed through a vertical hole in the drawbar held a large chain-type link that extended outwards from the center of the drawbar. With one car moving, the brakeman guided the link into the drawbar of the next car and dropped a pin in the hole on the second drawbar to secure the link. The only virtue of the system was its simplicity. It left slack between cars, and links and pins sometimes broke, causing runaway trains. Drawbar, link, and pin shapes varied, which made coupling and decoupling a time-consuming puzzle. Brakemen hoarded links and pins, making work more difficult for the next brakeman who coupled the same cars. Stockpiles of both components were held in the tender or (when it came into widespread use after the Civil War) the caboose.[108]

Coupling a train with an assortment of links and pins was an annoying task, but it was not the most important problem with this coupler design. A fraction of a second's delay in pulling back one's hand from the link left fingers and hands caught and crushed between the drawbars. Freight service was more dangerous because freight trains were more frequently decoupled and recoupled than passenger trains. Hand injuries were so common that former brakemen could supposedly be recognized by missing digits. Scarce antebellum occupational safety data prevents a precise calculation of coupler-related injuries, but in the 1870s and 1880s up to 40% of all accidents involved couplers. As railroading was an unusually dangerous sector, this gives some sense of the extraordinary risk produced by one cheap and badly designed component. Deaths were uncommon—they occurred if a brakeman stepped between

[108] White, *American Freight Car*, 490–92.

drawbars and was crushed by moving cars—but many workers lost fingers and hands trying to guide the link into the drawbar.[109]

Other Hazards

The motion of a locomotive and rolling stock required the engine to expel a substantial volume of smoke, which was generally thrown clear of trainmen by a tall smokestack, but could choke and temporarily blind them in tunnels. Poorly ballasted railroads also produced large volumes of dust in summer service that clogged the lungs of trainmen.[110] Any departure from normal running could be hazardous, including tunnels. If nothing else, a tunnel meant that the locomotive exhaust was distributed through the train for the trainmen and passengers to breathe. Another danger was produced by the high rotational speed of axles. Without proper inspection and lubrication, they heated up, which could cause the axle to fail and the train to crash or derail. At minimum remedying 'hot boxes' (named for friction-induced heat in the 'journal box' that held the bearings) took up crew time.

Liability for Accidents

The American mirror of *Priestly v. Fowler* (Chapter 4) was *Farwell vs. Boston and Worcester Railroad*. In this 1837 case brought by an engineman who lost his right hand under the wheels of a derailed car, the judge asserted that the injury was the fault of another worker and therefore the company was not liable. The judge pointed out that American precedents had never held employers responsible for worker injuries and

[109] *American Freight Car*, 496–97.
[110] Mencken, *Railroad Passenger Car*, 7.

stated that occupational risk was an implicit part of the labor contract. If Farwell had been a passenger and not an employee, he would probably have won the case. While some workers were able to secure compensation through the courts, the *Farwell* precedent was cited widely.[111] American employers had similar defenses to those used in Britain: they could claim that an accident was caused by another employee (the 'fellow servant' defense used in *Farwell*), the worker's own negligence had been partly the cause of the accident ('contributory negligence'), or that the employee had shown that they were aware of the danger and continued working ('assumption of risk'). These defenses enabled railroads to avoid financial responsibility for most employee accidents; as a result, there was little incentive for firms to adopt safety improvements.[112]

Supervision & Control

Managers realized quickly that railroading was a dangerous business and established rules to mitigate agency problems. Rules for where and when trains should stop and yield, timetables, and signaling rules were the start of an elaborate system of regulations. Canal boat rules could fit on a single broadside, but 19th century railroad rule books, distributed in small format to employees, stretched to 20 or 40 pages.[113] The

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[111] Jamie L. Bronstein, *Caught in the Machinery: Workplace Accidents and Injured Workers in Nineteenth-Century Britain* (Stanford: Stanford University Press, 2008), 21–25. Christopher L. Tomlins, *Law, Labor, and Ideology in the Early American Republic* (Cambridge: Cambridge University Press, 1993), 301–05, 68–72.

[112] David A. Moss, *When All Else Fails: Government as the Ultimate Risk Manager* (Cambridge: Harvard University Press, 2002), 162–63. Aldrich, *Safety First*, 78–79.

[113] New Jersey State Archives, Morris Canal and Banking Company Canal Regulations Broadside, PMORS048. Cornell University, Kheel Center, BLS Collection of Collective Bargaining Agreements, 6178/009 Boxes 20–22.

most important rules concerned train control and procedures to protect rolling stock, passengers, and freight. On canals, essentially co-equal captains were responsible for the safety of their own crew and others. Rails enabled faster transport, but also made running to rules essential, so railroads used a strict hierarchy with fines or dismissal for damaging errors. The detail of railroad rules was in part to counterbalance the fact that many employees could not be observed for most of their work. In the running trades, the divisional master mechanic was usually the highest authority, and he administered discipline through summary fines, suspensions, and dismissals, with no right of appeal to a higher manager.[114]

There were other rules that constrained employee conduct: the Pennsylvania Railroad (PRR) forbade workers from stopping 'at any public house or other place where spiritous, vinous or malt liquors are sold or kept as a beverage.'[115] A PRR executive who was an Army veteran also established a dress code in the early 1850s to impose sartorial discipline.[116]

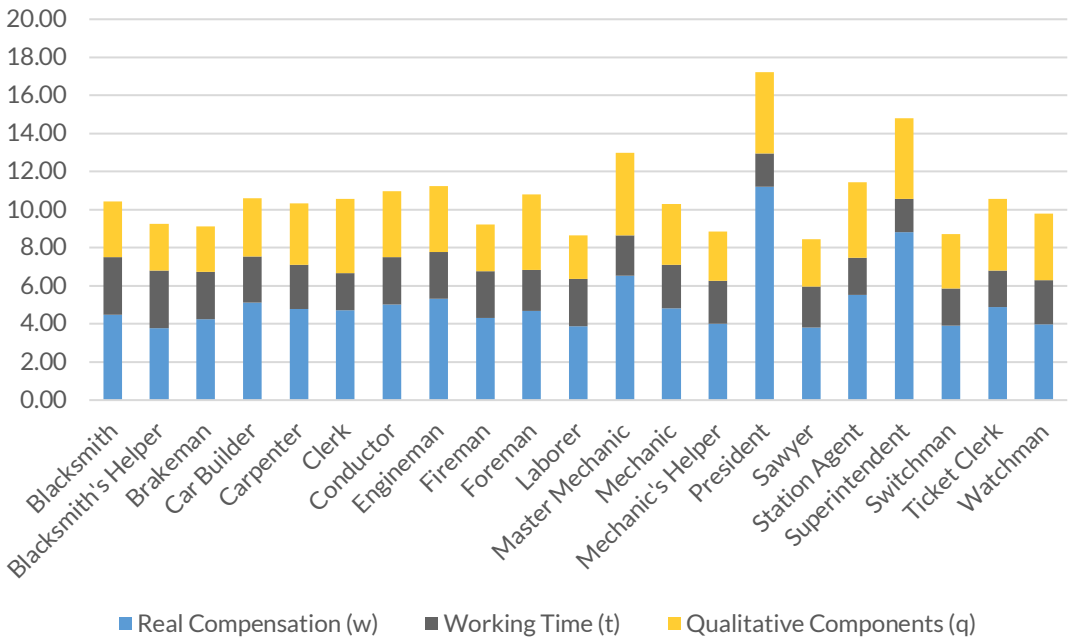
Composite Job Quality

As shown in the preceding sections, job quality varied widely across railroad occupations. Figures 8.1 and 8.2 present 1850 cross-sections of work-related wellbeing based on qualitative evidence and archival data for wages and working time. The blue bars in Figure 8.1 demonstrate the large differences in railroaders' pay, the grey sections show similarly long hours across railroading jobs, and the yellow bars and

[114] Stromquist, *Generation of Boomers*, 231–33, 40–41.
[115] Letter from J. Thomson to R. Clinton Wright, 10 December 1852, quoted in Churella, *Pennsylvania Railroad*, 154.
[116] *Pennsylvania Railroad*, 167.

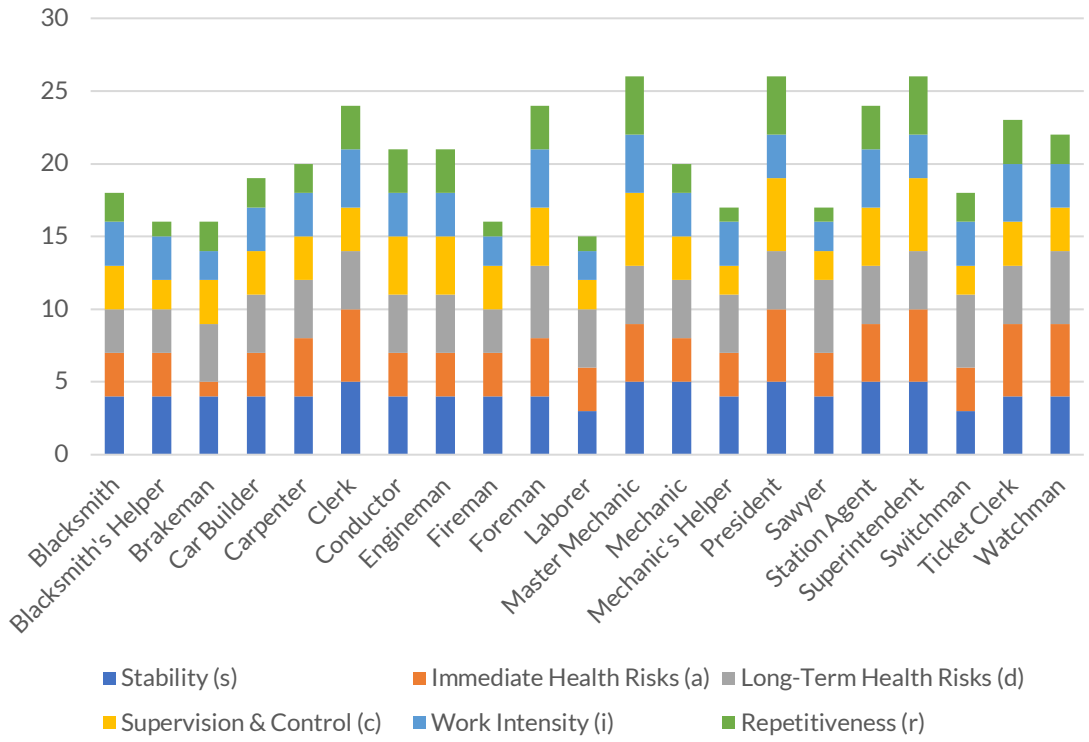
Figure 8.2 present the vast disparities in qualitative aspects of work. Not only were there far more occupations on railroads than road or canal work (Figure 8.3), but job quality was more stratified. Comparing Figures 8.1 and 8.2 also illustrates that many of the highest-paying railroad jobs also had the best qualitative conditions, including safer work, more control, and job security.

Figure 8.1: Railroad Job Quality, Top-Level Components, 1850



Sources: See Table 8.4

Figure 8.2: Railroad Job Quality, Qualitative Components, 1850



Sources: See Table 8.4

Occupational Availability & Distribution

Data on transport employment for the mid-19th century is imperfect but nonetheless demonstrates expanding job availability in railroading. The 1840 Census provided limited information about occupations, counting 11,758 Northeastern men employed in 'internal transportation' and 17,892 in 'navigation of canals, lakes and rivers'.[117] The 1850 Census provided clearer disaggregation, although it used occupational categories such as 'laborers' that included railroaders and non-railroaders. There were only 3,962 'Railroad men', but at least some of the 6,152 'engineers' and the 195 'firemen' were railroad employees.[118] The 1860 Census

[117] 1840 US Census, Compendium of the Sixth Census, 6–31, 360. These categories may have overlapped.
[118] 1850 US Census, Table L, lxvii—lxxix.

included more occupational titles (and omitted the vague 'engineer'). It counted 16,366 'railroadmen'—an extraordinary increase, partly attributable to the expansion of railroading and partly to enumeration practices. This total still trailed the group enumerated as 'boatmen' and 'canalmen' (19,244), but all three categories are imperfect for capturing employment in water and iron horse transport, and railroad employment was clearly rising.[119]

Gender segregation continued: nearly all railroad occupations were exclusively male. A few women were employed as station agents or maids for women's toilets, but they were exceptional.[120] There was also racial segregation as African-Americans were excluded from most railroad jobs, especially in the Northeast. Enslaved men were occasionally forced into railroad construction, but freemen were barred from work in railroad operation. Only in the post-Civil War period did African-Americans gain a small foothold in Northeastern rail employment.[121] Native-born workers predominated in most railroad jobs, especially in managerial roles.[122] The expansion of the railroads meant growing employment opportunities in this varied, frequently well-paid, dangerous sector, but opportunities were not open to all workers.

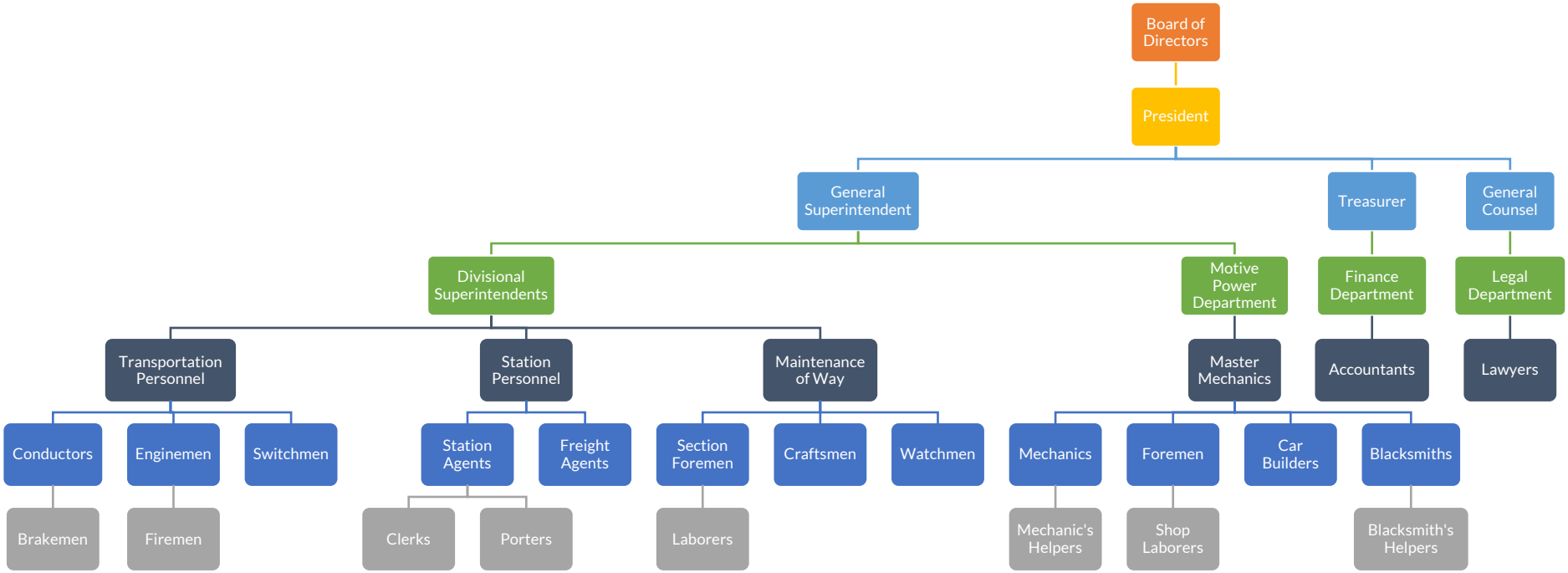
[119] 1860 Census, Occupations in the United States, 656–679.
[120] Potter, *American Railroad Stations*, 7–8.
[121] Arnesen, *Brotherhoods of Color*, 5–9. On African-Americans working on Southern railroads, including forced labor, see *Brotherhoods of Color*, 7–13, 24–26.
[122] Licht, *Working for the Railroad*, 148, 221–22.

Conclusion

The use of steam power over iron rails vastly expanded the task range and depth of work in transportation. Railroads did not only need workers to run the locomotives, but men to fuel the fire, to monitor passenger and freight consignments, to apply the brakes, to maintain track, to set switches, to sell tickets and collect parcels, to maintain rolling stock, and to administer the entire enterprise. As the stylized railroad organizational chart (Figure 8.3) shows, this technology produced a huge expansion in the division of labor, far beyond specialization on the longest canals. Differentiated work produced differences in pay, job security, and safety. A canal boat captain and a helmsman shared many of the same occupational risks; the same was not true of a railroad conductor and a brakeman, much less a station agent or superintendent and a brakeman. The weak American liability regime meant that the costs of dangerous work were primarily borne by employees.

As railroads developed different aspects of their technology to move more traffic quickly, they placed productivity in a race against their employees' job quality. Double-acting brakes and kerosene lamps could have improved safety for brakemen or reduced collisions in low light, but they also allowed railroads to run faster trains with fewer brakemen, and to operate at night. More freight and passengers in longer trains improved productivity, which might translate into higher earnings—but also meant more coupling, more braking, and a greater potential for collisions. American railroads spent the remainder of the 19th century slowly groping towards safety improvements while rapidly increasing their carrying capacity. The race between productivity and job quality continues in the next chapter, with a new player, the unions, and an unlikely referee: government regulation.

Figure 8.3: Organizational Chart of a Railroad, c. 1850



Sources: Elaboration from Churella, *The Pennsylvania Railroad* (University of Pennsylvania Press, 2012), 390 and manuscript sources in the Bibliography

Table 8.1: Task Range and Bundles by Transportation Technology, Infrastructure Maintenance

Municipal Roads	Turnpikes	Canals	Railroads
• Clearing brush and trees • Filling ruts or potholes • Bridge repairs (rare, frequently wood) • Cost accounting (very limited)	• Clearing brush and trees • Filling ruts or potholes • Clearing ditches • Cambering road surface • Bridge repairs (frequently wood) • Spreading gravel • Gatehouse repairs • Cost accounting	• Bank inspections • Clearing towpath • Repairing breakages • Repairing viaducts/aqueducts • Draining canal • Clearing base of canal when dry • Lock repairs (usually masonry) • Labor supervision • Cost accounting • Tool inventory	• Line inspections • Filling washouts and clearing landslides • Refilling ballast • Replacing ties and rails • Bridge repairs (wood or masonry) • Station repairs (usually wood) • Shop, roundhouse, turntable repairs • Tunnel repairs (wood and masonry) • Clearing obstacles (trees, snow) • Switch mechanism maintenance • Signal maintenance (block signaling) • Repair materials and tool procurement • Tool inventory • Labor supervision • Cost accounting

Sources for Tables 8.1–8.3: See the text of Chapters 7 & 8.

Table 8.2: Task Range and Bundles by Transportation Technology, Service Operation

Municipal Roads	Turnpikes	Canals	Railroads
Coach Driver: • Riding horse or driving stagecoach • Lifting luggage or packages • Signaling town arrival • Taking fares • Feeding animals	Coach Driver: • Riding horse or driving stagecoach • Lifting luggage or packages • Signaling town arrival • Taking fares • Feeding animals Gatekeeper: • Opening gate • Toll taking Clerk: • Toll accounting • Share and dividend accounting	Boat Crew: • Bow lookout • Warning of obstructions • Steering • Minding animal team • Feeding animals • Loading and unloading luggage • Loading and unloading freight • Taking passenger fares • Collecting freight payments • Passing operations • Cooking for and feeding passengers • Cleaning galley • Preparing bunks Land Workers: • Locking • Collecting boat charges	• Timetabling • Dispatching orders • Setting switches • Setting signals • Pre-run locomotive inspection • Coupling • Signaling for braking, stops • Car braking • Speed control (throttle, Johnson bar) • Stacking fire • Refueling (wood/coal, water) • Shunting • Composing trains • Freight consignment paperwork • Loading and unloading freight cars • Collecting fares • Station cleaning • Weather reports • Taking tickets • Providing travel information • Announcing stations • Loading and unloading passenger baggage • Cooking for and feeding passengers • Preparing sleeper cars • Cleaning dining car • Cleaning passenger cars • Telegraphy • Cost accounting • Rolling stock procurement • Fuel purchases

Table 8.3: Task Range and Bundles by Transportation Technologies, Vehicle Maintenance

Municipal Roads	Turnpikes	Canals	Railroads
• Shoeing horses • Feeding horses • Coach repairs (wheels, axles, straps/suspension, doors) • Harness repairs	• Shoeing horses • Feeding horses • Coach repairs (wheels, axles, straps/suspension, doors) • Harness repairs	• Shoeing mules (sometimes) • Feeding mules • Boat repairs • Boat cleaning • Harness repairs	• Rolling stock inspections • Firebox cleaning • Exterior cleaning • Boiler & flue washing & repairs • Cylinder repairs • Piston replacement/repairs • Wheel maintenance & tire replacement • Smokestack cleaning • Gauge cleaning • Whistle cleaning/repairs • Water tank maintenance • Axle & truck maintenance • Coupler repairs • Car body & frame repairs

Table 8.4: Occupational Quality for Railroad Workers, 1850

Occupation	Daily Wage ($)	CN ($)	*w*	Hours/ Week	Wkg. Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
Blacksmith	1.43	0.08	4.49	51.70	3.02	4	3	3	3	3	2	2.94	3.42
Blacksmith's Helper	0.91	0.08	3.78	51.70	3.02	4	3	3	2	3	1	2.45	3.04
Brakeman	1.11	0.08	4.25	60.38	2.48	4	1	4	3	2	2	2.40	2.93
Car Builder	1.68	0.08	5.13	61.60	2.40	4	3	4	3	3	2	3.09	3.36
Carpenter	1.38	0.08	4.77	62.70	2.33	4	4	4	3	3	2	3.24	3.30
Clerk	1.33	0.08	4.72	69.00	1.94	5	5	4	3	4	3	3.91	3.30
Conductor	1.70	0.08	5.02	60.38	2.48	4	3	4	4	3	3	3.46	3.50
Engineman	1.96	0.08	5.31	60.38	2.48	4	3	4	4	3	3	3.46	3.57
Fireman	1.15	0.08	4.31	60.38	2.48	4	3	3	3	2	1	2.45	2.97
Foreman	1.31	0.08	4.68	65.55	2.15	4	4	5	4	4	3	3.96	3.42
Laborer	0.88	0.08	3.89	60.38	2.48	3	3	4	2	2	1	2.29	2.80
Master Mechanic	2.83	0.08	6.54	66.00	2.13	5	4	4	5	4	4	4.31	3.91
Mechanic	1.40	0.08	4.83	63.80	2.26	5	3	4	3	3	2	3.20	3.27
Mechanic's Helper	0.86	0.08	4.00	63.80	2.26	4	3	4	2	3	1	2.57	2.86
President	9.59	0.08	11.20	72.00	1.75	5	5	4	5	3	4	4.26	4.37
Sawyer	0.76	0.08	3.80	65.55	2.15	4	3	5	2	2	1	2.49	2.73
Station Agent	1.98	0.08	5.54	69.00	1.94	5	4	4	4	4	3	3.96	3.49
Superintendent	5.61	0.08	8.80	72.00	1.75	5	5	4	5	3	4	4.26	4.03
Switchman	0.82	0.08	3.92	69.00	1.94	3	3	5	2	3	2	2.85	2.79
Ticket Clerk	1.44	0.08	4.87	69.00	1.94	4	5	4	3	4	3	3.77	3.29
Watchman	0.94	0.08	3.99	63.00	2.31	4	5	5	3	3	2	3.49	3.18

Sources: Chapters 2, 8, Appendix 1, manuscript sources in the Bibliography, Allen et al (2011), Allen (2015), UC-Davis Global Prices and Incomes Database. Notes: Hours/Week figures use scheduled hours and archival evidence of days worked per week. Time series for brakemen, firemen, enginemen, conductors, and laborers are in Tables 9.3–9.7.

Chapter 9
The Golden Age of Steam?
American Railroads, 1860–1910

Chapter Abstract

The final section of the transport case study examines the effects of a wide range of microinventions on American railroads in the late 19th and early 20th century. Many aspects of railroad technology changed in this period, which increased productivity but had mixed effects on safety and intensity. Railroads carried larger traffic volumes that strained bridges and challenged train control systems, leading to accidents and collisions. Railroad managers were quick to adopt safety-improving technology for passenger services, where deaths and injuries caused reputational damage and reduced revenues. However, the adoption of safe couplers and braking systems on freight traffic, where most on-train railroaders were employed, took far longer. Moreover, many technologies that could improve safety such as steel rails and air brakes also enabled railroads to run longer, faster trains, which counteracted improved safety. Railroad workers also formed unions in this period and enjoyed two periods of significant pay increases, separated by several decades of stagnation. Higher wages were the main driver of improved job quality for most workers, as hours barely changed. Continued growth in demand for transportation services expanded the number of jobs available in railroading, but work with the iron horse remained the preserve of white men.

Introduction

The late 19th and early 20th century saw the heyday of rail transportation in the United States. Railroads were among America's biggest corporations and they employed hundreds of thousands of workers to transport people and freight. Later challengers to steam traction—automobiles and airplanes—only made a small impact at the end of this period. As in Chapters 4 and 6, this chapter shifts to analysis of smaller technological changes. There was a much wider array of technical developments in this sector than in spinning, and their main direct impact on job quality was through occupational safety. Railroading from the Civil War to World War I saw inventions such as automatic couplers and air brakes that offered the potential to reduce injuries and deaths, but adoption was slow. Safety regulation emerged from an unlikely source: outrage over railroad rates led to the establishment of the federal Interstate Commerce Commission in 1887. The regulators were appointed to control pricing for freight, but passenger deaths created public pressure to require accident reporting. Reports provided evidence for campaigners to demand railroads adopt safety-improving technology.

Despite their promise, innovations like the air brake did not eliminate risk. Some mitigated the chance of injury with constant operational practices, but they allowed railroads to operate longer trains at higher speeds. Faster locomotives and heavier rolling stock partially negated safety improvements. The net effect was that American railroads remained more dangerous than many other jobs in the United

States and rail transport in other countries.[1] The race between productivity and safety was a tight contest, and improvements in job quality over this period were almost entirely driven by rising wages. Railroaders continued to work long hours in tiring conditions, and firemen experienced increased intensity from fueling larger locomotives.

The first section of the chapter discusses changes to infrastructure technology and how they impacted work. The second section considers major shifts in rolling stock, principally the development of more powerful locomotives and larger cars, as well as more specialized equipment. The third section describes three areas where technology intersected with regulation: air brakes, automatic couplers, and boiler inspection. The following, shorter sections present evidence on other components of job quality and discuss the development of railroad unions. The final sections outline the continuing growth of the railroad labor force, the share of different railroad occupations, and demographic data for employees.

Infrastructure

Changing technology in American railroading had its most immediate and significant effects on safety. In 1889, the employee fatality rate was almost 50% higher than in Britain, even though British railroads carried more traffic per distance, and work accidents were the most common cause of death for American railroaders.[2]

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[1] James Weinstein, *The Corporate Ideal in the Liberal State, 1900–1918* (Boston: Beacon Press, 1968); Mark Aldrich, *Death Rode the Rails: American Railroad Accidents and Safety, 1828–1965* (Baltimore: Johns Hopkins University Press, 2006).

[2] *Safety First: Technology, Labor, and Business in the Building of American Work Safety, 1870–1939* (Baltimore: Johns Hopkins University Press, 1997), 17. Unlike US railroads, most British traffic was passenger services. *Death Rode the Rails*, Appendices 1 & 2. Aldrich constructs figures on

Occupational risks had many sources, but derailments and collisions remained the most-discussed parts of railroad safety because they endangered passengers, though smaller accidents caused many worker injuries and deaths.

Steel Rails

Rail quality remained an important cause of derailments. The iron T-rail was nearly ubiquitous on Northeastern railways by 1860, but even fully iron rails curled up under heavy use, causing crashes and injuring or killing workers.[3] The Pennsylvania Railroad (PRR) led the shift to steel rails during the war, but most railroads were slow to follow. Over the last third of the 19th century more railroads replaced worn-out iron rails with steel, and by 1900 almost all newly laid track was steel. However, iron rails were often retained on quieter routes.[4] Mirroring developments with iron rails, railroads gradually purchased heavier and higher quality steel rails.[5] Despite the shift towards steel, derailments increased in the 1890s and 1900s. The railroads blamed steel manufacturers for low-quality rails, while manufacturers responded that railroads were running too much traffic over poor

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fatalities from state railroad commissions, but includes cautionary notes about coverage. The commissions did not record injuries. State-reported fatalities fluctuated, but the employee death rate was 1.69 per 1000 in 1860 and 1.68 in 1900. There were fatality peaks in 1866 (3.79), 1872 (3.41), and 1882 (3.55). National (not Northeastern) fatalities per trainman were 25% lower in 1910 than 1900, but injuries to all workers were 50% higher.

[3] Thomas Weber, *The Northern Railroads in the Civil War, 1861–1865* (New York: King's Crown Press, 1952), 44, 63–65.

[4] *Northern Railroads*, 82, 231. Ellis L. Armstrong, Michael C. Robinson, and Suellen M. Hoy, *History of Public Works in the United States, 1776–1976* (Chicago: American Public Works Association, 1976). Jeremy Atack and Jan K. Brueckner, "Steel Rails and American Railroads, 1867–1880," *Explorations in Economic History* 19, no. 4 (1982). Steven W. Usselman, *Regulating Railroad Innovation: Business, Technology, and Politics in America, 1840–1920* (Cambridge: Cambridge University Press, 2002), 94–96.

[5] *Regulating Railroad Innovation*, 215–17.

roadbeds. Railroads mitigated the problem by using heavier rails and changing locomotive design to reduce rail stress.[6] Steel rails could have made work much safer, but they also allowed railroads to operate heavier locomotives pulling heavier, longer trains.

Bridges

Heavier trains also strained American railroad bridges, which were commonly wood-built trusses. From 1865, wood for ties and bridges was pressure-treated with creosote to improve durability. Even so, American bridges were relatively dangerous by comparison with European infrastructure. Many early metal bridges were prefabricated, used link-and-pin connectors instead of rivets, and did not include floors. Moreover, American railroads rarely inspected bridges and spent little on maintenance. Rising traffic volume placed these structures under increasing, excessive strain in the late 19th century, and many failed. In the 1870s, the American Society of Civil Engineers began to campaign for bridge inspection and improvement. Engineers compiled statistics of bridge collapses and highlighted railroads' cheap but dangerous design choices. This push eventually led state governments to require bridge inspections, beginning in New York in 1883. Inspections rapidly identified many dangerous bridges and demanded railroads improve or replace them.[7]

[6] Aldrich, *Safety First*, 179–83.
[7] "Engineering Success and Disaster: American Railroad Bridges, 1840–1900," *Railroad History*, no. 180 (1999). Armstrong, Robinson, and Hoy, *Public Works*, 109, 40.

Grade Crossings

The growth of road traffic at the end of this period increased accidents at grade crossings. In response, railroads eliminated grade crossings entirely using road underpasses or overpasses, installed warning signs or gates, and hired gatemen to patrol high-traffic crossings. Flagmen and gate-tenders tediously cranked gates up and down and controlled the flow of traffic. Heavier and faster engines could smash through cross-traffic, but accidents were a potentially traumatic experience for crews and required repairs and accident reporting. Rapid braking to avoid collisions could also throw baggage or freight around and cause injuries.[8]

Railroad Stations

Railroad premises changed with increasing scale and standardization. Haphazardly-built early stations and repurposed residential or commercial buildings gave way to distinctive styles that drew on vernacular housing design, incorporating high gables and large windows. A common late-century station had three rooms: a passenger waiting room at one end, an office in the center, and a baggage room at the opposite end. The office frequently had a bay window overlooking the platform to give the station agent a view of the tracks. Some stations also included accommodation for the agent on a second floor and a tower with an office from which a telegrapher could see arriving and departing trains.[9]

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[8] John R. Stilgoe, *Metropolitan Corridor: Railroads and the American Scene* (New Haven: Yale University Press, 1983), 167–88.
[9] Jeffrey Richards and John M. MacKenzie, *The Railway Station: A Social History* (Oxford: Oxford University Press, 1986), 51. Janet Greenstein Potter, *Great American Railroad Stations* (New York: Wiley, 1996), 11–12.

More impressive were the grand city stations that displayed Italianate, Gothic, Romanesque, and Neoclassical styles. These transportation palaces, like New York's Grand Central Terminal and Penn Station, incorporated a wide range of services, from restaurants to shops, information kiosks, hotels, and even theatres, and railroads competed to build the largest and most impressive stations. More passengers and platforms required expanded stations to accommodate the flow of people and goods.[10] Increasing recreational travel meant more luggage. American railroad passengers could bring up to 150 pounds of baggage without a surcharge, and travelers took full advantage, which meant heavy work for porters that could delay trains.[11] Architects added trainsheds to city stations, which briefly sheltered travelers and workers from the weather.[12] Most coverings used iron or steel framing to hold glass that admitted light, but trainsheds also held in locomotive exhaust and noise. Smoke corroded structural iron and blackened the glass, requiring expensive cleaning and maintenance.[13]

Signaling

With larger termini, stations, and more traffic came more train control problems and potential for deadly collisions. Methods advanced, but as in other areas, widespread adoption lagged far behind the technological frontier. In the 1860s, almost

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[10] Richards and MacKenzie, *Railway Station*, 40–47.
[11] Albro Martin, *Enterprise Denied: Origins of the Decline of American Railroads, 1897–1917* (New York: Columbia University Press, 1971), 34. Sarah Gordon, *Passage to Union: How the Railroads Transformed American Life, 1829–1929* (Chicago: Ivan R. Dee, 1996), 232–33.
[12] Carroll L. V. Meeks, *The Railroad Station: An Architectural History* (New York: Dover Publications, 1995), 35–39, 114–16.
[13] Richards and MacKenzie, *Railway Station*, 40–47. Potter, *American Railroad Stations*, 35–36.

all trains ran to timetables and paper orders. Heavy traffic during the Civil War led some roads to install double-track, which allowed higher throughput and lowered the risk of collisions, but double-tracked roads were a minority. Telegraphy was hardly used until the beginning of the 1850s and only became somewhat common in the 1860s. It finally allowed rapid communication between stations, although direct communication with moving train crews was still impossible. The telegrapher or station agent transcribed orders received in Morse Code and passed them to the crew by hand or at the end of a stick for the engineman to grab as the train passed. A copy of the orders was sometimes given to the conductor in the same way.[14]

A few railroads tested telephones for dispatching in the 1870s, but adoption was slow until the first decade of the 1900s. Railroads already had timetables, paper orders, and telegraphs for communicating signals, and telephony was a new expense, with higher installation costs for isolated stations. Moreover, it took until the early 20th century for telephone companies to design apparatus that enabled direct communications between individual stations and dispatchers, as a railroad telephone cable otherwise functioned like a party line. Once these problems were resolved, telephones allowed better communication than telegraphy in the small share of stations where they were adopted.[15] The main system for controlling trains remained timetables and orders into the 1900s. After the economic recovery of the mid-1890s,

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[14] Hans Halberstadt and April Halberstadt, *The American Train Depot & Roundhouse* (Osceola, WI: Motorbooks International, 1995), 33. John H. White, *The American Railroad Freight Car: From the Wood-Car Era to the Coming of Steel* (Baltimore: Johns Hopkins University Press, 1993), 83–84.

[15] Warren H. Hay, "The Beginnings of Telephone Dispatching," *Railroad History*, no. 130 (1974); C. H. Gaunt, "Train Dispatching by Telephone," *Santa Fe Employes' Magazine* 3 (1909); J.C. Field, "Dispatching Trains by Telephone," *Bell Labs Record* 3, no. 4 (1926).

rising rail traffic was accompanied by increasing collisions. The popular and engineering press argued that railroads needed to upgrade train control systems, specifically with block signaling.[16]

This form of signaling separated lines into segments called 'blocks' that, if the dispatcher's information was correct, could safely be assigned to a train. American railroads usually used masts with paddles for 'go', 'caution', and 'stop'. In manual block signaling, the station agent changed the signal using a lever when he received instructions via telegraph from the dispatcher. At night, railroads used colored lamps (white for go, green for caution, and red for stop). A related development, the interlocking of signals and switches, ensured that signals matched switch positions. Relatively high wages for telegraphers compared to European railroads were one factor that delayed the adoption of block signaling, along with lower traffic volumes and speeds.[17] However, manual block signaling remained reliant on human accuracy.

Automatic block signaling eliminated human error by running electrical current through each block. When a locomotive entered the block, the current would travel through the wheels and axles, shorting the circuit and closing the signal for that block (indicating stop to the next train). Automatic block was slowly adopted in the 1890s and 1900s, first on main lines with high traffic volume, and more widely after 1910. However, in 1906 only about 20% of American rail mileage used manual block signaling and less than 4% used automatic signaling. This rose to 38% under both

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[16] Aldrich, *Safety First*, 168–71.

[17] *Safety First*, 21. White, *American Freight Car*, 84. Interstate Commerce Commission, *Report of the Interstate Commerce Commission on Block-Signal Systems and Appliances for the Automatic Control of Railway Trains*, 59th Congress, 2nd Session Senate Doc. 342 (Washington: Government Printon Office, 1907), 6–8.

forms of block signaling by 1915. Train control on the rest of the network was still by timetables and paper orders.[18]

Collisions were not only caused by primitive train control, but human error, including workers ignoring signals. The solution—automatic train control—was developed in the 1920s and implemented on some commuter routes after the Second World War. Aldrich argues that the frequent collisions in the first decade of the 1900s were caused by high traffic volumes and rising speeds (or dangerous speeds by enginemen), partly enabled by air brakes. Falling collision rates thereafter, which continued up to the Second World War, were primarily the result of more modest traffic and block signaling.[19] High throughput with antiquated train control systems raised productivity, but it also endangered workers.

Rolling Stock

The main changes in rolling stock technology were the development of larger and more specialized locomotives and cars. In turn, railroads increased the demands on equipment by loading cars more heavily and expecting locomotives to pull longer trains. Increased scale required better materials and component design. The cutting edge of railroad technology advanced substantially, though older locomotives and cars remained in service into the 20th century on minor lines.

[18] White, *American Freight Car*, 84–86. Aldrich, *Safety First*, 174–77.
[19] *Safety First*, 176–78.

Locomotives

The basic working of a steam locomotive—a fire boiling water that pushed pistons in cylinders to turn the driving wheels—remained, but there was extensive innovation to increase hauling power. In the 1860s, coal replaced wood as fuel because of lumber shortages that resulted from wartime demands and incipient deforestation.[20] Coal fires produced fewer sparks and coal's higher energy density enabled longer running.

Thereafter, the main technological change in motive power was visible: bigger engines with more driving wheels and longer tenders pulled longer and heavier loads. The traditional American 4-4-0 design was ubiquitous in 1860, but by the end of the period 2-8-2 and 2-8-0 arrangements were common in freight traffic.[21] At the very end of the period the first articulated locomotives entered service. Articulation placed additional driving wheels and a second pair of cylinders on a forward engine unit under an elongated boiler, linked to the cab section with a hinge pin. This allowed longer, more powerful engines to take corners with less damage to wheels and rails.[22] Fueling these locomotives required much more work from firemen, and enginemen had to control faster, heavier, slower-braking locomotives carrying larger loads. Even locomotives with the same wheel arrangements were improved to increase tractive force by as much as 80–90%.[23]

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[20] Albert J. Churella, *The Pennsylvania Railroad* (Philadelphia: University of Pennsylvania Press, 2013), 292. Weber, *Northern Railroads*, 44, 55–56. Louis C. Hunter, *A History of Industrial Power in the United States, 1780–1930*, vol. 2 (Charlottesville: University Press of Virginia, 1985), 402–07.

[21] John H. White, *Introduction of the Locomotive Safety Truck* (Washington: Smithsonian Institution, 1961), 126–29. Martin, *Enterprise Denied*, 61–67.

[22] John F. Stover, *American Railroads* (Chicago: University of Chicago Press, 1961), 164–66.

[23] Martin, *Enterprise Denied*, 67.

Building larger locomotives required improvements to many components, including firebox design, valve gears, and compound cylinders.[24] The Bessemer process made steel cost-effective for locomotive building, and it became the primary material for boilers after 1890, although components such as tires had been made from steel in the 1870s. By the early 20th century, new locomotives were generally all-steel.[25] Inside the cab, American railroads began to adopt the glass gauge to measure boiler water levels in the last third of the 19th century, although it was far from ubiquitous even by the 1890s.[26]

Although many aspects of railroad technology became more standardized, locomotives still varied widely. Railroads demanded different features and locomotive builders could only improve performance with new designs. Technical variations challenged enginemen and firemen who moved between railroads or changed locomotives, and complicated work for machinists who had to locate the correct tools and parts for maintenance.[27]

The Mechanical Stoker

Larger locomotives with more driving wheels required more steam, which had to be produced from a larger boiler and fire. To fuel that fire, the fireman had to shovel more coal from the tender into the firebox. By the first decade of the 20th century, a

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[24] *Enterprise Denied*, 65. Compound cylinders used steam twice, first in smaller high-pressure cylinders, and then larger low-pressure cylinders. Valve gears calibrated when steam should enter the cylinder to optimize the piston stroke.
[25] John H. White, *American Locomotives: An Engineering History, 1830–1880* (Baltimore: Johns Hopkins University Press, 1997), 32.
[26] *American Locomotives*, 133.
[27] John K. Brown, *The Baldwin Locomotive Works, 1831–1915: A Study in American Industrial Practice* (Baltimore: Johns Hopkins University Press, 1995), 57–59, 74–75.

heavy freight locomotive could require 5000 pounds of coal each hour.[28] Some early articulated engines had two firemen shoveling coal through a pair of fire doors to keep up with the cylinders' demand for steam. To cope with the increased demand for fuel, engineers developed the mechanical stoker. It used steam-powered paddles or a screw in a cylinder under the tender and cab to feed coal into the firebox. This innovation changed the fireman's work on a super-large locomotive from shoveling to controlling and directing the flow of fuel, satisfying the cylinders' demand for steam and maintaining an even fire. Like the self-acting mule, it reduced the physical strain of work, but did not eliminate an occupation that required experience for efficient operation. The Brotherhood of Firemen lobbied railroads to adopt stokers because they reduced workloads, improved safety by allowing firemen to sit for much of a run with the fire door closed, and reduced the demand for cleaning.[29]

Electrification

Experiments with electric traction began in the late 1840s using battery-powered locomotives pulling a handful of passengers over short distances. After decades of development, demonstrations at expositions, and use on urban trolley services and branch lines, the Baltimore & Ohio Railroad (B&O) opened the first four-mile section of electrified interurban main line in 1895. Electric locomotives were ideal for long tunnels and around city terminals because they eliminated the dangerous, choking smoke that obscured the engineman's view and caused accidents. Eliminating

[28] Aldrich, *Safety First*, 171–72.
[29] William L. Withuhn, *American Steam Locomotives: Design and Development, 1880–1960* (Bloomington, IN: Indiana University Press, 2019), 170–71. Mechanical stokers were mandated by the ICC for large locomotives in 1939.

or reducing smoke and steam also reduced corrosion in tunnels or stations.[30] However, electrification also had dangers: maintenance workers could fall while repairing overhead wires or be electrocuted by high-voltage third rails.[31]

The first electric locomotives were rectangular boxes with sloping ends. They were joined by electric multiple units which resembled steel passenger cars with a cab at one end and electric motors under the car. Locomotives grew rapidly, from B-B (with two trucks each containing two powered axles) on the first B&O locomotive to B-B+B-B on the New York Central by 1913. Removing the tender allowed for easier and safer bi-directional running with improved visibility from the cab, and electric locomotives had windows facing both directions.[32] Electrics did not require master mechanics and machinists with knowledge of boilers, cylinders, and steam locomotive design, and operated with one motorman instead of an engineman and fireman. However, the infrastructure cost of electrification limited adoption to high-traffic lines into major cities and a handful of very long tunnels. American railroads did not substantially reduce their locomotive manning until the age of diesel.

Passenger Cars

The passenger car's design changed relatively little for several decades after the addition of the clerestory roof in the 1860s. Cars had seats facing parallel to the direction of travel, a central aisle, and covered porches with side-steps for access and

[30] William D. Middleton, *When the Steam Railroads Electrified* (Milwaukee: Kalmbach Books, 1974), 12–36. *When the Steam Railroads Electrified*, 38–53, 114–30, 48–53.
[31] Aldrich, *Safety First*, 84. Third rails were more dangerous but less common than overhead wires. Railroads used protective covers for third rails to reduce the risk of electrocution. Middleton, *When the Steam Railroads Electrified*, 416–17.
[32] *When the Steam Railroads Electrified*, 25–54.

egress at each end. Size was also stable from the 1860s to the 1880s: 50–60′ long holding 50–60 passengers.[33] Despite the clerestory, complaints about poor air continued through the 1890s, and railroad cars were widely considered one of the worst-ventilated public accommodations. Introducing fresh air without dust and locomotive exhaust entering cars was difficult. New systems that brought air in through vents at the end of the car were introduced in the late 1890s on premier branded services like the Pennsylvania Railroad's *Federal Express* between Boston and Washington. These features slowly trickled down to common services.[34] The introduction of dining and parlor cars made the danger of walking between cars on a moving train more salient. The vertical end frame or 'vestibule' first introduced by the PRR in 1887 provided a flexible tunnel at the end of each car that attached to the next car that provided a safe route.[35] Other improvements to elite services included steam heating, toilets, and gas or, later, electric lighting. These developments were first introduced around the 1880s and were common on branded services by 1900.[36]

Wood remained the main construction material because of its cheapness, but wooden cars were flimsy: they could 'telescope' into another car when hit from behind or be torn apart by sharp accelerations.[37] By the 1870s and 1880s, wood supplies in the Northeast were dwindling and car builders found it difficult to build larger wooden

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[33] John H. White, *The American Railroad Passenger Car* (Baltimore: Johns Hopkins University Press, 1978), 30–31.
[34] *American Passenger Car*, 401–07. Theodore W. Fisher and William Ripley Nichols, *Ventilation of Railroad Cars: With Chemical Analyses* (Boston: Wright & Potter, 1875). Charles Benjamin Dudley, *The Passenger Car Ventilation System of the Pennsylvania Railroad Company* (Altoona, PA: The Pennsylvania Railroad Company, 1904).
[35] August Mencken, *The Railroad Passenger Car: An Illustrated History of the First Hundred Years, with Accounts by Contemporary Passengers* (Baltimore: Johns Hopkins Press, 1957), 32–34. White, *American Passenger Car*, 447–51.
[36] *American Passenger Car*, 380, 90–94, 415–26, 29–30. Mencken, *Railroad Passenger Car*, 54.
[37] *Railroad Passenger Car*, 37–41.

cars. The first response was composite wood-metal cars, but public pressure pushed car builders towards all-steel models. Steel had shown its value on freight traffic by the 1890s, providing higher capacity, and the above-discussed deadly accidents in the 1890s were a further impetus towards adopting a safer material. From about 1905, most new cars on named services were steel, although wooden cars remained in extensive use on branch lines and non-branded services.[38] Early steel cars looked like late 19th century wood cars: they were only slightly larger (perhaps 80′ long instead of 70′, with a slight increase in height to 14′), with a clerestory and similar window dimensions. Public expectations that steel cars would prevent in-car fatalities were misguided: in some cases they provided little more protection than wooden cars, as the bottom frame was very solid but the upper body was not, and telescoping remained a risk.[39]

Premier services used the newest and best rolling stock, which had the best amenities, safety features, and more frequent maintenance. By contrast, older coaches and locomotives ran on less prestigious services and minor lines.[40] The wide variation of cars in use meant that employees on passenger traffic experienced different working conditions depending on which services they worked, although the slow replacement of rolling stock probably improved conditions modestly.

[38] White, *American Passenger Car*, 44–49, 130–31.
[39] *American Passenger Car*, 148–51.
[40] Gordon, *Passage to Union*, 220–21.

Specialized Passenger Cars and Services

Competition for elite long-distance travelers led railroads to purchase a variety of luxurious specialty cars, including sleepers, diners, and parlors. These and first-class passenger cars were staffed by more service workers and, as described above, incorporated the newest safety features. After abortive efforts to make sleeping cars a commercial success in the antebellum period, overnight rail travel became popular in the late 19th century. From the 1870s, sleeping cars had compartments that opened onto an interior corridor, allowing passengers and crew to move along the car. Lounge and parlor cars were places for relaxation with luxurious furniture and exquisitely appointed interiors. Some new cars included a small conductor's berth with a linen closet, wine store, wardrobe, wash basin, and desk.[41]

The turn-of-the-century dining car was supervised by a steward, always a white man and frequently hired from the hospitality sector. He greeted passengers, seated them, and provided menus. The rest of the staff—a chef, perhaps three cooks, and four to six waiters—were frequently African-Americans. The kitchens were small: about 4' wide and 15' long, to accommodate a passenger walkway along the car. The food was usually separated into portions before it was loaded onto the train because of the space and time limitations of railroad cooking.[42] Meal service required waiters to sidle along the car carrying heavy platters of food while the train traveled 50 or 60 mph over bumps or around curves. The waiters served three meals daily and

[41] Mencken, *Railroad Passenger Car*, 55–73. White, *American Passenger Car*, 323, Chs. 3, 4.
[42] Eric Arnesen, *Brotherhoods of Color: Black Railroad Workers and the Struggle for Equality* (Cambridge: Harvard University Press, 2001), 19–20.

sometimes mid-morning or mid-afternoon sittings, which kept them occupied for nearly the whole day serving, clearing, and cleaning.[43]

Many workers on sleeper services were employed on Pullman cars, which were a unique labor arrangement: the employees worked for the Pullman Company, not the railroad.[44] From the company's founding in 1867 George Pullman employed African-American men as porters and women as maids, under white supervisors. His choice was based on racist stereotypes about African-Americans as servants and the fact that they could be paid low wages. Each Pullman car had one porter and each train of Pullmans had a maid for the female passengers.[45] Porters' hours were long, and they were only paid for the time the train was in motion, even though they needed to report hours before departure to load luggage and prepare the cars, and stay to unload luggage at the destination.[46] Despite these extended shifts, sleeping car attendants frequently had no chance to sleep on long runs and could only rest sitting up while on call. Dining car stewards received berths, but waiters and cooks had to sleep on the tables or in the baggage car.[47]

Pullman porters were frequently treated with contempt by white passengers, who called porters 'George'—a carryover from when slaves were addressed by their enslaver's name. Nonetheless, like all customer-facing roles on railroads they were

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[43] *Brotherhoods of Color*, 20.
[44] Martin, *Enterprise Denied*, 31–32.
[45] Robert L. Allen and Joyce Henderson, *The Brotherhood of Sleeping Car Porters: C.L. Dellums and the Fight for Fair Treatment and Civil Rights* (Boulder: Paradigm Publishers, 2015), 23–24. Brailsford Reese Brazeal, "The Brotherhood of Sleeping Car Porters: Its Origin and Development" (Columbia University, 1946), 1–5. Arnesen, *Brotherhoods of Color*, 16–18. Pullman porters frequently received tips, but amounts varied widely.
[46] Allen and Henderson, *The Brotherhood of Sleeping Car Porters*, 24–26.
[47] Arnesen, *Brotherhoods of Color*, 21.

expected to be courteous, even obsequious.[48] Passenger complaints or violations of rules could be punished by suspensions, and employees had the cost of broken or missing plates, glassware, silverware, and pillows or linen deducted from their pay. Sometimes African-American workers were searched for railroad property by railroad police detectives, and they were occasionally the targets of racist violence by white passengers and crew.[49] However, railroad service was a long-term consistent employment, and one of the better jobs open to African-Americans.[50]

The new sleeping, dining, lounge, and other specialized cars employed more workers per passenger, but they remained a small share of passenger business. Most employees in passenger service were conductors and brakemen in day cars.

Freight Cars

Freight car developments paralleled many changes to passenger rolling stock: builders gradually replaced wood with iron and then steel, built longer cars, and railroads added specialized rolling stock. Starting in the 1850s freight cars were reinforced with iron rods and metal bottom frames to handle extreme pulling and torsional forces. Car builders also attempted crude waterproofing by applying double layers of wood and then metal sheets to the roof and sides of boxcars. Iron and then steel was first used for hopper or gondola cars that carried very heavy loads like coal and minerals. Steel trucks to hold the axles, improved suspensions, and wider axles all contributed to more durability and a smoother journey. Steel-plate cars could

[48] *Brotherhoods of Color*, 18.
[49] *Brotherhoods of Color*, 20–21, 23.
[50] *Brotherhoods of Color*, 23–24.

handle much larger volumes of bulky goods such as coal, sand, and ore, but larger cars took longer to load and unload.[51]

Traditional traffic like coal, other minerals, wood, and grain remained the most common freight, but in late 19th century new types of goods were carried in specialized cars, including fresh food in refrigerated cars and petroleum in oil tank cars. The main freight rolling stock remained boxcars and coal cars, with flatcars the third most common type.[52] Exchanging cars across railroads was essential to integrating a national market for freight. Eliminating transshipping introduced more bureaucracy as railroads communicated the locations of their and other roads' cars and the final disposition of shipments. It also meant that trainmen and depot staff had to deal with a wider variety of rolling stock.[53]

A typical 1830s or 1840s freight train might have pulled 20 cars at 10 mph. By the 1850s, this had grown to around 30 cars, and in the 1870s, perhaps 40 cars. Trains pulling empty cars, which were lighter, stretched well over 100 cars in the 1880s, and multiple locomotives occasionally pulled more than 500 four-wheel coal cars by the end of the 1870s. These trains were more than a mile in length.[54] Speeds remained low, but long trains meant more cars for freight brakemen to clamber over when they heard the signal for 'down brakes'.

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[51] Martin, *Enterprise Denied*, 70–71. White, *American Freight Car*, 178–84, 212–29, 481–83, 87–89, 555–67.
[52] *American Freight Car*, 19–35, 121–23, 270–84, 362–76.
[53] *American Freight Car*, 55–61.
[54] *American Freight Car*, 68–69.

The Caboose

In the 1850s and 1860s American conductors had to keep accounts of ticket sales or freight offloaded at depots, but without office space. In the first decades of the railroads, they had to find a place to work on the fly, perhaps in an empty part of a passenger car or in the baggage car. The origins of the caboose are unknown, but it was surely developed from a boxcar and was used on some New York railroads by the late 1850s. The pace of adoption varied but it was common by 1880 at the latest. Purpose-built cabooses began as short, four-wheeled cars 10–12′ long, and they eventually included front and rear porches for safer access and egress. A coal or wood stove provided heat and kerosene lamps lit the interior. Early cabooses were called 'bobbers' because their rigid four-wheel chassis jostled over uneven track. The caboose was the freight conductor's office and a place to watch the rear cars of a long train. The rear brakeman stayed inside when he was not applying the brakes, flagging, or setting switches. Most importantly, it allowed some of the train crew to stay out of the elements for part of the journey. A cupola for observation was probably first added in the 1860s or 1870s, and became common after about 1880. The typical American freight caboose—in its classic red livery—included beds, desks, and storage for tools and lamps. Communicating between the caboose and the locomotive was usually done with whistle blasts and lantern signals. By the end of the 19th century it was 15–20′ long and some had two pairs of four-wheel trucks, which smoothed the ride. However,

'bobbers' remained in use on eastern roads because they had shorter freight runs. Unlike other cars, cabooses remained built from wood up to 1914.[55]

Regulating Safety-Improving Technology

Many rolling stock components developed as railroads sought to transport more goods and people quickly, but some important elements of car design only changed with state intervention. Government regulation in the early decades of railroading had been limited to financial matters. Most railroad charters circumscribed stock or debt issuance, required that the funds were used for construction, and controlled the use of eminent domain. Some charters or incorporation laws limited passenger fares, freight rates, and dividends.[56] Merchants and farmers angered by what they saw as unfair pricing for shipping freight led states to establish railroad commissions. Rhode Island set up the first commission in 1839, and most Northeastern states had a commission by 1860.[57] Commissions usually oversaw eminent domain, published financial statistics, and sometimes examined railroad safety to protect passengers.[58] Light-touch regulation aimed to protect financial stakeholders, property owners, perhaps passengers, but not workers.

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[55] Mike Schafer, *Caboose* (Osceola, WI: Motorbooks International, 1997), 9–20, 29. White, *American Freight Car*, 409–12. Brian Solomon and John E. Gruber, *Caboose* (St. Paul: MBI, 2001), 9–20.

[56] Lee Benson, *Merchants, Farmers, & Railroads: Railroad Regulation and New York Politics, 1850–1887* (Cambridge, MA: Harvard University Press, 1955), 2–7.

[57] Stover, *American Railroads*, 125. For detail on the state commissions, see Edward C. Kirkland, *Men, Cities and Transportation: A Study in New England History, 1820–1900*, vol. 2 (Cambridge: Harvard University Press, 1948), Chapters 22 & 23.

[58] Colleen A. Dunlavy, *Politics and Industrialization: Early Railroads in the United States and Prussia* (Princeton: Princeton University Press, 1994), 74–76. Aldrich, *Safety First*, 25.

This limited oversight lacked enforcement capabilities, even to control rate discrimination. Commissions could only highlight problems and pressure railroads to change their pricing.[59] In addition to their weak enforcement powers, the state railroad commissions were limited by the commerce clause. Even commissions that succeeded in equalizing freight rates between different types of traffic could only constrain railroad behavior within state borders.[60] The failure of the state railroad commissions to solve the rate problem in the 1870s and 1880s discredited a laissez-faire approach.[61]

After years of arguments based on sectionalism, ideology, and economic interests, Congress passed the Interstate Commerce Act in 1887, which set up the Interstate Commerce Commission (ICC). The Act empowered the ICC to regulate rates, it required financial reporting from railroads, and authorized the ICC to investigate ratemaking abuses.[62] The ICC accordingly focused on rate-setting and discrimination, and safety issues were at best secondary in its early years. Once the ICC began compiling accident and injury statistics in the 1880s, reformers used this data to lobby for federal regulation of safety devices.[63] The justification was twofold: safety regulation would protect passengers and it would ensure that railroads would not be disadvantaged by adopting safer technology. Legislators arrived at this

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[59] Frank Dobbin, *Forging Industrial Policy: The United States, Britain, and France in the Railway Age* (Cambridge: Cambridge University Press, 1994), 69–70. Aldrich, *Safety First*, 25–26.
[60] Ari Arthur Hoogenboom and Olive Hoogenboom, *A History of the Icc: From Panacea to Palliative* (New York: Norton, 1976), 7–8. Dobbin, *Industrial Policy*, 75–81.
[61] Benson, *Merchants, Farmers, & Railroads*, 24–28, 88–101. Dobbin, *Industrial Policy*, 72–74. Hoogenboom and Hoogenboom, *History of the I.C.C.*, 8–9.
[62] *History of the I.C.C.*, 13–17. *History of the I.C.C.*, 17–18. Interstate Commerce Commission, *Interstate Commerce Commission Activities, 1887–1937* (Washington, D.C.: Government Printing Office, 1937), 9.
[63] *I.C.C. Activities*, 117. Robert Dawson Kennedy, "The Statist Evolution of Rail Governance in the United States, 1830–1986," in *Governance of the American Economy*, ed. J. Rogers Hollingsworth, John L. Campbell, and Leon N. Lindberg (Cambridge: Cambridge University Press, 1991), 160.

principle slowly and unenthusiastically, but they eventually yielded to campaigns to regulate two of the most dangerous railroad components: brakes and couplers.[64]

The Air Brake

With increased tractive power came rising demand for more powerful braking systems.[65] This was a public relations problem in passenger traffic, where accidents caused reputational damage. The first air braking system was invented by George Westinghouse in 1867. It operated the brakes using a system of air tanks, with each car connected to the next by a hose. Compressed air was fed into the system from the locomotive, and the brakes were applied when the air pressure dropped. The engineman could release air using a lever in the cab. The system was fail-safe because in the event of an accidental decoupling a disconnected hose would expel air, reducing the pressure in the uncoupled cars and applying the brakes. Westinghouse's invention was adopted on most passenger trains by the late 1870s, but rarely on freight cars.[66]

Railroads did not have the same reputational concerns about accidents on freight trains or injuries to freight brakemen who fell when applying hand brakes. Freight trains were also heavier than passenger services, and managers were skeptical that air brakes provided enough stopping power. Moreover, it was an expensive technology to adopt, as Westinghouse had a monopoly on production, and the financial benefits were harder to calculate. There were also organizational and coordination problems. To use compressed-air braking, any freight service with air-

[64] Dobbin, *Industrial Policy*, 62–63.
[65] Nathan Rosenberg, *Technology and American Economic Growth* (New York: Harper & Row, 1972), 42–43.
[66] Aldrich, *Safety First*, 26–27.

and hand-braked rolling stock had to place the air-braked cars in an uninterrupted block behind the locomotive. Trains with cars that had both braking systems needed the same number of brakemen, preventing cost savings. If only a few railroads adopted air brakes, those roads would see little benefit as many freight cars were interchanged across railroads. Some western railroads adopted air brakes for freight service in the 1880s, but eastern railroads had gentler gradients and paid brakemen lower wages. Most callously, because of the weak protection for injured workers in American law, brakemen's injuries were not costly. Wage premia for dangerous jobs were modest, and there is little evidence of differences between firms based on their use of safety devices. Railroads saw little benefit to air braking, but high up-front costs and coordination problems.[67]

In response, the ICC organized a conference of state railroad regulators in 1889 that recommended Congress pass national safety legislation.[68] The Safety Appliance Act (1893) finally required railroads to replace handbrakes on locomotives with power (air) brakes, and install air brakes on enough freight cars to stop a train without the use of hand brakes. The act set a deadline of January 1898 for the changeover, although the ICC eventually allowed railroads until 1900 to comply.[69]

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[67] *Safety First*, 27–32. Steven W. Usselman, "Air Brakes for Freight Trains: Technological Innovation in the American Railroad Industry, 1869–1900," *The Business History Review* 58, no. 1 (1984). *Regulating Railroad Innovation*, 276–80.

[68] Hoogenboom and Hoogenboom, *History of the I.C.C.*, 19–33. Interstate Commerce Commission, *I.C.C. Activities*, 81.

[69] Hoogenboom and Hoogenboom, *History of the I.C.C.*, 33–34. Interstate Commerce Commission, *I.C.C. Activities*, 118–19. Legislation in 1903 and 1910 expanded the number of cars required to have air brakes. I. Leo Sharfman, *The Interstate Commerce Commission: A Study in Administration Law and Procedure*, vol. 1 (New York: The Commonwealth Fund, 1931), 251–52.

Even after railroads finally adopted air brakes, the new technology did not immediately eliminate braking issues. Railroads had agreed a low fee to maintain brakes on interchanged cars, which incentivized them to send cars that needed upkeep to other railroads. This problem was solved when the maintenance fee was raised in 1902. It also took several years for railroads to acquire enough tools to repair air brakes quickly, and sufficient equipment train new repairmen. The air brake probably had a modest effect on reducing fatalities, but it was tempered by railroads' use of longer, faster trains, as well as adoption problems.[70] The race between technology and safety was at best a narrow success for safety, at worst a draw.

With air brakes, the front or 'head-end' brakeman usually rode in the locomotive, acting as a flagman when needed and operating switches when a freight train picked up or dropped off cars. This meant that he had to jump on and off the train at regular intervals. He also helped the fireman pull coal down from the rear of the tender and lowered the water spout at stations to refill the tender reservoir. Brakemen remained responsible for coupling and uncoupling, as well as connecting or disconnecting the air brake hoses. The rear brakemen performed some of the same roles and could find shelter in the caboose when unoccupied, while the head-end brakeman was confined to the locomotive cab.[71] The conductor was responsible for monitoring air pressure gauges in the caboose to ensure that a faulty hose did not apply the brakes unnecessarily. Most railroads retained a mid-train brakeman, and all three brakemen could operate the hand brakes (which were retained) if necessary.[72]

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[70] Aldrich, *Safety First*, 37–38.
[71] White, *American Freight Car*, 73–74.
[72] *American Freight Car*, 74, 530.

Automatic Couplers

The second challenging microtechnological development that required regulatory intervention was the coupler. As discussed in the previous chapter, link-and-pin couplers were one of the most common hazards on railroads and a major cause of injuries to brakemen. Improved semi-automatic couplers were available to replace the hazardous link-and-pin system as early as the 1840s, and an automatic hook-style coupler, which was attached to a trussed metal platform that reduced the risk of telescoping, was introduced in the 1860s and quickly adopted on passenger trains.[73] Like other safety-improving innovations, it was not adopted on freight trains. To mitigate growing negative press about worker injuries, companies issued brakemen with wooden sticks or paddles to guide the link into place. Workers spurned these implements because of pride and because they made coupling more difficult.[74]

The continuing problem of linking cars was not the result of apathy: by the middle of the 1880s, more than 4000 patented designs claimed to offer a safer coupler. However, originality did not necessarily imply functionality, and many patented designs were bizarre, unworkable, and hardly safer than the link-and-pin. Some included a cut-out on the side of the coupler to provide space for the brakeman's hand, and while this was safer than the original link-and-pin, cut-outs were rarely adopted and were not as safe as a fully automatic coupler.[75]

As with air brakes, railroads were concerned by the up-front cost of shifting to the new technology and installation time, which temporarily removed cars from

[73] *American Passenger Car*, 563–66.
[74] *American Freight Car*, 498–500.
[75] *American Freight Car*, 496–500.

service. They were also hesitant because they worried that other roads might adopt a different standard, preventing car interchanges. The coupler required both a workable design and a coordinated solution. Like the air brake, worker injuries were a trivial cost and freight brakemen had little option to change jobs when there were few adopters of automatic couplers.[76]

The design that eventually became the standard automatic coupler was invented by Eli Janney in 1873. It resembled a pair of curled, partly open fists. When pressed against each other by the motion of the train, the 'fingers' interlocked and held their position, coupling the cars together. Janney's coupler was first installed on the passenger cars of the Pittsburgh, Fort Wayne & Chicago Railway in 1878, but freight adoption was slow. Railroads and car builders were unsure that his coupler would survive freight service, and hybrid models that combined link-and-pin with the Janney coupler were less secure and difficult to maintain. Railroads installed Janney variants piecemeal on some freight cars in the 1880s, but most continued with link-and-pin. Massachusetts and New York required the use of automatic couplers as early as 1884 but most rolling stock was (or could be) used for interstate commerce and therefore beyond the scope of state regulation. An extensive lobbying effort led by a preacher-turned-railroad commissioner, Lorenzo Coffin, supported by the Brotherhood of Brakemen, pushed the ICC to investigate and Congress to regulate coupling technology. Coupler technology was the second major element of the Safety Appliance Act, which required the railroads to adopt automatic couplers for all interstate traffic

[76] *American Freight Car*, 498–500. Aldrich, *Safety First*, 27–32.

by the same date as air brakes (January 1898). Again, the ICC allowed railroads additional time to install automatic couplers.[77]

Automatic couplers did not immediately end coupling-related injuries. There were many automatic coupler designs, which made maintenance difficult. Worker safety rose as designs improved, automatic couplers became universal, they were properly maintained, and workers learned how to use them safely. Overall, coupler accidents declined from 32% of railroad accidents (11,710 in 1893) to 4% by 1902.[78]

Boiler Explosions

Boiler explosions remained another catastrophic risk for trainmen, but regulation only came at the end of this period. Between 1905 and 1909, the death and injury rate from explosions was 0.19 per 1000 workers, roughly a quarter of the rate for brakemen in coupling. Railroads blamed enginemen running low water, while the Brotherhood of Firemen and Enginemen and the Brotherhood of Locomotive Engineers pointed to defective or poorly-maintained boilers and lobbied for federal inspections. The Boiler Inspection Act (1911) required railroads to inspect locomotives based on rules they submitted to the ICC. Inspections in 1912 found that 65% of all locomotives inspected had at least one defect, and 3377 locomotives (4.5% of all inspected) were removed from service for immediate repairs. The Act's main effects occurred outside of this period, and it eventually reduced boiler explosions

[77] White, *American Freight Car*, 510–26. Aldrich, *Safety First*, 28, 32–35. Hoogenboom and Hoogenboom, *History of the I.C.C.*, 33–34. Interstate Commerce Commission, *I.C.C. Activities*, 118–19. Sharfman, *Interstate Commerce Commission*, 1, 251–52.
[78] White, *American Freight Car*, 510–26. Aldrich, *Safety First*, 28, 32–39.

significantly, at substantial expense.[79] Inspections demonstrated railroads' minimal expenditure on and organization for safety-related maintenance of rolling stock.

Regulated Railroad Safety

Government intervention did not immediately make railroading a safe occupation for several reasons. First, the ICC's enforcement capacity was limited, especially in the 1890s: it began with only five commissioners and did not hire an employee to work on safety issues until 1896, and a second only in 1900. The safety inspection staff reached 25 by 1908, but this paled in comparison to the size of the railroad workforce.[80] Therefore, much safety inspection remained a company responsibility, and railroads had continuing principal-agent problems in maintenance.[81]

Most importantly, few railroad innovations were *only* safety-enhancing. Almost all of them enabled railroads to use rolling stock and track more intensively. On balance railroading became slightly but not dramatically safer up to 1900 because increased traffic, larger and faster locomotives, and more interchanges of heterogenous equipment between railroads offset technological improvements in safety. The one occupation that had a slightly clearer trajectory was brakmen, whose work did eventually become less hazardous.[82] In the 20th century, the picture was more positive: there was a modest fall in fatalities per worker after 1905, though injuries and

[79] Interstate Commerce Commission, *I.C.C. Activities*, 136. Aldrich, *Safety First*, 184–86. For the later history of boiler inspection and its costs, see "Running out of Steam: Federal Inspection and Locomotive Safety, 1912–1940," *The Journal of Economic History* 67, no. 4 (2007).
[80] Interstate Commerce Commission, *I.C.C. Activities*, 122.
[81] Aldrich, "Federal Inspection and Locomotive Safety."
[82] *Safety First*, 15–16. *Death Rode the Rails*, Figure 1.3, Appendix 1.

fatalities per worker both declined faster in the 1920s.[83] In 1910, the race between safety and productivity was still finely balanced.

Wages

There were two phases of substantial wage increases for many workers during this period. The first occurred just after the Civil War, when wartime inflation was more than offset by rising incomes. Wages for most occupations were stable for the following three decades and even declined slightly in nominal terms during parts of the 'Long Depression' of the 1870s and 1880s. The first decade of the 20th century saw another sharp increase in real incomes, although it was partly interrupted by a downturn in transport demand after 1907.[84]

Wage ratios between blue-collar railroad jobs were fairly stable across this 50-year period. For example, enginemen earned about 65% more than firemen by the 1900s, similar to the ratio at mid-century. Increased Gilded Age inequality is primarily visible at the top: by 1905 on the Pennsylvania Railroad, senior officers of subsidiary railroads usually earned more than $5000 per year, and divisional superintendents generally made more than $3500.[85] The senior officer salaries were close to those of the executive officers of the PRR at midcentury, which demonstrates that increasing scale not only built up the organizational pyramid, but also the maximum rewards for

[83] Interstate Commerce Commission, *I.C.C. Activities*, 123–25.
[84] Shelton Stromquist, *A Generation of Boomers: The Pattern of Railroad Labor Conflict in Nineteenth-Century America* (Urbana: University of Illinois Press, 1987), 122. Pennsylvania Railroad executives offered 10% pay rises to workers earning under $200/month in 1910. Hagley Museum & Library, Pennsylvania Railroad Company Records, 1807 B-153.
[85] Cf. Thomas Piketty, *Capital in the Twenty-First Century* (Cambridge: Harvard University Press, 2014), 438–40.

managers.[86] There was also increased inequality within occupations, as railroads established gradations of remuneration between different categories and classes of workers. The Boston & Maine, for example, paid Enginemen from $2.50 to $3.50 per day based on location and seniority, and the Philadelphia & Reading Railroad separated trainmen into three pay classes for each occupation, and distinguished between freight and passenger traffic.[87] Generally, workers secured promotions and higher pay if they remained on the same railroad and provided satisfactory service.

Stability of Earnings

Railroad payrolls show that almost all workers continued to be paid monthly, although some state-level regulations in the 1900s required semi-monthly disbursement, and laborers were sometimes paid more quickly for short stints.[88] Section workers' earnings could also be reduced by seasonality, as railroads cleared snow but otherwise did less routine maintenance during the winter. Payment usually took the form of cash or checks, depending on the railroad or division. Some banks only cashed paychecks at a discount, even for large railroad corporations.[89]

Systematic figures on unemployment are available in the 1890 and 1900 Censuses. In New York in 1890, 8.12% of railroad employees had been out of work in

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[86] E.g. Hagley Museum & Library, Pennsylvania Railroad Company Records, 1807 B-153.
[87] Hagley Museum & Library, Reading Company Records, 1520 B-133.
[88] PRR officials discussed changing to semi-monthly payment in New York and New Jersey in 1909 and 1911. Strikes by PRR warehousemen in New York during the 1880s had secured semi-monthly payment. Hagley Museum & Library, Pennsylvania Railroad Company Records, 1807 B-153, M-85.
[89] Hagley Museum & Library, Pennsylvania Railroad Company Records, 1807 M-85. Hagley Museum & Library, Robert B. Watson collection of Pennsylvania Railroad (PRR) Company documents, 2421 Box 5 Folder 4. John W. Orr, *Set up Running: The Life of a Pennsylvania Railroad Engineman, 1904–1949* (University Park, PA: Pennsylvania State University Press, 2001), 38.

the previous year, most of them for 1–3 months. The share was much higher in Pennsylvania, where 14% of railroad employees had been out of work in the preceding year, with 1–3 months again the most common duration.[90] The 1900 census found similar figures: 10% of New York railroaders had been unemployed in the previous year, 5% for 1–3 months and 4% for 4–6 months. In Pennsylvania 12% of workers had been unemployed, 7% for 1–3 months, 3% for 4–6 months. In both states about 1.5% of workers had been out of work for 7–12 months. This was far higher than the unemployment rates and durations for boatmen and sailors, the only water transport group for whom the census collected unemployment data. 35% of New York and Pennsylvania water transport workers had been unemployed in 1900, 19% for 4–6 months.[91] The lower seasonality of railroad transport stabilized earnings. The Massachusetts state censuses of 1885 and 1895 showed higher unemployment in the running trades (20% for enginemen and 13% for firemen) than for station and clerical personnel. Laborers were consistently in the top quartile of frequently unemployed occupations, although transferable skills to other sectors reduced their measured unemployment.[92]

Railroaders exhibited lower turnover in the late 19th century, probably in part because there were more experienced workers, which made switching jobs a less attractive prospect. Quitting to join another railroad was not as easy as it had been at

[90] 1890 Census, Volume 1, Table 116.
[91] 1900 Census, Special Reports: Occupations at the Twelfth Census, Table 41.
[92] Alexander Keyssar, *Out of Work: The First Century of Unemployment in Massachusetts* (Cambridge: Cambridge University Press, 1986), Tables A.1, A.2, A.4, A.6.

midcentury. Moreover, railroads' use of seniority-based promotion meant that switching roads could set back career progression.[93]

Control & Supervision

In the first decades of railroading, the systems for train control, finance, and purchasing capital equipment were rarely matched by sophisticated labor management structures. Railroads had extensive rules, as discussed in Chapter 8, but discipline could be capricious. Payroll and performance records (when railroads kept them) were retained at a local or divisional level. During the last decades of the 19th century, railroads belatedly developed systems to monitor employee performance, including stricter working rules and more enforcement, the latter of which became easier as the shortage of experienced workers abated.[94] Railroads also changed their discipline systems, replacing summary judgments from master mechanics with records of rules violations. If a worker accumulated too many demerits, he could be dismissed.[95] Common causes for suspension or dismissal included causing accidents, damaging railroad property, late arrival or absence, errors that incorrectly shifted baggage or freight, and intoxication.[96] Hierarchy also became stricter among managers: by the 1880s, intermediate managers were expected to only communicate through their chain of supervision and not appeal to higher executives.[97]

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[93] Stromquist, *Generation of Boomers*, 125, 95.
[94] Thomas C. Cochran, *Railroad Leaders, 1845–1890* (Cambridge: Harvard University Press, 1953), 174–75.
[95] Stromquist, *Generation of Boomers*, 230–41.
[96] Hagley Museum & Library, Reading Company Records, 1520 V-437.
[97] Cochran, *Railroad Leaders*, 59.

Intensity

In addition to examples described above, such as firemen working on larger engines, there is some evidence of increased work intensity during this period. An important one for trainmen was 'double-heading': adding a second (and sometimes a third) locomotive to pull longer trains, especially over mountain passes. Double-heading allowed railroads to run longer trains without purchasing new locomotives. Railroads also used double-headers to save on trainmen's wages: they had two engine crews, but normally only one conductor and two to four brakemen. Double-headers required extensive coordination between the enginemen to ensure that both locomotives operated at the same speed. The trailing engineman had very poor visibility and had to rely on the lead engineman for signals. Double-heading also changed stopping distances, and conductors had to supervise brakemen across more railcars. The brakemen were under even more pressure as they had to set brakes on more cars, climbing over freight, gondolas, and boxcars.[98] As we have seen in Chapters 4 and 6, managers' cost-cutting strategies increased work intensity and placed workers at greater risk, although most trains were not double-headers.

Working Time

Workers on railroads continued to work long hours, and the increased traffic meant that railroads expanded their nighttime operations, both over lines and in the yards. Railroaders undertaking extra trips to earn more income sometimes worked for days with only brief breaks. Most trainmen's roles required strength, endurance, focus,

[98] Martin, *Enterprise Denied*, 63–65. E. C. Robbins, *Railway Conductors, a Study in Organized Labor* (New York: Longmans, Green & co., 1914), 88.

and dexterity, and attention to each of these points became more difficult with every passing mile. The increasing number of night runs and shifts were generally given to the least experienced employees.[99]

Working time was regulated at the end of this period, when the Hours of Service Act (1907) responded to concerns about the effects of exhausted railroad workers on passenger safety.[100] It limited trainmen to 16 consecutive hours of work, or not more than 16 hours within a 24-hour period. When a worker had been on-shift for 16 consecutive hours, he would receive at least 10 hours off, and if he had worked 16 hours within a 24-hour period, he would receive at least eight consecutive hours off. Dispatchers and telegraphers were limited to nine hours in 24 in a continuously open office or 13 hours in 24 for a daytime-only office.[101] In response, some railroads closed telegraph offices, abandoned manual block signaling, and returned to timetable-based train control, though others substituted telephone communications or shifted to automatic block signaling. Aldrich argues that the Hours of Service Act slightly improved safety as collisions involving overworked trainmen had accounted for 2.9% of deaths and 0.7% of injuries from 1901–1906.[102] There may have been a slight decline in hours worked in the 1900s across railroad occupations because of this legislation and stronger worker bargaining power.

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[99] Orr, *Set up Running*, 5–6, 20.
[100] Aldrich, *Safety First*, 171–73.
[101] Interstate Commerce Commission, *I.C.C. Activities*, 122–23. Railroads avoided the law by spreading telegraphers' hours over longer intervals, and communications workers not directly involved in dispatching were unaffected by hours regulation. Archibald MacDonald McIsaac, *The Order of Railroad Telegraphers: A Study in Trade Unionism and Collective Bargaining* (Princeton: Princeton University Press, 1933), 195.
[102] Aldrich, *Safety First*, 173, 78–79.

Unions and Strikes

The position of railroad workers at key bottlenecks of the economy and the early scarcity of experienced workers in some occupations enabled labor combinations. The Brotherhood of Locomotive Engineers was founded in 1863, a conductors' brotherhood was formed in 1868, an association for firemen and enginemen in 1873, and a grouping for all trainmen in 1883.[103] These 'Big Four' unions took different approaches to organizing. The enginemen maintained a non-militant stance: they only struck briefly in 1876–77 and assisted the other Brotherhoods when it was clearly in their own interest.[104] The conductors were also very conservative and did not strike up to the 1880s.[105] Other occupational unions included a Brotherhood of Railway Clerks in 1899 and a union of telegraph operators, but they remained weak until federal control of the railroads during the First World War.[106] There were two brief attempts to form unions that crossed occupational lines, the Trainmen's Union and the American Railway Union. The former collapsed almost as soon as it had been formed in 1877, in part because enginemen refused to join. The latter was based in the Midwest and only endured for a year before the defeat of the Pullman strike in 1894 ended its cohesion.[107]

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[103] Stover, *American Railroads*, 119. The first three were initially benevolent societies. Harry Henig, *The Brotherhood of Railway Clerks* (New York: Columbia University Press, 1937), 10.
[104] Gerald G. Eggert, *Railroad Labor Disputes: The Beginnings of Federal Strike Policy* (Ann Arbor: University of Michigan Press, 1967), 6. Donald L. McMurry, "Federation of the Railroad Brotherhoods, 1889–1894," *Industrial and Labor Relations Review* 7, no. 1 (1953): 74–75. Some enginemen remained members of the Firemen's brotherhood after promotion.
[105] Robbins, *Railway Conductors*, 19–23.
[106] Henig, *Railway Clerks*, 3, 14–17.
[107] Eggert, *Railroad Labor Disputes*, 7. Stromquist, *Generation of Boomers*, 85. McMurry, "Federation of the Railroad Brotherhoods," 73–74.

By 1914, the Trainmen's union had 65% coverage nationally, the Engineers 90%, the Firemen 75%, and the Conductors 90%.[108] These four major unions limited their membership to white men.[109] The Big Four had secured a superior bargaining position compared to other railroaders and other American workers.[110] Railroad unionism divided the labor force as trackmen and shop laborers did not have a union.

Executives steadfastly opposed unions and believed that labor combinations should be outlawed or at least prohibited from striking. The American legal system frequently aided railroads by denying unions legal recognition and treating members as individuals or co-conspirators.[111] However, managers sometimes compromised when shortages of experienced workers required a more conciliatory stance to keep rolling stock in motion.[112]

Despite inchoate organization, there were many strikes on late 19th century American railroads. The largest work stoppage in the Northeast occurred in 1877 when thousands of workers halted traffic along the B&O and the PRR in protest over wage cuts and increased work intensity.[113] In response, state governors and President Rutherford Hayes mobilized militia and federal troops to remove strikers, arrest strike leaders, and restore train service. There was no official federal or state policy or formal deliberation about the government's role in strikes, but a combination of politicians' and judges' decisions in 1877 and after placed legal authority and military force firmly

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[108] Robbins, *Railway Conductors*, 10.
[109] Arnesen, *Brotherhoods of Color*, 28–29.
[110] Stromquist, *Generation of Boomers*, 274.
[111] Eggert, *Railroad Labor Disputes*, 227.
[112] Cochran, *Railroad Leaders*, 179–81. Alfred D. Chandler, *The Railroads: The Nation's First Big Business* (New York: Harcourt, Brace & World, 1965), 129.
[113] Eggert, *Railroad Labor Disputes*, 24–25. Philip Sheldon Foner, *The Great Labor Uprising of 1877* (New York: Monad Press, 1977).

on the side of the railroads.[114] By the 1890s, management and labor understood that the federal government would prevent any effective railroad strike by coercive, or later more conciliatory, means.[115]

Less confrontational approaches to ensuring labor peace came in the form of government-sanctioned arbitration. The first effort to establish this mechanism in the Arbitration Act (1888) was unsuccessful, but the Erdman Act (1898) instituted a stronger arbitration regime and prevented railroads from blacklisting union members.[116] The latter Act empowered the Commissioner of Labor and the Chairman of the ICC to intercede in railroad labor disputes. However, the law was basically inoperative for the first eight years after its passage, and railroads frequently rebuffed recommendations for mediation (slightly under half of all requests for arbitration were agreed by both parties). The ICC was more successful after 1906, and many roads agreed to reductions in hours (to 10 hours for railroads that had required 12-hour shifts) and pay rises. The scope for mediation and arbitration was widened by the Newlands Act (1913), which broadened the definition of railroad workers who were eligible for dispute resolution mechanisms.[117]

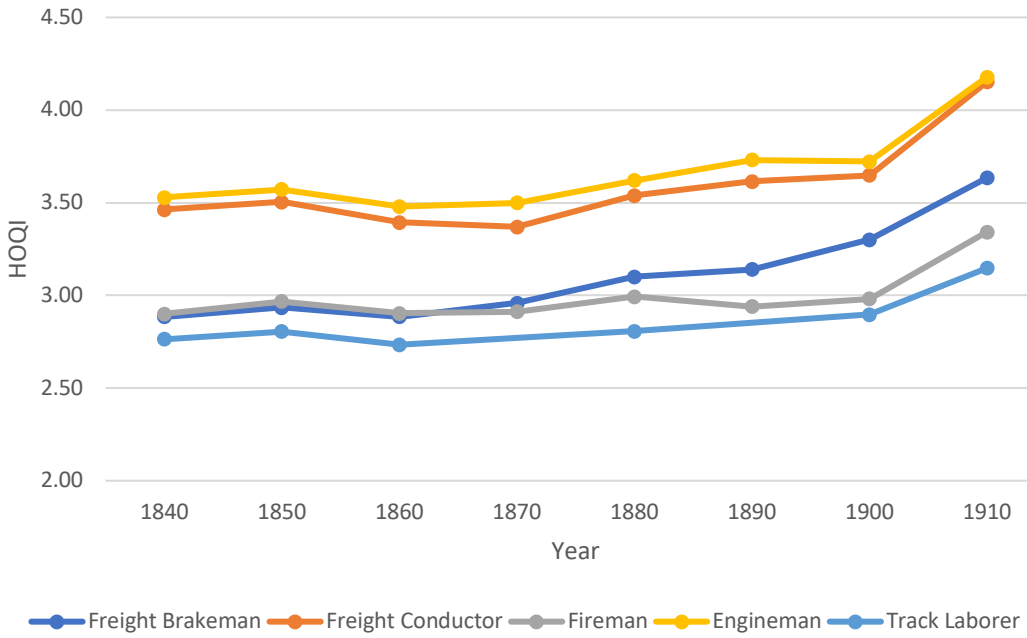
Composite Job Quality

Technological improvements that could have increased safety were usually negated by rising speeds and traffic volumes, so wages were the main contributor to improvements in work-related wellbeing (Figure 9.1 and Tables 9.3–9.7). Unlike in

[114] Eggert, *Railroad Labor Disputes*, 19–23, 41–46, 86–87, 189–90, 228–34.
[115] *Railroad Labor Disputes*, 239–40.
[116] Kennedy, "Rail Governance," 160–62.
[117] Hoogenboom and Hoogenboom, *History of the I.C.C.*, 59. Henig, *Railway Clerks*, 31–32.

Chapters 4 and 6, government regulation only limited working time at the end of the period under consideration and only restricted the longest shifts, which had a modest impact on wellbeing. Some improved accommodations such as the caboose mildly improved conditions for trainmen, although this could be counteracted by rising intensity from doubleheading. Wages for top-end executives continued to rise, and the limited improvements in safety meant that substantial inequality of work-related wellbeing continued.

Figure 9.1: Job Quality on American Railroads, 1840–1910



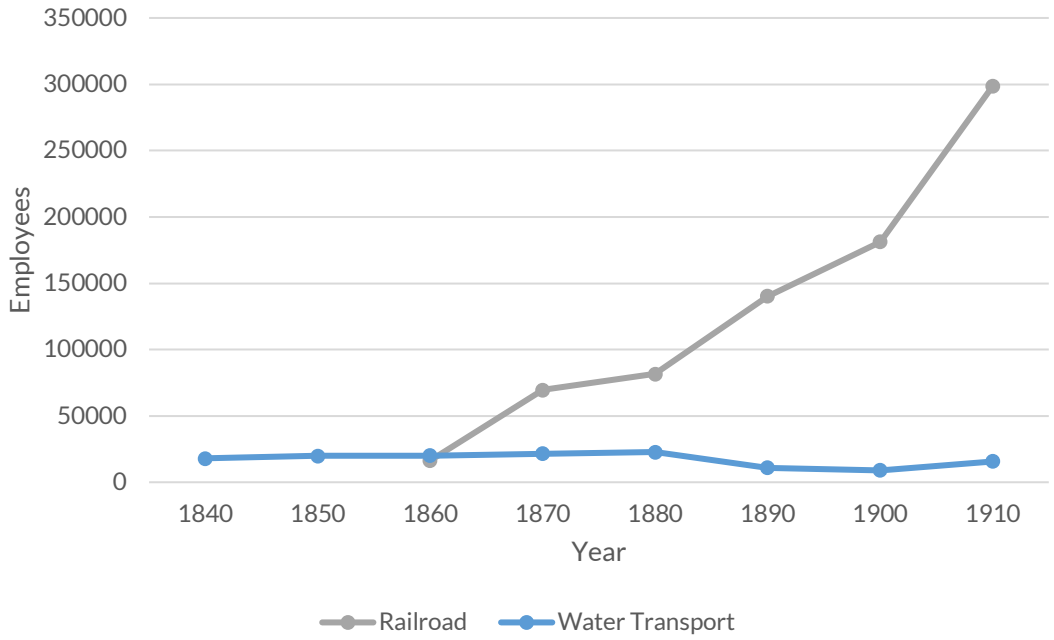
Sources: See Tables 9.3–9.7

Occupational Availability

The 1860–1910 period saw exceptional employment growth in the transportation sector. By 1880, enumerated railroad workers had risen to more than 80,000, and in 1910 more than 296,000 Northeastern workers were employed on

railroads, far outstripping all other modes of interurban transport (Figure 9.2).[118] More powerful locomotives and larger cars raised productivity per worker but rarely allowed railroads to dispense with their existing workforce. Growing demand for transportation services continued to expand employment opportunities.[119]

Figure 9.2: Transport Employment in the Northeastern US, 1840–1910



Sources: US Censuses, 1840–1910. Notes: Railroad workers were not comprehensively enumerated until 1860, and street railroad workers and motormen are excluded; Water transportation workers are those described as boatmen, canalmen, boatkeepers, stewards, and steamboatmen. Road transportation work is excluded because occupations were enumerated inconsistently, and inter- and intra-urban transport workers were counted together.

As discussed in the previous chapter, the railroad's expanded task range required many new occupations, but in the early decades of railroading employees sometimes had to work outside of their nominal remit. The combination of a growing pool of experienced workers and the increased demands of individual occupations (such as longer runs for trainmen) produced more specialization. For example,

[118] 1880 Census, Volume 1. Statistics of the Population of the United States, Table XXXIII, Occupations; 1910 Census: Volume 4. Population, Occupation Statistics, Table 2.
[119] Stromquist, *Generation of Boomers*, 101–02.

enginemen largely ceded repairs and cleaning to dedicated shopmen.[120] Tables 9.1 & 9.2 present census data from 1880 and 1910 on the share of railroad workers in enumerated occupational categories. The greater density of stations and shorter trains in New England explains the larger share of station personnel and enginemen, while the smaller number of stations and longer stretches of track meant more track laborers in the Mid-Atlantic and Midwest.[121]

Table 9.1: Railroad Occupational Groups, 1880

Occupation Group	Region 1 (New England)	Region 2 (Mid-Atlantic, Midwest)
General Officers	1.24%	0.66%
General Office Clerks	1.56%	1.69%
Station Men	21.6%	16.53%
Enginemen	5.51%	4.94%
Conductors	3.61%	3.12%
Other Trainmen	12.66%	12.78%
Machinists	4.29%	4.49%
Carpenters	5.92%	5.41%
Other Shopmen	7.46%	14.20%
Trackmen	22.35%	25.62%
Others	13.59%	10.57%

Source: 1880 Census, Volume 4, Table VI, 257. Region 1: Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut; Region 2: New York, Pennsylvania, Ohio, Michigan, Indiana, Maryland, Delaware, New Jersey, and the District of Columbia.

Inconsistent enumeration practices make comparisons of employment between 1880 and 1910 difficult, but the introduction of automatic couplers and air brakes probably did not displace many brakemen, who were counted as 'Other Trainmen' in 1880. The share of cabmen is difficult to deduce for 1880 and likely at least 8%, but they were 15% of the workforce in 1910.[122] Larger engines and the early

[120] *Generation of Boomers*, 105.
[121] The 1880 Railroad statistics report only provided occupational data by the regions presented in the table.
[122] See Tables 9.1 & 9.2 and 1890 Census, Volume 1, Table 79.

use of mechanical stokers did not allow railroads to dispense with these key operatives.

Table 9.2: Railroad Occupational Groups, 1910

Occupation	% of Railroad Labor Force
Laborers	38.96%
Brakemen	10.37%
Locomotive Engineers	8.77%
Switchmen and Flagmen	7.31%
Conductors	6.96%
Locomotive Firemen	6.53%
Foremen and Overseers	5.37%
Inspectors	3.30%
Other Occupations	3.07%
Ticket and station agents	2.53%
Officials	1.73%
Baggagemen	1.64%
Yardmen	1.04%
Mail clerks	0.95%
Boiler washers and Engine hostlers	0.93%
Freight Agents	0.52%

Source: 1910 Census, Volume 4. Population, Occupation Statistics, Table 2. Data are for the ten Northeastern states.

Occupational Distribution

The Northeastern railroad workforce was homogenous except in national origin. White men from 20–50 were by far the majority of railroaders. In 1870, 98.6% of all American railroad workers were men, and a majority were born in the United States, although 22.6% were from Ireland.[123] The 1880 Census showed similar gender distribution, a lower share (13.2%) of Irish-born workers, and 98% 16–59 year olds.[124]

[123] 1870 Census, Volume 3. The Statistics of Wealth and Industry of the United States, Table XIX. The 1870 and 1880 censuses did not provide occupation-level demographic data by state.
[124] 1880 Census, Volume 1, Table XXXII.

Foreign-born white workers were 29.7% of the workforce in Pennsylvania and 39% in New York in 1910.[125] The negligible share of female employees continued into the 20th century. Only a handful of women were employed on railroads, mostly in station service.[126]

The age composition of the workforce was stable into the 20th century, with 64.4% of New York and 72.9% of Pennsylvania railroad workers aged 21–44 in 1910. The two states had more than 200,000 railroaders combined, and only 0.24% of them were under 16 and fewer than 2% were over 65. The occupations with the largest shares of over-45 workers were enginemen, foremen, and officials, while laborers, boiler washers, and engine hostlers had the largest shares of young (16–20) workers. There were few firemen or brakemen over 45—they either advanced or left railroad service.[127] Many years of service were required to become an engineer or conductor, but railroads preferred to hire the youngest eligible men (under 35) when vacancies arose, which meant that senior trainmen who lost their positions could find themselves shut out.[128] Railroads also applied maximum ages to occupations—by the 20th century, telegraphers were limited to 45, despite union resistance.[129] In 1900, the Pennsylvania Railroad established a maximum hiring age (35) and mandatory retirement (70 for able-bodied workers, 65 for disabled employees).[130]

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[125] 1910 Census, Volume 4, Table 7. The 1910 census only provided demographic information by occupation at the state level for male railroad workers.
[126] Several women are listed in the Providence & Worcester payrolls for 1880. They were employed as telegraph operators (for which they were paid 30% less than male operators) and maids. University of Connecticut Special Collections, Providence & Worcester Railroad Records, 1997.012 Box 45.
[127] 1910 Census, Volume 4, Table 7.
[128] Robbins, *Railway Conductors*, 87.
[129] McIsaac, *Railroad Telegraphers*, 254–55.
[130] Brian Gratton, "'A Triumph in Modern Philanthropy': Age Criteria in Labor Management at the Pennsylvania Railroad, 1875–1930," *The Business History Review* 64, no. 4 (1990).

As discussed in the previous chapter, African-Americans were excluded from almost all railroad jobs in the Northeast. From the 1860s they began to find some passenger service work as porters, waiters, cooks, and maids.[131] However, they remained less than 1% of the male workforce of New York and Pennsylvania railroads in 1910.[132] In the few occupations where they were employed, such as by the Pullman Company, they had no opportunity for promotion to supervisory roles.[133]

Conclusion

Despite the wave of technological change on railroads in the late 19th and early 20th century, work on trains remained dangerous compared to other occupations and railroads in other countries. Improvements to infrastructure, rolling stock, and train control could have reduced injuries and fatalities substantially, but demands for higher productivity meant workers only saw modest reductions in occupational risk. Regulation belatedly pushed railroads to adopt safety-improving technology, but air brakes had mixed effects and automatic couplers required training, experience, and ubiquity before brakemen's work became safer. Workers benefitted from the rising productivity enabled by technological improvements intermittently during their two phases of significant wage increases. However, they also endured decades of stagnant incomes and job quality before the 1900s. Income apart, firemen experienced greater

[131] Arnesen, *Brotherhoods of Color*, 13–14. Some African-Americans were briefly employed as porter-brakemen in the early 20th century, but white brakemen successfully lobbied state legislatures in three Northeastern states to prohibit the employment of porter-brakemen. *Brotherhoods of Color*, 38–39.
[132] 1910 Census, Volume 4. Population, Occupation Statistics, Table 7.
[133] Arnesen, *Brotherhoods of Color*, 17.

work intensity, while freight conductors and some brakemen finally received protection from the elements in the caboose.

Railroad unions provided some benefits to the minority of organized workers, and lobbied the ICC to regulate important aspects of safety for brakemen, enginemen, and firemen. However, their strongest bargaining tool, industrial action, was blunted by the federal government's haphazardly-formed but clear anti-strike policy. A more favorable arbitration system in the 1900s finally aided unionized railroaders to secure pay rises and some limits on hours.

Technology transformed American interurban transportation in the 160 years from 1750 to 1910, turning it from a tiny share of a frontier economy to a leading sector of the global technological leader. Turnpikes, canals, and then railroads expanded the task range, which led to a profusion of new occupations with widely differing job quality. Technological dynamism was an important contributor to falling transport costs, which, when combined with broader economic growth, expanded job opportunities in transportation. Once the railroad was firmly established as the superior mode for moving people and freight, employees found themselves in a race between work safety and increasing productivity, with neither side gaining a decisive advantage up to the First World War. Americans learned how to run railroads efficiently, quickly, and sometimes profitably, but frequently not safely. For workers in shops, stations, and railroad offices the benefits of higher productivity were unalloyed by the dangers of faster-moving locomotion. The fundamental differentiation of working conditions that resulted from the expanded task range and division of labor remained.

Table 9.3: Occupational Quality for Freight Brakemen, 1840–1910

Year	Daily Wage ($)	CN ($)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1840	1.07	0.09	3.09	60.38	2.48	4	1	4	3	2	2	2.40	2.89
1850	1.11	0.08	3.24	60.38	2.48	4	1	4	3	2	2	2.40	2.93
1860	1.22	0.10	3.05	60.38	2.48	4	1	4	3	2	2	2.40	2.88
1870	2.00	0.13	3.45	60.38	2.48	4	1	4	3	2	2	2.40	2.96
1880	1.85	0.10	3.70	60.38	2.48	4	1	4	3	3	2	2.57	3.10
1890	1.83	0.09	3.76	60.38	2.48	4	1	4	3	3	2	2.57	3.14
1900	1.85	0.09	3.94	60.38	2.48	4	2	4	3	3	2	2.88	3.30
1910	2.69	0.10	5.61	52.50	2.97	4	2	4	3	3	2	2.88	3.63

Sources for all tables: Chapters 2, 8, 9, Appendix 1, manuscript sources in the Bibliography, *History of Wages in the United States* (1934), *Statistics of Railways in the United States* (1910, 1911) Allen et al (2011), Allen (2015), UC-Davis Global Prices and Incomes Database. Note: Missing decades are those for which there is no wage data.

Table 9.4: Occupational Quality for Freight Conductors, 1840–1910

Year	Daily Wage ($)	CN ($)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1840	1.71	0.09	4.84	60.38	2.48	4	3	4	4	3	3	3.46	3.46
1850	1.70	0.08	5.02	60.38	2.48	4	3	4	4	3	3	3.46	3.50
1860	1.68	0.10	4.56	60.38	2.48	4	3	4	4	3	3	3.46	3.39
1870	2.53	0.13	4.77	60.38	2.48	4	2	4	4	3	3	3.24	3.37
1880	2.49	0.10	5.27	60.38	2.48	4	2	4	4	4	3	3.40	3.54
1890	2.61	0.09	5.62	60.38	2.48	4	2	4	4	4	3	3.40	3.62
1900	2.59	0.09	5.77	60.38	2.48	4	2	4	4	4	3	3.40	3.65
1910	4.03	0.10	6.64	52.50	2.97	4	3	4	4	4	3	3.63	4.15

Table 9.5: Occupational Quality for Enginemen, 1840–1910

Year	Daily Wage ($)	CN ($)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1840	1.97	0.09	5.12	60.38	2.48	4	3	4	4	3	3	3.46	3.53
1850	1.96	0.08	5.31	60.38	2.48	4	3	4	4	3	3	3.46	3.57
1860	2.03	0.10	4.91	60.38	2.48	4	3	4	4	3	3	3.46	3.48
1870	3.35	0.13	5.34	60.38	2.48	4	2	4	4	3	3	3.24	3.50
1880	3.30	0.10	5.92	60.38	2.48	4	2	4	4	3	3	3.24	3.62
1890	3.67	0.09	6.47	60.38	2.48	4	2	4	4	3	3	3.24	3.73
1900	3.36	0.09	6.43	60.38	2.48	4	2	4	4	3	3	3.24	3.72
1910	4.71	0.10	7.09	52.50	2.97	4	3	4	4	3	3	3.46	4.18

Table 9.6: Occupational Quality for Firemen, 1840–1910

Year	Daily Wage ($)	CN ($)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1840	1.06	0.09	4.02	60.38	2.48	4	3	3	3	2	1	2.45	2.90
1850	1.15	0.08	4.31	60.38	2.48	4	3	3	3	2	1	2.45	2.97
1860	1.22	0.10	4.03	60.38	2.48	4	3	3	3	2	1	2.45	2.90
1870	2.00	0.13	4.36	60.38	2.48	4	2	3	3	2	1	2.29	2.91
1880	1.90	0.10	4.73	60.38	2.48	4	2	3	3	2	1	2.29	2.99
1890	1.99	0.09	5.03	60.38	2.48	4	2	3	3	1	1	2.04	2.94
1900	2.05	0.09	5.24	60.38	2.48	4	2	3	3	1	1	2.04	2.98
1910	2.88	0.10	5.77	52.50	2.97	4	3	3	3	1	1	2.18	3.34

Table 9.7: Occupational Quality for Track Laborers, 1840–1910

Year	Daily Wage ($)	CN ($)	*w*	Hours/ Week	Working Time (*t*)	Stability (*s*)	Immediate Health Risks (*a*)	Long-Term Health Risks (*d*)	Control & Supervision (*c*)	Intensity (*i*)	Repetitiveness (*r*)	Qualitative Measures (*q*)	HOQI
1840	0.86	0.09	3.72	60.38	2.48	3	3	4	2	2	1	2.29	2.76
1850	0.88	0.08	3.89	60.38	2.48	3	3	4	2	2	1	2.29	2.80
1860	0.90	0.10	3.60	60.38	2.48	3	3	4	2	2	1	2.29	2.73
1880	1.15	0.10	3.90	60.38	2.48	3	3	4	2	2	1	2.29	2.81
1900	1.23	0.09	4.29	60.38	2.48	3	3	4	2	2	1	2.29	2.90
1910	1.63	0.10	4.59	52.50	2.97	3	3	4	2	2	1	2.29	3.15

Chapter 10
Conclusion

Chapter Abstract

The conclusion reviews the main contributions of the thesis and places them in the context of research on historical wellbeing, present-day employment conditions, and the future of work. It returns to the utility of a structured approach to describe and measure work-related wellbeing in the past and suggests further uses of the occupational quality measure. It then summarizes and synthesizes the findings of the case study chapters about the effects of macro- and microinventions on good jobs and the availability and distribution of work. Finally, it considers the implications of the findings for contemporary debates about good jobs in an age of work polarization and concerns about the effects of automation.

Overview

This thesis has argued that jobs are an important part of wellbeing and showed that technology has changed the quality of occupations. Chapter 2 constructed the first index to measure work-related wellbeing in the past, and the seven case study chapters applied the index to historical instances of innovation using quantitative and qualitative evidence from primary and secondary sources. Pathbreaking technologies widened the range of tasks, which encouraged a greater division of labor and stratified work-related wellbeing. In some cases, macroinventions dramatically raised productivity, causing technological unemployment. Firms' push to continue reducing unit labor costs after adopting macroinventions usually led them to require higher effort levels from workers, especially in highly competitive sectors. This counteracted the intensity-reducing potential of smaller technological changes and mitigated the effects of some safety-improving inventions. In all three case studies, access to the best jobs was limited, and frequently not by capability.

The following sections synthesize the key arguments of the thesis in more detail and discuss how the findings contribute to scholarly and public debates. The first sections emphasize the value of measuring job quality and summarize specific findings from the case studies. The next sections recapitulate the job stratification thesis and the race between productivity and good jobs, before moving to the employment race between productivity and demand and how technological change enabled shifts in the demographics of the workforce. The final sections situate the findings in research on historical living standards, discuss how the thesis contributes to understanding the challenges of job polarization and the future of work, and

consider how to balance the work-related and broader wellbeing benefits and pitfalls of innovation.

The Value of Good Jobs

Work-related wellbeing extends our knowledge of historical living standards. By including quantitative and qualitative aspects of employment, the Historical Occupational Quality Index presented in Chapter 2 adds to research that has used income, consumption, and the biological standard of living to assess quality of life in the past. It can be used across historical periods and locations, and the inductive approach to measuring wellbeing is a transparent effort to base measurement of historical wellbeing on past preferences. As discussed in Chapters 1 and 2, present-day researchers have increasingly recognized the importance of work-related wellbeing. Describing and measuring the quality of historical jobs contributes to a multidimensional view of living standards in the past, allows researchers to explore different levels and trends in wellbeing across the workforce, and enables economic historians to contribute to current debates about how to improve work. Analysis of work-related wellbeing has wide utility beyond studying the effects of technological change. As suggested in Chapters 4, 6, and 9, it can assess the effectiveness of union bargaining and protective legislation. A disaggregated approach can add structure to our understanding of occupational discrimination by race or gender, as noted in Chapters 4 and 9.

Case Studies

The job quality approach, underpinned by extensive primary source analysis and contextualized using estimates and data for occupational availability and distribution, has implications for wellbeing in each of the case studies. The spinning innovations rapidly transformed the locations and organization of work in Britain, stratified work-related wellbeing, and caused large-scale unemployment. Mechanization with inanimate power to drive water frames and common mules expanded the task range by shifting control of draft and twist from the spinner's hands and arms to machinery that required maintenance, cleaning, adjustment, and piecing, as well as new workers to operate the power-generating apparatus. Water and steam power enabled increased, centralized production at scale with direct labor supervision. The overseers, mule operatives, and mill managers enjoyed the highest work-related wellbeing, while piecers and frame operatives had much lower job quality. The incomplete automation of the self-actor allowed experienced workers—almost always men—to retain their craft control of production, and their labor combinations kept up wages and controlled entry into the best jobs. Inequality of wellbeing continued into the 20th century, although all British spinning jobs improved. The main contributors to improved work-related wellbeing were rising wages and statutory reductions in hours.

The small number of dedicated hand spinners in the pre-industrial United States meant that industrialization had fewer negative effects than in Britain, where many hand spinners suffered from job destruction. There were downsides to some American factory models, such as the more unstable, competitive, and lower-paid Philadelphia system, but most American continuous spinning workers had slightly

higher job quality than their British counterparts. Rising job intensity and stagnant wages in the mid-19th century limited improvement in wellbeing before working time regulation and rising incomes ameliorated conditions. Modestly reduced inequality of wellbeing in the US spinning sector was largely the result of technological pressures on self-actor minders, which restrained wage growth as they ceded control of the shopfloor. The cross-country job quality measurements generally fit with the accepted view that living standards were higher in America than in Britain during the First Industrial Revolution. However, incorporating diminishing returns to income in the HOQI, earlier British hours regulation, and lower work control for some American employees narrows the gap and, in the case of mule operatives, suggests some British jobs may have been superior to American employment in the late 19th century.

The two defining features of the Transportation Revolution in the United States were the spectacular expansion of employment in transportation and the equally dramatic explosion of specialized occupations. The increased physical and employment scale of canals, and especially railroads, required bureaucratic management. Maintaining and operating rail infrastructure, rolling stock, and train control systems demanded a vast array of differentiated workers who had large disparities in work-related wellbeing. After the Civil War, improvements to many aspects of rail transport technology such as better rails and air brakes could have improved safety, but railroad managers used these developments to raise productivity by running heavier, longer trains.

Macroinventions and Job Stratification

The macroinventions discussed in Chapters 3, 5, 7, and 8 broadened the range of tasks or required repetition of tasks to produce yarn or provide transportation services. In response, firms increased the division of labor, which led to stratification of work-related wellbeing. Stratification was double-edged: it produced new, higher-quality jobs, but did not consistently improve the worst jobs and it increased inequality. The two main mechanisms that broadened the task range were technical complexity, or horizontal task expansion, and increased scale, or vertical task expansion. Horizontal task expansion widens the range of tasks required for one step in a productive process or in service provision. Vertical expansion adds management tasks to oversee larger production units, such as labor oversight, bookkeeping, and raw material procurement.

Machinery that replaced human or animal muscle required maintenance, cleaning, monitoring, and adjustment. It was soon driven by inanimate power sources, which added further tasks for operation and upkeep. Employers responded to horizontal task expansion by dividing new tasks into separate bundles for specialized workers. The expanded production potential of inanimate power enabled and encouraged large-scale operations, which required management. Industrial enterprises were not the first organizations to employ hundreds or thousands of workers or to employ managers.[1] However, vertical task expansion from increased scale was a feature of all the macroinventions discussed in the case studies, and coordinating inputs, labor discipline, sales, and business strategy required

[1] Sidney Pollard, *The Genesis of Modern Management: A Study of the Industrial Revolution in Great Britain* (London: E. Arnold, 1965), 48–51.

professional managers. While wage inequality across the workforce may be explained by skill-biased technical change, differences in other components of wellbeing such as job control, intensity, and safety were shaped by management decisions and not a limited supply of workers trained as mule operatives, railroad managers, or master mechanics.

The Race Between Good Jobs and Productivity

Macroinventions were a major source of productivity growth. However, after most firms adopted similar machinery, they continued to search for operational practices and innovations that could lower their costs per unit of output. This was particularly important in highly-competitive sectors with low barriers to entry like textile production. One approach, described in Chapter 4, was to economize on raw material inputs ('bad spinning'), which required workers to increase their effort and focus. A related practice was to directly demand more effort from workers, which occurred in the American speedup and stretch-out (Chapter 6). Reductions in staffing to lower labor costs, which increased intensity, also occurred when American railroads adopted doubleheading. Adding capital per worker in the form of larger locomotives that could pull heavier loads at higher speeds mitigated safety-enhancing effects of improved rails, train control systems, and air brakes. Managers' strategies to increase productivity made work more exhausting and prevented safety improvements, meaning that most increases in job quality came from higher wages or statutorily-reduced hours. Unionized workers such as the Lancashire self-actor minders were able to coordinate resistance to labor intensification, but none of the other employees in the case studies had the same collective organization. As a result, few were successful in

resisting higher effort demands or more intensive use of capital goods that mitigated safety improvements.

The relationship between operational practices and the features of new technology was crucial in the race between good jobs and productivity. Most innovations discussed in the case studies had potential to increase productivity if effort levels remained constant. Alternatively, new technologies could have allowed workers to reduce effort levels, but firms would not have seen the same productivity gains. Two rare examples of productivity-enhancing and intensity-reducing innovations were the self-acting mule and the mechanical stoker. These improvements offered the best of both worlds: they allowed firms to increase output or throughput while reducing workloads. A larger group of inventions raised productivity with stable or rising effort levels. These include macroinventions like the water frame and the common mule, as well as microinventions such as ring spinning when married with the speedup. Alternative work practices could have used these machines to lower effort demands, but such an approach would have required firms to forgo some output benefits of the new technology. Instead, they chose to push their workforce. A third group of innovations could have improved safety, but their effects were mitigated by the opportunity to increase productivity and profits: steel rails, and, to a lesser extent, air brakes fall into this category. A few inventions, like the caboose, the automatic coupler, and covers or guards for textile machinery, primarily improved working conditions and safety. The effects of technologies on work-related wellbeing varied widely depending on the innovation. Firms generally tried to maximize the productivity-improving potential of new technology, so many innovations that could have reduced intensity or improved safety did not achieve these ends.

The relationship between innovations and work intensity may also have implications for growth measurement. For example, a rising capital-labor ratio was an important contributor to rising railroad productivity during the 19th century.[2] However, adding capital per worker in the form of larger locomotives required additional but unmeasured labor effort (Chapter 9). Observed capital deepening that leads to increased output may also require increases in labor inputs that are not captured by hours worked.

The Race Between Productivity and Demand

The availability of work followed a familiar pattern: a race between productivity and demand.[3] In the British spinning case, mechanization raised productivity far more quickly than demand increased as textile prices fell and consumers purchased factory-spun cotton instead of hand-spun wool or linen goods. The result was technological unemployment, probably in the low tens of thousands by 1790 and hundreds of thousands by the early 19th century. However, the technologically unemployed workers were politically marginalized and could not mount sustained opposition to industrialization or secure recompense for their lost employment. The United States imported a substantial volume of textiles from Britain before mechanization, so tariff-protected factory production substituted for imports. This mitigated the negative employment effects of higher productivity in factories. In

[2] Albert Fishlow, "Productivity and Technological Change in the Railroad Sector, 1840–1910," in *Output, Employment, and Productivity in the United States after 1800*, ed. Dorothy S. Brady (New York: Columbia University Press, 1966).
[3] Richard E. Baldwin, *The Globotics Upheaval: Globalisation, Robotics and the Future of Work* (London: W&N, 2019).

the later 19th century, British spinning grew substantially, almost entirely on the strength of overseas demand, while the productivity increases provided by ring spinning and labor intensification allowed American spinning factories to only increase their workforce modestly.

American transportation grew alongside and supported economic growth in the 19th century while carrying more goods and passengers per worker. Road and canal transportation employment stagnated or even fell after the introduction of railroads, but the spectacular growth of rail transport more than outstripped any technological unemployment in other technologies. Broader growth and the cost-reducing effects of improved transportation provided many job opportunities for former canallers or road laborers. Macroinventions with large positive spillovers can more than offset their job-destroying potential if the broader economy is buoyant.

Technology and the Reorganized Workforce

The case studies also illustrate how technological change enables shifts in the demographic composition of the workforce. By dislocating the gender or age segregation of occupations and allowing firms to reorganize task bundles, technological change can produce conditions and incentives for higher-status workers—in the case of spinning, adult men—to claim good jobs in previously segregated occupations.[4] Once adult men secured the best positions, they restricted entry into these roles. In the United States, the only disruption of this pattern was

[4] Compare with changes in the gender composition of computer science after the introduction of personal computers. Jane Margolis and Allan Fisher, *Unlocking the Clubhouse: Women in Computing* (Cambridge: MIT Press, 2002).

when managers installed ring frames to replace the highly-paid self-actor minders. In American transportation, an effective gender and race bar excluded women and African-Americans until the late 19th century and then restricted them to low-quality jobs. The best jobs in new technologies were not distributed evenly, or by ability. Workers with relatively high social status before technological change claimed and generally retained those roles.

Historical Living Standards

Disaggregating wellbeing by occupation illustrates that there was no single standard of living. Wellbeing varied widely between jobs and aggregation can hide more than it reveals, particularly because of gender and age segregation. This is particularly important in the British spinning example.[5] Second, any attempt to summarize changes in British quality of life in the 1750–1830 period needs to incorporate the extensive dislocation and reduction in wellbeing of technological unemployment.[6] Incorporating job destruction and the significant hours, control, and occupational safety downsides of factory work tempers optimism about the wellbeing implications of the early Industrial Revolution. Third, as noted above, American work-related wellbeing was generally (but not always) higher than for equivalent jobs in

[5] This is a post-industrialization mirror to Jane Humphries, "The Lure of Aggregates and the Pitfalls of the Patriarchal Perspective: A Critique of the High Wage Economy Interpretation of the British Industrial Revolution," *The Economic History Review* 66, no. 3 (2013). See also Stephen Nicholas and Deborah Oxley, "The Living Standards of Women During the Industrial Revolution, 1795–1820," *The Economic History Review* 46, no. 4 (1993); Sara Horrell and Deborah Oxley, "Bringing Home the Bacon? Regional Nutrition, Stature, and Gender in the Industrial Revolution," *The Economic History Review* 65, no. 4 (2012); Jane Humphries and Jacob Weisdorf, "The Wages of Women in England, 1260–1850," 75, no. 2 (2015).

[6] Technological unemployment has been ignored in many contributions, including the classic Jeffrey G. Williamson, "Urban Disamenities, Dark Satanic Mills, and the British Standard of Living Debate," *The Journal of Economic History* 41, no. 1 (1981).

Britain, and wage stagnation in textiles and rising intensification fit with the 'Antebellum puzzle' found in biological measures of living standards.[7] Improvements across the case studies in the early 20th century also match established patterns. Fourth, this study integrates explanations for the development of bureaucratic management and technology's contribution to rising inequality during the 19th century.[8]

Job Polarization

The race between productivity and work-related wellbeing in the past offers perspective and insights for contemporary discussions of declining job quality and polarization. The rise of 'bad spinning' in Britain and the American speedup occurred during periods of increasing competition. This supports contemporary research that indicates the globalization of manufacturing has been one important factor that has reduced job quality in recent decades, with labor intensification a key channel.[9] However, America's 19th century protectionist tariffs for textiles did not prevent labor intensification. Domestic competition was more than sufficient to encourage firms to

[7] John Komlos, "The Height and Weight of West Point Cadets: Dietary Change in Antebellum America," *The Journal of Economic History* 47, no. 4 (1987); Brian A'Hearn, "The Antebellum Puzzle Revisited: A New Look at the Physical Stature of Union Army Recruits During the Civil War," in *The Biological Standard of Living in Comparative Perspective*, ed. John Komlos and Jörg Baten (Stuttgart: Franz Steiner Verlag, 1998); Ariell Zimran, "Sample-Selection Bias and Height Trends in the Nineteenth-Century United States," *The Journal of Economic History* 79, no. 1 (2019).

[8] Alfred D. Chandler, *The Visible Hand: The Managerial Revolution in American Business* (Cambridge: Harvard University Press, 1977); Peter H. Lindert and Jeffrey G. Williamson, *Unequal Gains: American Growth and Inequality since 1700* (Princeton: Princeton University Press, 2016).

[9] Jeffrey S. Rothstein, *When Good Jobs Go Bad: Globalization, De-Unionization, and Declining Job Quality in the North American Auto Industry* (New Brunswick: Rutgers University Press, 2016).

raise effort demands, which is also the case for recent intensification in nontradeable sectors.[10]

One area where low-quality jobs have proliferated is in the growing area of the gig economy. Firms have used digital platforms that masquerade as a 'marketplace' for services to engage in regulatory arbitrage. Gig work is replete with examples of labor intensification, long hours, and extremely low pay, provided through platforms that ignore labor law.[11] Intensification remains a potential source of productivity growth in sectors that are not easily automated.[12] The most unionized workers in the case studies, the British self-actor minders, suffered less from labor intensification—in part by shifting the burden of 'bad spinning' onto their assistants—and retained a privileged wage position. Common standards for working conditions that limit hours and require firms to adopt safety practices can mitigate declines in some components of work-related wellbeing, although international agreement and enforcement are significant challenges.[13] Encouraging unionization may be a complementary 'bottom-up' approach, although Chapters 4 and 9 show that narrow unionism had narrow benefits. Sectoral bargaining may be an alternative to limit inequality of work-related wellbeing by establishing broader floors for wages and conditions.[14]

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[10] Jeremias Prassl, *Humans as a Service: The Promise and Perils of Work in the Gig Economy* (Oxford University Press, 2018). Harry August and Julia Rock, "Working at an Amazon Warehouse Is a Tough Job. It's the First of Many Problems Facing Injured Workers," *Boston Globe*, 24/07/2021. Jason Beeferman, "Workers in Chicago-Area Warehouses Allege Harsh, Dangerous Working Conditions," *Chicago Sun-Times*, 23/11/2021.
[11] Prassl, *Humans as a Service*.
[12] Aaron Benanav, *Automation and the Future of Work* (London: Verso, 2020).
[13] For a modern parallel to historical problems of dead-letter labor laws, see Ravi Kanbur and Lucas Ronconi, "Enforcement Matters: The Effective Regulation of Labour," *International Labour Review* 157, no. 3 (2018). On the value of a common rulebook, see Kevin H. O'Rourke, *A Short History of Brexit: From Brentry to Backstop* (London: Pelican, 2019).
[14] Lynn Rhinehart and Celine McNicholas, "Collective Bargaining Beyond the Worksite," (Economic Policy Institute, 2020). David Madland, *Re-Union: How Bold Labor Reforms Can*

The Future of Work

Humans are generalist workers, but we have much more limited endurance and capacity than inanimate power and machinery. Many technologies of the first two Industrial Revolutions used machines to replace human or animal control and power for tasks in manufacturing. Our capability to carry out cognitive tasks for extended periods with accuracy is also limited, and computers vastly exceed our capacity in a growing number of areas. Artificial intelligence that replaces routine cognitive work is the result of decades of work by computer scientists and engineers, who are also increasingly specialized—the task range of work has again increased. Replacing the generalist human brain and body with physical and digital technologies expands the range of tasks and incentivizes specialization. Distinctive task bundles and skill requirements enable stratified job quality and inequality of wellbeing. While most discussions of the future of work have focused on the potential for mass technological unemployment in rich countries, job stratification is also a threat to widely-shared improvements in quality of life.[15] Moreover, the tendency for higher-status workers to claim the best jobs may reinforce existing inequality. On the other hand, if labor-replacing technological change and reshoring prevent low-income countries from industrializing, they could lose the opportunity to create middle-income jobs through technologically-induced division of labor.[16]

Repair, Revitalize, and Reunite the United States (Cornell University Press, 2021). But see also Veena Dubal, "Sectoral Bargaining Reforms: Proceed with Caution," *New Labor Forum* Early View (2021).

[15] Martin Ford, *Rise of the Robots: Technology and the Threat of a Jobless Future* (New York: Basic Books, 2015); Daniel Susskind, *A World without Work: Technology, Automation and How We Should Respond* (London: Allen Lane, 2020).

[16] Dani Rodrik, "Premature Deindustrialization," *Journal of Economic Growth* 21, no. 1 (2016).

Striking a Balance

The wellbeing implications of industrialized textile production and improved transportation extended beyond the factory and the roundhouse. Consumers benefitted from a growing choice of lighter, more colorful, and cheaper fabrics. Travelers journeyed longer distances in speed and relative comfort, albeit at some risk of accidents. Businesses sold their goods to wider markets, and consumers could purchase a growing array of products with lower transportation costs. The potential of future automation and artificial intelligence is at least as transformative as the innovations of the Industrial Revolution. AI systems may be able to diagnose illnesses based on large datasets and robot carers may tend to our needs. Automated transportation might eliminate traffic fatalities and remove the need for humans to carry out tedious and tiring logistics work.[17] However, these and other future technologies include potential downsides. Job destruction and increased inequality of work-related wellbeing are both risks of widespread adoption of automation technology.

Most present-day workers have a political voice, unlike the unemployed hand spinners or the frame tenders who experienced the speedup. Technological unemployment or further increases in inequality of wellbeing could compound populist political movements of the 2010s. It took decades for 19th century politicians to address the downsides of industrial innovation for work-related wellbeing, and their eventual responses ignored job destruction and were slow to improve

[17] Erik Brynjolfsson and Andrew McAfee, *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*, New ed. (New York: W.W. Norton & Company, 2016).

occupational safety. A future with higher quality of life needs innovation, worker bargaining power, and common rules for working conditions to secure the benefits of new technology while improving jobs.

Appendix 1

Historical Occupational Quality Index Codebook

Updated October 2021

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Introduction to the Historical Occupational Quality Index

The Historical Occupational Quality Index (HOQI) is a structured approach to measure the quality of occupations in the past. The components of the index are based on qualitative and quantitative sources that provide historical workers' perspectives about the aspects of jobs that they valued. This document is a guide to the methodology for computing the quantitative elements and rubrics for scoring qualitative evidence.

Occupations

The HOQI unit of analysis is the occupation. An occupation is defined as a set of tasks that an individual completes for non-leisure reasons, i.e. the individual engages in these tasks *at least in part* to ensure their material survival. The definition encompasses paid, market-facing employment, unpaid (e.g. household) work, and forced labor. Many occupations will incorporate the same tasks or be composed of related tasks, and occupational titles may change over time despite including similar or even identical tasks. Defining when a worker with multiple jobs stops one occupation and starts another may be determined by one or more of: 1) the employer/source of payment; 2) the occupational title; 3) contextual information about location of work and organization (e.g. does the worker move from one worksite to another, collaborate with different colleagues, etc.). Future developments to the HOQI may allow for measurement of career quality.

Timing of Measurement

The second element of an HOQI figure is the timing of observation and measurement. Using historical sources makes precise measurement for a specific date challenging, and the scale of this challenge is inversely related to the amount of data and descriptive evidence available for the occupation(s) under consideration. Measuring year-by-year changes in the HOQI is discouraged. Annual measurement makes changes in outputs very sensitive to shifts in the quantitative components, which are easier to capture in historical sources. Therefore, the HOQI is most suitable for assessing changes over longer periods (e.g. several decades), using benchmark years or multi-year/decadal bins. This thesis uses bins, gathering data and evidence for the years before and after decade years (e.g. 1900).

Locations and Employers

The third element that bounds an HOQI figure is the location and/or employer. Job quality for an occupation may vary over space as well as time. The appropriate geographic or firm unit of observation will depend on the historical

context in which the HOQI is applied. Researchers may attempt to ascertain if there were meaningful differences in any of the index components between firms or across locations in their analysis.

Tasks

The *r* component requires an understanding of the task composition of the occupation. A task is defined here as a physical action (e.g. pulling a rope) or cognitive process (mental addition) or a combination of the two (writing a sentence by hand). A task will end with some change in the state of the worker's surroundings or a nonphysical output (an idea for how to improve a machine).

Assumption of Invariance Over Time

Capturing changes in the qualitative components is challenging, even more so when there are few sources. A qualitative score for a benchmark year or year bin should be maintained *until a later point at which there is evidence that the score should change*. Put another way, the HOQI assumes that absence of evidence meant no change in that component of job quality. This assumption is included to avoid the intrusion of strong *a priori* views about occupational changes, whether positive or negative, and to ensure that changes in OQ components can be clearly and directly linked to evidence in historical sources.

Components of the HOQI

Real Compensation – *w*

Real Compensation, which uses the symbol *w*, is computed in several steps.

Total Compensation

The first step is to collect data on Total Compensation [TC]: the total market value of all cash and non-cash remuneration provided to the worker, including perquisites, payments in-kind, subsidized housing, and deferred compensation (pensions). All compensation should be converted into current nominal values; deferred compensation should be given a present value at the date of the point-in-time analysis based on a discounting of future income that accounts for historical life expectancy. The unit of analysis for real compensation is one week. For occupations that show substantial variation in Total Compensation over the year, Total Compensation should be the arithmetic mean average for the period when work was available. Variation in earnings is incorporated into occupational quality in the Stability of Earnings [*s*] measure. Total Compensation should be *actual amounts earned* and not probable day rates. Care should be taken to ensure that the amount recorded in historical sources is the actual remuneration to a worker and not payment to an intermediary (see Stephenson 2018).

Consumption Needs

Total Compensation is adjusted for the cost of living using Consumption Needs [CN]. Consumption Needs are measured for the geographical unit of analysis (when exploring regional variation in occupational quality, it will be necessary to gather local price data) at the point-in-time of the occupational quality measurement using Allen's 'respectability basket'. Just as the unit of analysis for Total Compensation is the week, so is the unit for Consumption Needs. This will normally mean a mismatch between the number of days normally worked (likely between five and six for many historical occupations) and the seven-day week. The quantity of goods to be purchased in the basket is adjusted based on the metabolic category of worker engaged in the occupation.

CN Conversion Factors

Adult male = 100% basket

Adult female = 85%

Children = 60%

If the occupation includes many categories of workers, the occupational quality scores should be calculated separately for each. Whenever possible, the prices in

the basket should be consumer-facing prices; institutional prices should be converted to retail prices using contextual evidence about markup levels.

Once data for TC and CN have been collected, it is possible to compute the Welfare Ratio [WR].

Formula for WR

$$\mathrm{WR} = \frac{\mathrm{TC}}{\mathrm{CN}}$$

The WR is then converted to a *w* value using the formula below, which incorporates diminishing returns from increasing income levels, but avoids negative values from using logarithms when WR < 1. The lowest possible value of *w* is 1, to match the lowest possible value for the qualitative components.

Formula for *w*

$$w = \sqrt{\mathrm{WR}} + 1$$

Working Time – *t*

Figures for historical working time, especially in the pre-industrial period, are notoriously difficult to locate in primary sources. Therefore, this element may require estimation based on descriptive evidence, possibly from similar jobs or using conventional expectations about the length of the working day. When accounts of working time provide days worked, these should be matched with qualitative sources about standard working hours. It may also be possible to calculate standard working hours when the primary source provides an occasional entry for hourly work.

As with the Real Compensation component, Average Hours [AH] should be measured as *average hours actually worked per week*, and *not* standard scheduled hours.

The scaling for this component is drawn from the Human Development Index, which uses assumed minimum and maximum values for components such as life expectancy and scales the index values between 1 and 0. In this case, the assumed maximum value of AH is 84, and plausible minimum is 20, which, when combined with a scaling factor to allow the minimum value (20 hours per week) to match the best possible score for qualitative components (5) and simplified, produces the formula below.

Formula for *t*

$$t = 6.25 - \frac{\mathrm{AH}}{16}$$

There is an obvious trade-off between hours worked and earnings, and this is implicitly captured by incorporating both elements.

Stability of Earnings – *s*

The *s* component measures how likely it is that a worker consistently receives the full present compensation that forms part of the *w* component and how frequently the worker is paid. Less frequent (even if regular) payment, missed payments, or ease of dismissal (which disrupts earnings) are all factors that will reduce the score for this component. For piece rate occupations, the equivalent of frequent payment is timely payment and regular access to work. Since piece rate work will have started before a bill or invoice is delivered for payment, more than a one-week delay in payment should be considered delayed payment (equivalent to monthly payment), and more than two weeks a long delay in payment (equivalent to quarterly wage payment).

Table A.1: Contributing Factors to *s*

Positive Contributing Factors	Negative Contributing Factors
• More frequent or timely payment • Consistent payment • Consistent level of earnings • Low probability of dismissal • Full payment of earnings	• Less frequent or delayed (e.g. quarterly) payment • Irregular/unpredictable payment • Varying earning levels over a year • High probability of dismissal • Partial payment of earnings

Table A.2: Scoring Rubric for *s*

Score	Criteria
5	Very stable earnings. Consistent, frequent, and full payment. Job security is high (firing/layoff/redundancy is very unlikely).
4	Stable earnings. One of the four positive contributing factors is absent, or payment is provided less than once per month.
3	Payment is less frequent (monthly) and either inconsistent or job security is low; alternatively, dismissal probability is moderate and payment is provided less than once a month.
2	Somewhat unstable earnings. No more than one of the positive contributing factors is present.
1	Very unstable earnings. Inconsistent payment at long intervals and little or no job security.

Short-Term Health Risks – *a*

The *a* component is a qualitative probability component. It captures the chance of suffering a substantial injury (physical or psychological) on the job and the severity of the potential injury (including death). The higher the chance of injury and the more serious the potential injury, the lower the *a* score. Death from an occupational accident is the worst possible outcome. This component also accounts for injuries caused by intentional acts of supervisors, such as corporal punishment of child workers. Any physical harm caused in the course of a work shift, or psychological harm with immediate implications, should be considered as part of the *a* component.

Table A.3: Scoring Rubric for *a*

Score	Criteria
5	No occupational risk. No evidence of death or serious injury, minimal chance of minor injuries.
4	Low occupational risk. No evidence of death or serious injury, some chance of minor injuries.
3	Moderate occupational risk. Death or serious injury is rare, but minor injuries are common.
2	Fairly high occupational risk. Death or serious injury is frequent or a majority of workers suffer minor injuries.
1	High occupational risk. Many workers are killed or seriously injured and/or nearly all workers suffer minor injuries.

Long-Term Health Risks – *d*

The *d* component captures the chance that a worker will suffer a reduction in their life expectancy or a serious long-term illness (including mental illness) from their occupation. As in the *a* component, more serious ailments (those that shorten life expectancy or have a greater impact on quality of life) and the greater probability of suffering such an illness will lower the *d* score. Psychological traumas with long-term impacts (beyond one year) should be incorporated in this component rather than the *a* component. As in other aspects of the index, there may be compounding of multiple deleterious aspects of jobs: work that is dangerous and has a low *a* score may also cause mental illness and a low *d* score.

Table A.4: Scoring Rubric for *d*

Score	Criteria
5	No occupational risk. No evidence that this occupation leads to a reduction in life expectancy or reduced quality of life.
4	Low occupational risk. No evidence of a reduction in life expectancy, but a small chance of conditions that may lower quality of life in the long run.
3	Moderate occupational risk. Little evidence of a reduction in life expectancy, but some workers may experience a lower quality of life.
2	Fairly high occupational risk. Some workers suffer a reduction in life expectancy, and/or many have a condition that lowers their quality of life.
1	High occupational risk. Many workers suffer a reduction in life expectancy and/or nearly all workers experience conditions that lower quality of life.

Control & Supervision – *c*

The *c* component captures worker flexibility in timing and organization of tasks. This component implicitly incorporates that the tasks and location for an occupation are given by the job requirements. Example: a mason is employed to build a brick wall, which is a fixed outcome; if he has discretion in how he organizes his tools and the order in which he completes his tasks, this occupation should receive a higher score. If an occupation has flexibility in the location and schedule of work it should be scored higher, lack of options in these two areas should mean an occupation receives a lower score.

Note: Discipline that may cause physical or psychological harm is incorporated in the *a* component.

Table A.5: Scoring Rubric for *c*

Score	Criteria
5	Complete worker control. The worker in the occupation under consideration has full discretion over the organization of their work, as well as where and when to complete it.
4	Predominant worker control. The worker controls most of their tasks, the organization of those tasks, and has flexibility in the timing or location of their work.
3	Moderate worker control. The worker controls either the manner of completion of their tasks or the organization of tasks; they may have some control over when or where they work.
2	Low worker control. The worker controls some, but few of their tasks, and little control over when or where they work.
1	No worker control. The ordering and manner of task completion is entirely determined by a supervisor. No control over the place and time of work.

Intensity – *i*

The intensity *i* of an occupation is the level and frequency of exhaustion that a typical worker experiences by the end of their working shift. This intentionally compounds the component *t* as it reflects both the lack of time available to the worker to complete non-work tasks or enjoy leisure, as well as the worker's exhaustion-induced reduction in physical and mental capacity. Intensity captures both physical and mental exhaustion of workers, and they should be given equal consideration when applying evidence to the rubric below. If irregular hours (e.g. night shifts) increase exhaustion, such patterns should be incorporated into scoring a job for *i*.

Table A.6: Scoring Rubric for *i*

Score	Criteria
5	Very low intensity. Workers do not experience physical or mental exhaustion at the end of their shift.
4	Low intensity. Workers rarely experience physical or mental exhaustion at the end of their shift, and never both.
3	Moderate intensity. Workers occasionally experience physical or mental exhaustion at the end of their shift, but very rarely both.
2	High intensity. Workers are frequently physically or mentally exhausted at the completion of their working shift.
1	Very high intensity. Worker exhaustion (both physical and mental) by the completion of their shift is very common, or one type of exhaustion is universal.

Repetitiveness – *r*

The frequency with which workers complete the same tasks is captured in the *r* component. This requires an understanding of the task composition of the job. To score *r*, the job should be broken down into its tasks and the researcher should assess the frequency with which teach task is repeated using qualitative sources. A highly repetitive occupation is likely to be one in which there are fewer than ten core physical or cognitive acts that are repeated frequently.

Table A.7: Scoring Rubric for *r*

Score	Criteria
5	Highly varied occupation. The occupation consists of many different tasks that the worker completes with minimal replication during a shift.
4	Varied occupation. The occupation consists of many tasks, but the worker has to complete a few tasks repeatedly.
3	Somewhat varied occupation. The occupation consists of many tasks, but the worker has to complete a few very frequently; OR the occupation consists of a few tasks, but the amount of repetition is lower.
2	Fairly repetitive occupation. The occupation consists of few tasks and the worker repeats some of them frequently.
1	Highly repetitive occupation. The occupation consists of very few tasks that the worker repeats many times during a shift.

Combining the Components

After calculating components *w* and *t* and scoring the further six components, there are two steps to combine the components into a broad measure of job quality.

Formula 1: Qualitative Components – *q*

The first formula takes the geometric mean of the six scored components (*s*, *a*, *d*, *c*, *i*, *r*) to produce a composite *q* component.

$$q = \sqrt[6]{s \bullet a \bullet d \bullet c \bullet i \bullet r}$$

Formula 2: HOQI Measure

The final formula to produce the HOQI is the geometric mean of *q*, *w*, and *t.*

$$\text{HOQI} = \sqrt[3]{w \bullet t \bullet q}$$

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