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Chapter Author: Daniel Nelson

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2 Industrial Engineering and the Industrial Enterprise, 1890–1940

Daniel Nelson

The growth of industry during the last quarter of the nineteenth century inspired one of the most influential efforts to promote the coordination of economic activity: the industrial engineering movement of the early twentieth century. Although railroads had devised elaborate methods of internal communications and record keeping by midcentury, the late-nineteenth-century factory remained a loosely organized cluster of operations. Coordination depended on the leadership of plant executives and personal relationships between supervisors. Indeed, the distinguishing feature of factory management was the conspicuous role of the first-line supervisor; foremen organized materials and labor, directed machine operations, recorded costs, hired and fired employees, and presided over a largely autonomous empire. In the 1870s and 1880s, however, critics began to attack the "chaotic" condition of contemporary industry and to propose a more systematic, centralized approach to production management. Their critique became the basis for the best-known effort to encourage coordination within the firm during the first half of the twentieth century. Under various labels—systematic management, scientific management, efficiency engineering, and, by the 1920s, industrial engineering—it fostered greater sensitivity to the manager's role in production and greater diversity in industrial practice, as managers selectively implemented ideas and techniques.

2.1 Systematic and Scientific Management

The attack on traditional management originated in two late-nineteenth-century developments (see Nelson 1992a, 6–9). The first was the maturation of the engineering profession, whose advocates sought an identity based on

Daniel Nelson is professor of history at the University of Akron.

formal education and mutually accepted standards of behavior and who rejected empiricism for scientific experimentation and analysis. The second development, closely related, was the rise of systematic management, an effort among engineers and sympathizers to substitute system for the informal methods that had evolved with the factory system. Systematic management was a rebellion against tradition, empiricism, and the assumption that common sense, personal relationships, and craft knowledge were sufficient to run a factory. The revisionists' answer was to replace traditional managers with engineers and to substitute managerial systems for guesswork and ad hoc evaluations.

By the late 1880s, cost accounting systems, methods for planning and scheduling production and organizing materials, and incentive wage plans were staples of a burgeoning literature of industrial management. Their objective was an unimpeded flow of materials and information. In human terms, systematic management sought to transfer power from the first-line supervisor to the plant manager and to force all employees to pay greater attention to the manager's goals. Most threatening to the status quo, it promoted decisions based on performance rather than on personal qualities and associations (see Yates 1989, 1991; Levenstein 1991).

In the 1890s, an ambitious young inventor, manager, and consultant, Frederick Winslow Taylor, became the most vigorous and successful proponent of systematic management. As a consultant, he introduced accounting systems that permitted managers to use operating records to guide their actions, production-control systems that allowed managers to know more precisely what was happening on the shop floor, piece-rate systems that encouraged workers to follow orders and instructions, and various related measures. In 1895, he employed a colleague, Sanford E. Thompson, to help him determine the optimum time to perform industrial tasks; their goal was to compute, by rigorous study of the worker's movements and the timing of those movements with stopwatches, standards for skilled occupations that could be published and sold to employers. Between 1898 and 1901, as a consultant to the Bethlehem Iron Company, Taylor introduced all of his systems and vigorously pursued his research on the operations of metal-cutting tools. This experience, punctuated by controversy and escalating conflict with the company's managers, was the capstone of his creative career. Two features of it were of special importance. Taylor's discovery of high-speed steel, which improved the performance of metal-cutting tools, assured his fame as an inventor. In the meantime, his effort to introduce systematic methods in many areas of the company's operations forced him to take an additional step: to develop an integrated view of managerial innovation and a broader conception of the manager's role. By 1901, Taylor had fashioned scientific management from systematic management (Copley 1923; Nelson 1980; Kakar 1970).

As the events of Taylor's career make clear, the two approaches were intimately related. Systematic and scientific management had common roots, attracted the same kinds of people, and had the same business objectives. Yet in retrospect the differences stand out. Systematic management was diffuse and utilitarian, a series of isolated measures that did not add up to a larger whole or have recognizable implications beyond day-to-day industrial operations. Scientific management added significant detail and a larger view. It was the first step toward the utopian vision of the 1910s. In 1901, when he left Bethlehem, Taylor resolved to devote his time and ample fortune to promoting his new conception of industrial management. His first report on his work, *Shop Management* (1903), portrayed an integrated complex of systematic management methods, supplemented by refinements and additions such as time study.

In the following years, as Taylor's reputation grew, he modified his presentation to make it more appealing. Two changes were notable. First, he began to rely more heavily on anecdotes from his career to emphasize the links between improved management, greater productivity, and social melioration to audiences that had little interest in technical detail. He liberally interpreted his records and recollections to make his point. His parable of "Schmidt," a laborer who supposedly prospered because of an incentive wage, was largely apocryphal, but it captured the imaginations of legions of readers (Wrege and Perroni 1974). Second, apart from the object lessons, Taylor spoke less about factory operations and more about the significance and general applicability of his ideas. Between 1907 and 1909, with the aid of a close associate, Morris L. Cooke, he wrote a sequel to *Shop Management* that became *The Principles of Scientific Management* (1911) (Wrege and Stotka 1978). Rather than discuss the specific methods he introduced in factories and shops, Taylor relied on colorful stories and language to illuminate "principles" of management. To suggest the integrated character and broad applicability of scientific management, he equated it to a "complete mental revolution."

Taylor's reformulation of scientific management was the single most important step in the popularization of industrial engineering. *The Principles* extended the potential of scientific management to nonbusiness endeavors and made Taylor a central figure in the "efficiency craze" of the 1910s (Haber 1964). To engineers and nonengineers alike, he created order from the diverse prescriptions of a generation of technical writers. By the mid-1910s, he had achieved wide recognition in American engineering circles and had attracted a devoted following in France, Germany, Russia, and Japan (Fridenson 1987; Moutet 1975; Homburg 1978; Beissinger 1988; Daito 1989; Gordon 1989). His growing body of admirers at universities such as Pennsylvania State College, which introduced the first industrial engineering major in 1907, was another measure of the potency of his message (Nelson 1992b).

Taylor also had a major influence on the diffusion of scientific management in industry. His insistence that the proper introduction of management methods required the services of an expert intermediary linked the progress of industrial engineering to the activities of independent consultants and accelerated the rise of a new profession.

2.2 The Role of the Consultant

Initially, the spread of systematic and scientific management occurred largely through the work of independent consultants, a few of whom, such as the accountant J. Newton Gunn, achieved prominence by the end of the nineteenth century. By 1900, Taylor overshadowed the others; by 1910, he had devised a promotional strategy that relied on a close-knit corps of consultants to install his techniques, train the client's employees, and instill a new outlook and spirit of cooperation. The expert was to ensure that the spirit and mechanism of scientific management went hand in hand. The formula did not always work smoothly, as many accounts have emphasized (Nelson 1980, 137–67; Aitken 1960; Nadworny 1955). Nevertheless, it produced a number of successful consulting firms and the largest single cluster of professional consultants devoted to industrial management.

Between 1901 and 1915, Taylor's immediate associates introduced scientific management in nearly two hundred American businesses, 80 percent of which were factories (Thompson 1917, 36–104). Some of the plants were large and modern, like the Pullman and Remington Typewriter works; others were small and technologically primitive. Approximately one-third of the total were large-volume producers for mass markets. A majority fell into one of two broad categories. First were those whose activities required the movement of large quantities of materials between numerous workstations (textile mills, railroad repair shops, automobile plants). Their managers sought to reduce delays and bottlenecks and increase throughput. On the other hand were innovative firms, mostly small, that were already committed to managerial reform. Their executives were attracted to Taylor's promise of social harmony and improved working conditions. A significant minority of the total fell in both categories. Many of the textile mills, for example, were leaders in welfare work (Nelson 1984, 56–57).

The records that have survived suggest that the consultants provided valuable services to many managers. They typically devoted most of their time to machine operations, tools and materials, production schedules, routing plans, and cost and other record systems. Apart from installing features of systematic management, their most notable activity was to introduce elaborate production-control mechanisms (bulletin boards and graphs, for example) that permitted managers to monitor operations. At the Franklin Automobile Company and a number of textile mills, the consultant's work consisted almost exclusively of improvements in scheduling and routing (Babcock 1917; Nelson 1980, 149–54). Critics complained of excessive detail and red tape, but most executives expressed satisfaction with the engineers' work.

The records do not support the contention, common to many later accounts, that the experts' central concern was the work of the individual employee. In one-third of the factories, the consultant's activities generated such controversy that time and motion studies were never undertaken. Many workers in other plants were unaffected. At least one-half of the employees of the industrial companies must have been essentially onlookers. They may have experienced fewer delays, used different tools, or found that their supervisor's authority had diminished, but their own activities were unchanged (Nelson 1992b, 11–12).

What about those who were directly affected? Judging from the available evidence, neither Taylor nor his critics provided an accurate guide to the experts' activities. Supervisors lost much of their discretionary authority as they became subject to centrally imposed policies and regulations. Machine operators worked more steadily and performed fewer peripheral tasks. They also earned higher wages, though there were enough exceptions to blur the effect. Some unskilled jobs disappeared as improved scheduling and routing reduced the need for gangs of laborers and encouraged the introduction of materials-handling machinery. But few firms embraced functional foremanship, which called for substituting specialists for the traditional supervisor, and even fewer tried to substitute management systems for the expertise of skilled operatives. While no systematic accounting is possible, improvements in production and costs resulted overwhelmingly from the elimination of delays and bottlenecks, improved communications, and the introduction or extension of wage incentives, not from new techniques of work or work organization.

Initially, at least, social harmony was more often a casualty than a consequence of scientific management. Supervisors opposed the erosion of their powers and autonomy, while production workers often resisted the introduction of time study. The proper use of time study became and remained a delicate issue. The consultants' promises of harmony and prosperity depended on the fair and "scientific" application of time study, but many workers suspected that it would be a pretext for rate cuts and lower wages. In many cases their fears were warranted. Labor disputes (and strikes at Watertown Arsenal, Joseph & Feiss, and American Locomotive) resulted from the inability of many managers to resist the temptation to use time study for short-term cost cutting. Such abuses led to vigorous union campaigns against time study and incentive plans in the mid-1910s.

The contrast between the theory and practice of industrial engineering reflected several factors. The most obvious was the tradition of decentralized production management and the established web of interests that resisted innovation. A second factor was closely related: in most settings prior investment in machinery and other equipment limited the engineer's ability to introduce changes, regardless of the liberality of his or her mandate. An ideal arrangement would have required a new plant as well as new attitudes and responsibilities. A third element, ironically, was the role of the consultant, which contributed to a short-term, cost-cutting perspective. By definition a consultant was a transient, short-term employee. Taylor had proclaimed that a thorough reorganization required three or four years, but few of his successors had the temerity or financial security to make similar demands on their clients. They promised results and concentrated on goals that would justify their employment. Taylor's reliance on the consultant had been a way to accelerate the diffusion of his ideas. In practice, however, it undermined the likelihood of a "complete mental revolution."

Between 1910 and 1920, industrial engineering spread rapidly. Although large firms introduced staff departments devoted to production planning, time study, and other industrial-engineering activities, the most notable development of those years was the proliferation of consulting firms. By 1915, the year of Taylor's death, he and his immediate followers no longer controlled the diffusion of his methods. Professional organizations, notably the Taylor Society (1910) and the Society of Industrial Engineers (1911), provided forums for the discussion of techniques and the development of personal contacts. But after brief and unsuccessful trials, they did not try to regulate entry to the profession or certify the competence of practitioners (Nelson 1980, 181–85; Haber 1964). Financial success and professional recognition increasingly depended on entrepreneurial and communications skills rather than technical expertise. Several of Taylor's closest associates, including Carl G. Barth and H. K. Hathaway, failed as consultants, while a new generation of practitioners, including many university professors who had had no direct contact with Taylor and whose credentials would have been viewed with suspicion a decade earlier, developed successful consulting practices.

Competition for clients and recognition—especially after the recession of 1920–21 made executives more cost-conscious—produced other changes. Some consultants began to seek clients outside manufacturing. Spurred by the growing corps of academicians who argued that the principles of factory management applied to all businesses, they reorganized offices, stores, banks, and other service organizations (Davies 1982, 97–108; Strom 1989, 64–69; Rotella 1981, 51–58; Yates 1989, 21–64). Others specialized. A Society of Industrial Engineers survey of leading consulting firms in 1925 reported that many confined their work to plant design, accounting systems, machinery, or marketing (Quigel 1992, 403). A third trend was an increasing preoccupation with labor issues and time study. This emphasis reflected several postwar developments, most notably and ominously the increasing popularity of consultants who devoted their attention to cost cutting through the aggressive use of time study.

By the early 1920s, industrial engineers who worked in industry had divided into two separate and increasingly antagonistic camps. On the one hand were the pioneers and their heirs who viewed scientific management as an interrelated group of techniques that included increasingly sophisticated policies for managing production workers. Taylor and his associates had devoted little attention to labor issues apart from wage incentives. The attacks of labor unions and their political allies exposed the limitations of this approach, and the World War I economic boom showed that other personnel activities such as recruitment and training programs, representation schemes, and employee benefit plans were as important to improved economic performance as time study and the incentive wage. In the postwar years, the most influential group of industrial engineers, centered in the Taylor Society, embraced personnel management and combined it with orthodox industrial engineering to form a revised and updated version of scientific management. A handful of Taylor Society activists, Richard Feiss of Joseph & Feiss, Henry S. Dennison of Dennison Manufacturing, Morris E. Leeds of Leeds & Northrup, and a few others, mostly owner-managers, implemented the new synthesis. They introduced personnel management and more controversial measures such as profit sharing, company unionism, and unemployment insurance that attacked customary distinctions between white- and blue-collar employees and enlisted the latter, however modestly, in the management of the firm (Goldberg 1992; Heath 1929; Berkowitz and McQuaid 1992; Nelson 1970).

A larger group emphasized the potential of incentive plans based on time and motion study and disregarded or deemphasized other features of orthodox scientific management. Their more limited approach reflected the competition for clients, the trend toward specialization, and the continuing attraction of rate cutting. Indicative of this tendency was the work of two of the most successful consultants of the post-1915 years, Harrington Emerson and Charles E. Bedaux. Emerson (1853–1931) was a restless, creative, and flamboyant personality. Attracted to Taylor at the turn of the century, he briefly worked as an orthodox practitioner and played an influential role in Taylor's promotional work. He soon became a respected accounting theorist and a successful reorganizer of railroad repair facilities. As his reputation grew, however, he broke with Taylor and set up a competing business with a large staff of engineers and consultants. Between 1907 and 1925, he had over two hundred clients (Nelson 1980, 127–30; Johnson and Kaplan 1987, 51; Quigel 1992, 279–325). He also published best-selling books and promoted a mail-order personal efficiency course. He was probably the best-known industrial engineer of the late 1910s and early 1920s.[1]

Emerson's entrepreneurial instincts defined his career. An able technician, he was capable of overseeing the changes associated with orthodox scientific management. He also recruited competent assistants, such as Frederick Parkhurst and C. E. Knoeppel, who later had distinguished consulting careers, and E. K. Wunnerlund, who became the head of industrial engineering at General Motors. But Emerson always viewed his work as a business and tailored his services to this customer's interests. In practice, this meant that his employees spent most of their time conducting time studies and installing incentive wage systems. By the mid-1920s, General Motors, Westinghouse, the Baltimore & Ohio Railroad, Aluminum Company of America, American Radiator, and many other large and medium-sized industrial firms had introduced the Emerson system and in many cases an industrial engineering department staffed by former Emerson employees.[2]

1. "Harrington Emerson, 1853–1931," Harrington Emerson Papers, box 9, Pennsylvania State University Library, University Park, Pennsylvania.

2. Emerson Papers, boxes 2–9.

Bedaux (1886–1944) was even more adaptable. A French immigrant who was a clerk at a St. Louis chemical company in 1910 when an expert arrived to conduct time studies, Bedaux quickly grasped the essentials of time study and replaced the outsider. During the "efficiency craze" that followed the publication of *The Principles,* he found other clients. The turning point in his career came in 1912, when he accompanied several Emerson engineers to France as an interpreter. In Paris he struck out on his own, reorganized several factories, and studied the writings of Taylor and Emerson. Returning to the United States during World War I, he launched the Bedaux Company and began to cultivate clients. Bedaux rejected the promotional strategy that Taylor, Emerson, and Frank and Lillian Gilbreth, other Taylor disciples, had perfected. He gave no speeches, wrote no books or articles, avoided professional meetings, and never discussed his methods in public. Instead he relied on personal contacts and a simple, compelling promise: he would save more money than he charged. Although Bedaux employed able engineers and usually made some effort to reorganize the plant, his specialty was the incentive wage. His men worked quickly, used time studies to identify bottlenecks and set production standards, installed a wage system similar to Emerson's, and explained their activities in incomprehensible jargon. Bedaux's clients included General Electric, B. F. Goodrich, Standard Oil of New Jersey, Dow Chemical, Eastman Kodak, and more than two hundred other American firms by the mid-1930s. His European offices were even more successful (Kreis 1992).

Bedaux's secretive approach makes it impossible to generalize about his services in the United States, but the records of his British subsidiary, recently opened, reveal a consistent effort to pressure workers for greater output. Whereas Taylor and his followers opposed wage cutting and "speed-up" efforts, Emerson was more flexible, and Bedaux made a career of forcing workers to do more for less. One notable result was a resurgence of strikes and union protests. By the 1930s, Bedaux had become infamous on both sides of the Atlantic. In response to his notoriety, he revised his incentive plan to increase the worker's share and dropped much of his colorful terminology, including the famous B unit. Bedaux's business survived, though neither he nor his firm regained the position they had enjoyed in the late 1920s and early 1930s (Kreis 1992).

Bedaux's unsavory reputation was a substantial burden for other industrial engineers. The growth of labor unrest in the 1930s and the frequent appearance of the "Be-do" plan on grievance lists revived the association of industrial engineering with labor turmoil. Regardless of their association with Bedaux and his tactics, industrial engineers became the targets of union leaders and their allies. In industries such as autos and tires, worker protests paralyzed the operations of industrial engineering departments and led to the curtailment or abandonment of many activities.

These problems were closely related to a longer-term threat to industrial engineering. The growth of labor unrest and government regulation of labor relations in the mid-1930s led many large industrial firms to create or strengthen personnel departments (Jacoby 1986). In theory, industrial engineers and personnel and industrial relations experts subscribed to the same values and objectives. In practice, however, they were often antagonists and competitors. Apart from influencing wage, salary, and employee-benefit policies, industrial-relations managers had a strong intellectual and professional interest in maintaining stability on the shop floor. They helped curb the work of Bedaux and others like him, but they also resisted other changes that might lead to unrest.[3] Managerial innovation became more difficult, and industrial engineers found themselves increasingly confined to activities that did not directly affect wages or working conditions (Kochan, Katz, and McKersie 1986).

2.3 The Impact of Industrial Engineering in the 1920s and 1930s

Although the archives of the major consulting firms and the publications of professional associations document the evolution of industrial engineering as an intellectual discipline and a professional specialty, they provide only the most general indications of the effects of this activity on the firm and its employees. The client lists that have survived generally do not explain what was done, who was affected, or, in most cases, how influential the work was on operations or the viewpoint of executives. The thrust of Bedaux's work and of the expansion of industrial-relations management is clear, but its practical effects are less obvious. What, if anything, can be concluded from the experiences of later years?

There are at least three partial measures of the diffusion of industrial engineering that help answer this question. First, the many references to cost accounting, centralized production planning and scheduling, systematic maintenance procedures, time study, and employment management in the trade press and in the records of industrial corporations indicate that these activities were no longer novel or unfamiliar to executives. The promotional work of the consultants, the "efficiency craze," and the growth of management education in universities had made the rudiments of industrial engineering widely available; only the oldest or most isolated executives were unaware of them. The critical issue was no longer the desirability of the new management; it was the particular combination of techniques suitable for a given firm or plant, the role of the outside consultant, if any, and the authority of the staff experts.

Second, the information on industrial wage systems that the National Industrial Conference Board assiduously collected in the 1920s and 1930s documents widespread acceptance of incentive wage plans, particularly among large corporations. In 1928, for example, 6 percent of the smallest companies (1–50 employees) had incentive wage plans, while 56 percent of the largest

3. Unions had a similar impact, although their influence was comparatively short-lived. See Harris 1982.

firms (more than 3,500 employees) had such plans. In earlier years, small firms devoted to industrial reform had been among the most vigorous proponents of industrial engineering. But their ranks did not grow, and they were soon overshadowed by large corporations, which found in industrial engineering an effective answer to the problems that often prevented large, expensive factories from achieving their potential (Nelson 1991, 79). Incentive wage plans were an indicator of this trend, but—Bedaux notwithstanding—they were also indicators of more extensive managerial initiatives.

The popularity of incentive plans did not mean, however, that industrial engineering had a more uniform or predictable effect on work organization and job content than in earlier years. Feiss, Dennison, and others hoped to transform the character of industrial work through the use of incentives and personnel programs; judging from the information that survives, big business managers had more modest goals. Their principal objective was to make the best use of existing technology and organization by enlisting the workers' interest in a higher wage. In the early 1930s, many managers were attracted to the "work simplification" movement that grew out of the Gilbreths' activities, but the effects were apparently negligible, at least until the World War II mobilization effort. To most manufacturers, industrial engineering provided useful answers to a range of shop-floor problems; it was a valuable resource but neither a stimulus to radical change nor a step toward a larger goal.

A third source, contemporary surveys of the industrial engineering work of large corporations, provides additional support for this conclusion. The most interesting of these surveys, by Stanley Mathewson in 1928, found no difference in attitude between workers at General Motors, Westinghouse, and other giants noted for their advanced managerial practices, and workers in smaller, less modern plants. Mathewson discovered widespread efforts to restrict production in order to protect wages or jobs (Mathewson 1931). Clearly, the mental revolution had not reached the shop floor at these plants. A 1928 survey by the Special Conference Committee, an elite group of large industrial firms, emphasized related problems.[4] It reported wide differences in the practice of time study, in the duties of time-study technicians, and in the degree of commitment to time study as an instrument for refining and improving the worker's activities. At Western Electric, which had one of the largest industrial engineering staffs, a manufacturing planning department was responsible for machinery and methods; the time-study expert was simply a rate setter. At Westinghouse, which also had a large industrial engineering department, time-study technicians were responsible for methods and rates. However, a report from the company's Mansfield, Ohio, plant indicated that the time-study engineer could propose changes in manufacturing methods "in cooperation with the foremen." Most companies had similar policies. The time-study expert

4. E. S. Cowdrick, "Methods of Wage Payment," Bethlehem Steel Company Papers, accession 1699, Hagley Library, Wilmington, Delaware.

was expected to suggest beneficial changes to his superiors, often after consulting the foreman, but had no independent authority to introduce them. Essentially, the "expert" was a rate setter. In most plants, industrial engineering focused on detail, seldom threatened the supervisors or workers, and even more rarely produced radical changes in methods. Except in the hands of a Bedaux, it was not a serious threat to the status quo.

A recent, detailed examination of industrial engineering at E. I. Du Pont de Nemours & Company, a Special Conference Committee member, suggests the range of possibilities that could exist in a single firm (Rumm 1992, 175–204). Du Pont executives created an Efficiency Division in 1911 after the company's general manager read *The Principles*. Rather than employ an outside consultant, they appointed two veteran managers to run the division. These men conducted time and motion studies, "determined standard times and methods for tasks, set standard speeds for machinery, and made suggestions for rearranging the flow of work, improving tools, and installing labor-saving equipment." Yet they encountered a variety of difficulties; their proposals were only advisory, they clashed with the new employment department when they proposed to study fatigue and the matching of workers and jobs, and they found that many executives were indifferent to their work. Worst of all, they could not show that their activities led to large savings. In 1914, after the introduction of functional supervision in the dynamite-mixing department apparently caused several serious accidents, the company disbanded the Efficiency Division (Stabile 1987).

Although some Du Pont plants introduced time-study departments in the following years, the company did nothing until 1928, when it created a small Industrial Engineering Division within the larger Engineering Department. The IED was to undertake a "continuous struggle to reduce operating costs." That battle was comparatively unimportant until the Depression underlined the importance of cost savings. In the 1930s, the IED grew rapidly, from twenty-eight engineers in 1930 to over two hundred in 1940. It examined "every aspect of production," conducted job analyses, and introduced incentive wage plans. Like Taylor's associates a quarter century before, IED engineers began with surveys of existing operations. They then "consolidated processes, rearranged the layout of work areas, installed materials-handling equipment, and trimmed work crews." To create "standard times" for particular jobs, they used conventional stopwatch time study as well as the elaborate photographic techniques the Gilbreths had developed. By 1938, they had introduced incentive wage plans in thirty plants; one-quarter of all Du Pont employees were affected (Rumm 1992, 181–87).

Du Pont introduced a variety of incentive plans. Three plants employed the Bedaux Company to install its incentive system. Other managers turned to less expensive consultants, and others, the majority, developed their own "in-house" versions of these plans. Some executives, and workers, became enthusiastic supporters of incentive wages; others were more critical. Despite the work of the aggressive and ever-expanding IED, many workers found ways to take advantage of the incentive plans to increase their wages beyond the anticipated ranges. Wage inflation ultimately led the company to curtail the incentive plans. Time and motion study, however, remained hallmarks of Du Pont industrial engineering (Rezler 1963).

The Du Pont experience illustrates several larger themes. The diversity of manufacturing operations in large corporations such as Du Pont militated against a "complete mental revolution" and a more aggressive approach to shop-floor problems than had been characteristic of the engineers' activities in earlier years. Like other novel proposals, industrial engineering at Du Pont had to compete for resources. The failure of the Efficiency Division to produce immediate benefits compromised its position and ultimately led to its downfall, despite its appealing message. Only the collapse of the economy, the rise of new cost pressures, and, concomitantly, the company's success in avoiding or deflecting labor unrest revived interest in industrial engineering and created the consensus that sustained the IED in the 1930s. By 1940, IED technicians approached the goals of the original scientific management movement. Still, Du Pont did not entirely escape the pattern of opportunistic cost cutting. The executives who employed Bedaux or who introduced Bedaux-like wage plans with minimal prior study and reorganization were examples of the other, more controversial side of industrial engineering.

The eventual success of the IED obscured a more central problem. By 1910, Du Pont was supposedly one of the best-managed American corporations. It had reorganized successfully and had absorbed much of the spirit of the scientific management movement. Yet Du Pont's top executives had little interest in extending managerial reform to the shop floor. During the depression of the 1930s, when they developed a new sensitivity to the value of industrial engineering, they defined it as a way to cut factory costs. They transcended the Bedaux approach but remained surprisingly parochial. One reason for this perspective was bureaucratic: Du Pont had developed an extensive personnel operation in the 1910s and 1920s, which had authority over employee training, welfare programs, and labor negotiations. Equally important was the apparent assumption that industrial engineering only pertained to the details of manufacturing activities, especially the work of machine operators. Despite mounting pressures to reduce costs, the company's offices, laboratories, and large white-collar labor force remained off-limits to the IED. Despite these handicaps, the IED had a significant impact because rapid technological change in the industry created numerous opportunities for organizational change and Du Pont avoided relations with powerful unions.

Apart from its timing, the Du Pont experience was consistent with the evidence noted above. Like most manufacturers, Du Pont executives were receptive to the "principles" of industrial engineering but focused on the particulars, which they assessed in terms of their potential for improving short-term economic performance. As a result there was little consistency in their activities until the 1940s; even then, industrial engineering was restricted to the company's manufacturing operations. This approach, fragmentary and idiosyncratic by the standards of Taylor or Dennison, was logical and appropriate to executives whose primary objective was to fine-tune a largely successful organization.

2.4 Conclusions

During the first third of the twentieth century, industrial engineers successfully argued that internal management was as important to the health of the enterprise as technology, marketing, and other traditional concerns. Their message had its greatest impact in the 1910s and 1920s, when their "principles" won wide acceptance and time study and other techniques became commonplace. Managers whose operations depended on carefully planned and coordinated activities and reformers attracted to the prospect of social harmony were particularly receptive. By the 1930s, the engineers' central premise, that internal coordination required self-conscious effort and formal managerial systems, had become the acknowledged basis of industrial management.

Although the popularity of industrial engineering was due in large measure to the writings of Taylor and other pioneers, few executives took those statements literally or introduced all or most of the changes that Taylor and other industrial engineers advocated. Their customary approach was pragmatic and selective. This selectivity was apparent in their relations with consultants and in the work of corporate industrial engineering departments. It was also evident in the treatment of factory employees, the feature of industrial engineering that received the greatest attention. Time-study techniques differed from firm to firm, with diverse effects, and incentive wage plans were equally varied in conception and application. In view of these tendencies, it is hardly surprising that industrial engineering had no consistent or predictable effect on the character of industrial work.

Industrial engineering thus contributed to the growing diversity of industrial management in the early twentieth century. Using techniques developed by proponents of systematic management, by Taylor and his followers, and by their successors of the 1920s and 1930s, industrialists were able to adjust their organizations to market pressures, technological innovations, and their conceptions of how a factory or business ought to perform. If they were unsure how to proceed, armies of eager consultants, of varying degrees of fidelity to the tenets of orthodox scientific management, were available to assist them. In the nineteenth century, few industrialists had recognized the potential of this form of internal coordination. By the 1930s, they took it for granted. Although the expansion of industrial relations activities in the late 1930s threatened to reverse this pattern and impose a new uniformity, it affected only a small percentage of plants and industrial workers before World War II.

The variability in the practice of industrial engineering, evident from Taylor's day to the 1940s, greatly complicates any effort to assess its economic impact. In a minority of cases, it led to the realization of Taylor's original objectives and long periods of growth and prosperity. In other instances, it precipitated unrest, disruption, and organizational turmoil. In the majority of cases, however, it contributed in numerous ways, large and small, to improvements in manufacturing operations and firm performance. This mixed legacy, apparent by the eve of World War II, became the foundation for a second, more complex, and even more controversial chapter in the history of industrial engineering that extends to the present.

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Comment Michael J. Piore

Daniel Nelson's paper reviews the impact of Frederick Taylor, scientific management, and industrial engineering upon American manufacturing in the early part of the twentieth century. It is difficult not to read it in the context of the current debate about the competitiveness of the U.S. economy. Many analysts (including myself) have attributed the problems of U.S. manufacturing in the 1970s and 1980s to the persistence of a set of managerial principles and practices developed earlier in the century and built into standard operating procedures of most large American corporations. As a result, it is argued, American manufacturing lacks the flexibility required to adjust to the rapidly changing business environment. Its practices and procedures are also too rigid to use new information and communication technologies effectively. This view has spawned a number of institutional reforms designed to make American business more supple.

On the shop floor, these reforms include pay for knowledge, as opposed to payment linked to output or to particular job assignments; the broadening, even the wholesale elimination, of job categories; the elimination of in-process inventories which isolate individual production operations from one another; increased use of production teams in place of individual work assignments. Reform is not of course limited to shop-floor practice. Indeed, the changes elsewhere in the organization are, if anything, more revolutionary: efforts to reduce hierarchy and eliminate intermediate management positions, matrix management which blurs the clear lines of authority of the traditional organizational charts, efforts to draw suppliers and customers into the design process, parallel engineering through cross-functional teams. We do not have a single name for all of the practices under attack taken as a group. Many organizational structures that are now being eliminated are those whose origin and development were heralded by Alfred Chandler in his monumental work *The*

Michael J. Piore is the David W. Skinner Professor of Economics and Management at the Massachusetts Institute of Technology.

Visible Hand; the reform movement might be called anti-Chandlerian were it not somewhat anachronistic to use his name to describe a set of practices that are on the verge of elimination even as he arrived to celebrate them. But the shop-floor practices are generally linked to Frederick Taylor and the industrial engineering profession, and are often referred to as Taylorism.

Read in this context, the paper constitutes an attack on the use of this term. Its central argument is that industrial engineering, as it was incorporated into American managerial practice in the 1920s, was little more than the view that good management involved "self-conscious effort and formal managerial systems"; it was a "systematic, centralized approach to production management," an attack on "the 'chaotic' condition of contemporary industry," on "guesswork and ad hoc calculations."

The practitioners of industrial engineering (Taylor, his disciples, and other management consultants who delivered similar messages but with whom Taylor generally competed) championed a variety of specific techniques, including job evaluation and time study, but, Nelson insists, U.S. managers were "pragmatic and selective" in the way they absorbed these lessons. "Techniques differed from firm to firm. . . . industrial engineering had no consistent or predictable effect on the character of industrial work." If there was uniformity in the patterns that replaced the "chaotic" conditions that prevailed in the 1880s and 1890s, it affected only a small percentage of plants and industrial workers prior to World War II. There is a strong suggestion at the end of the paper that the uniformity implied by the term "Taylorism" emerged later, in the 1940s. We will have to wait for Nelson's subsequent work to find out how this happened. One imagines that it was imposed by government regulators and industrial unions.

A good deal of what we know about industrial engineering comes from Nelson's own work, and one would be hard-pressed to dispute his scholarship. At one level, I am sure that he is correct: there was much more diversity among industrial engineers and the particular managerial practices that were instituted at their behest than most recent accounts of the development of modern management admit and more diversity still in the way in which the industrial engineering movement was felt in individual firms. In this sense, we have probably been rather sloppy in the way in which we have used the term. But "industrial engineering" and "Taylorism" may nonetheless be an appropriate shorthand for the old managerial approaches in contrast to the new.

The evolution of recent managerial practice suggests that what the industrial engineers viewed as "objective" and "scientific" was in fact a particular way of looking at production operations. The contrast between the older views and the current prescriptions for managerial practice is suggested by two recent titles promoting what their authors clearly conceive of as a revolution: *Thriving on Chaos* and *When Giants Learn to Dance.* Space does not permit a detailed examination of the differences between the new practices and the old. Indeed, we may be too close to the revolution to fully assess its character. Some part of what is going on may be a fashion that will not survive the moment. But the underlying principle seems to be related to the distinction between two fundamental dimensions of organization form, specialization and integration. Taylor, and the industrial engineering profession more broadly, emphasized the dimension of specialization, the division of the production process into neat and well-defined pieces with clearly new tasks that could be unambiguously assigned to particular workers or work groups. In this, they applied on the shop floor principles that analysts such as Weber, and later Schumpeter, thought of as modern and bureaucratic, and Chandler views as the hallmark of the organizational revolution heralded by the advent of the modern cooperation. The newer managerial practices, inspired by Japan, stress the integration of the different elements of the production process with each other. Matrix management, for example, and cross-functional teams break down and blur the lines of authority around which Chandler's exemplary corporate organization was built. The parallel reforms on the shop floor are typified by the effort to eliminate in-process inventories. Production is then brought to a halt by the failure of any single operation, and each operator is thereby forced to pay attention not only to his or her own immediate tasks but to all related tasks as well. This reform requires changes in accounting procedures that were once thought of as modern, since these typically focus on individual components rather than the process as a whole; more important in the present context, it is incompatible with the payment systems pioneered by industrial engineering, which for all their diversity nonetheless shared a predisposition to reward workers for the performance of individual tasks in ways that failed to take account of the system as a whole.

It turns out, then, that what practitioners of industrial engineering viewed as "systematic" and "scientific" is in fact a way of looking at the world that emphasizes specialization at the expense of integration. Alternative practices that emphasize integration appear in this perspective to be, as the titles of the texts that promote them suggest, "chaotic." One is thus led to ask whether the "chaos" of the perspective that Taylorism began to replace at the end of the last century was not actually different, but an equally coherent way of looking at the world, whether Nelson's perspective is not as limited by this way of looking at the world as that of the American managerial community.

This does not completely vitiate Nelson's conclusions about the limited impact of industrial engineering before the war. It does suggest that his view of what industrial engineering was all about is both too broad and too limited. It is too limited because it reduces industrial engineering to the specific shop-floor practices that its practitioners recommended; on these specific practices, the industrial engineers differed among themselves and with the managers whom they advised and who were evidently quite selective in what they actually introduced. But it is too broad in the sense that it accepts the engineers' claim that their role was to impose an objective systemization and order upon a set of practices that, before them, was objectively chaotic. Industrial engineering was much more than a set of specific practices: it was a general way of viewing the productive process. But it was also a limited perspective, one that spread at the expense of alternatives that were, in other times and places, at least valid.

Nelson is probably right in his assertion that the specific practices that we associate with industrial engineering gained dominance in the 1940s. But it may be that the critical moment for the ascendancy of the perspective out of which these practices emerged was the two decades before that. Indeed, reading Nelson against the background of Chandler and the new managerial literature, one might well argue that the relatively late arrival of Taylorism on the shop floor simply reflected the fact that the broader perspective upon management that it embodied rose to dominance in the shop last, only after other, higher-priority managerial practices had been changed to reflect it. Given the central place that industrial engineering gave to shop-floor practice, this would also be consistent with Nelson's argument in the narrow sense; but again it is not consistent with the broader thrust of the paper.

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