The Baldwin Locomotive Works, the Capital Equipment Sector, and American Industrial Practice in the Nineteenth Century

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In this century, mass-producing manufacturing corporations turning out standardized products in bulk are the leading industrial form. So dominant in the modern era, these companies have also come to signify much of our nineteenth-century industrial history. While mass production certainly deserves its biographers, the sheer volume of this literature has blocked many from perceiving the full variety of production practices which propelled and sustained the industrializing nation. This dissertation summary examines an ignored segment of the nineteenth-century economy - the capital equipment builders - and it describes how operations in this sector diverged greatly from the mass producing paradigm.[2] I define capital equipment as those mechanisms sold to secondary firms for their use in the final production of goods or delivery of services. Examining this sector through a case study of the Baldwin Locomotive Works, I argue that capital equipment builders pursued a distinctive business strategy of related policies in product innovation, management, production, and labor relations. This multi-faceted strategy arose from challenges particular to the capital equipment sector, and it clearly distinguishes capital equipment builders from American System machinery manufacturers. Once examined and acknowledged, these distinguishing attributes of the sector will substantially revise nineteenth-century business,

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[1]This essay is drawn from my dissertation, "The Baldwin Locomotive Works, 1831-1915: A Case Study in the Capital Equipment Sector," written in the Department of History at the University of Virginia under the supervision of Olivier Zunz and W. Bernard Carlson. Any uncited material here is drawn from the dissertation. A revised version of the dissertation is forthcoming from the Johns Hopkins University Press.

[2]In a general way, historians such as Thomas Cochran and Nathan Rosenberg have long pointed to firms in the capital equipment sector as vital prime movers in industrialization and economic growth. But only rarely have such generalizations been followed up by detailed examinations of these heavy machinery builders.

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labor, and technological history, while informing our basic portrait of the character of U.S. industrial development.[3]

Although largely unnoted by historians, technical writers at the turn of the century frequently compared the contrasting formats of American System manufacturing and capital equipment building. For example, a dean of American technological history, Joseph Wickham Roe, wrote that

> Two well-defined methods of [metalworking] production are used in industry, and the principles which differentiate them run through all stages of factory production, even to marketing...we may call them *building* and *manufacturing*. The predominate use of one or the other affects the nature of the whole plant, its equipment and methods used...[2]

A resume of each format's characteristics will delineate their noteworthy differences. Manufacturers turned out standard consumer products in volume, whereas builders made custom capital goods in batch or one-off production. A manufactured product, for example, a rifle was designed in complete detail by its maker. A capital good, such as an engine for a waterworks, was described in general specifications written by the purchaser, let for bids, and then designed by the builder in close collaboration with the customer. Rifle production took place on sequentially arranged production lines, using automated or semi-automated production machinery and semi-skilled labor when possible. The engine builder relied on skilled labor from a number of craft trades to make such a custom product. In general, manufacturing required capital intensive production, while machinery building was comparatively labor intensive. The rifle manufacturer sold its volume output to wholesalers for national distribution and eventual retail sale. On the other hand, the engine builder dealt directly with the customer - delivering the engine for testing, acceptance, and final payment. In manufacturing, market success derived largely from securing efficiencies from volume output, national advertising, and effective distribution. Builders based their success on continuous technical refinements, rapid deliveries of their made-to-order products, and close relations with customers.

In describing manufacturing here, I have outlined the well-known story of the American System. Although less apparent in industrial historiography, capital equipment builders also constituted a large sector in the nineteenth-century economy - accounting for 25 percent of the seventy largest industrial employers in America in 1900 [1]. In the nineteenth century, building techniques predominated among such batch-produced capital goods

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[3]Philip Scranton is currently researching a panoply of late nineteenth and early twentieth-century batch producers, including a number of capital equipment firms. His study confirms "the existence of a spectrum of possible approaches to manufacturing" each involving "distinctive technical considerations, labor requirements, and marketing stances, hence different managerial challenges." His preliminary findings are summarized in "Diversity in Diversity: Flexible Production and American Industrialization, 1880-1930," *Business History Review*, 65 (Spring 1991), 27-90.

as machine tools, ships, bridges, mill machinery, railway cars, and locomotives.

This dissertation summary focuses on two related topics which suggest how the capital equipment builders' unique business format can inform the history of industrialization. These two issues are: the underlying reasons for the continuous technical flux in heavy machinery, and a description of those steps which the Baldwin Works took in production management to efficiently produce locomotives in all the design variety required by customers.

To reveal the technical dynamism which lay at the heart of the capital equipment sector, one must start with the products involved in building and manufacturing.[4] As David Hounshell has shown, manufacturers from the Springfield Armory of 1812 to the Ford Motor Company of 1912 increasingly based their operations upon the rigorous standardization of product design. Overseen by managerial bureaucracies, manufacturers integrated standard product designs, routinized production methods, and mass marketing strategies - all harnessed to the single goal of producing uniform products in bulk.

Nineteenth-century capital equipment firms generally found such standardization of products impossible or undesirable. As Nathan Rosenberg has noted, "the capital goods sector is, in effect, engaged in custom work"[3]. For example, in just one year, 1890, the Baldwin Works made 946 locomotives to 316 different designs. Such an accomplishment suggests a technical philosophy and a productive capacity greatly at variance with the manufacturers' model of operations. This was the fundamental issue which drew me to studying this sector, and it raised a number of interesting questions. Why was such variety necessary to Baldwin's customers? Why did this trend of mounting product variety occur in the same half-century, 1850-1900, that saw manufacturers pursuing an opposite course of product standardization? And how could a firm efficiently produce such a range of heavy machinery?

Thomas Hughes has offered a concept which helps answer the first of these questions - why locomotive buyers sought such specially-adapted products. As Hughes notes, technologies generally develop systemically, with each facet or component ideally designed as a part of an integrated system. Buyers of capital goods sought designs that would mesh well with their own systems of production or distribution. Consequently, in the 1850s railway master mechanics began to order locomotives that were custom-built to their own specifications. By 1860, product innovation had become a joint endeavor of the builder and its customers.

The master mechanics' desire for custom engines - which had parallels among most other users of capital equipment - amounted to a call for continuous change in locomotive design over time. Again the Hughesian notion of systemic technical development helps explain this variety over time. Unlike rigid standards, custom designs met the needs of dynamically growing railway systems. Design change over time also arose from the empirical

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[4]I use building and manufacturing here as descriptive terms, rather than strict definitional boundaries.

character of technical development in capital equipment. Finally, personality or ego played a role in this technical flux, since many master mechanics saw locomotives as ideal showcases of their own engineering expertise. In combination the needs of dynamically growing systems, empiricism, and ego propelled continuous evolution in locomotive design, helping to account for Baldwin's 316 varieties of 1890. I have described the underlying causes of this design flux in some detail here because such customer-sponsored innovation on demand characterized most capital goods markets, it defined Baldwin's relationship to its leading mainline customers, and it called forth the firm's highly adaptive productive capacity.

So how did Baldwin build engines in all the designs required by customers? The locomotive builder began refining its management and production practices in the 1850s, twenty years after making its first engine. With customers increasingly preferring custom locomotives, rather than Baldwin's standard engine designs, the company made a fundamental strategic decision. It would retreat from marketing only standard products, while expanding efforts to standardize component designs. Such standard parts would serve as the foundation for a new flexibility in engine design. Specifically circa 1855, Baldwin's General Superintendent, Charles Parry, decided that the optimal way to produce custom engines required use of as many standard components as possible. To that end, he ordered that all work in the factory be done to drawings - a systematizing reform in itself. Thereafter, the Drawing Room became the focal point of systems to coordinate work in the firm's eleven craft departments. The process of establishing sets of standard parts, described in lists and profiled in drawings, began in 1855. These drawings were kept on file and reused frequently for subsequent orders of engines in a variety of designs. As locomotives grew in size, complexity, and variety during the Gilded Age, new standard parts were added to the lists, allowing Baldwin to maintain its efficiency in production while meeting the railways' mounting custom requirements.

This consolidation of coordination in the Drawing Room increased top managers' control while it changed the character of work on the factory floor. For example, standard parts designs allowed some standardization of work and the use of piecerate pay for many tasks, which in turn improved productivity. As noted in 1860 by a Philadelphia journal, *The Engineer*, many employers in the mechanical trades were following this general tendency, "to work the intellectual element out of the shop and confine it to the draughtsman's room"[4].

The Baldwin company created other control and coordination systems in the 1860s as demand, employment, and the custom-design trend all increased. Chief among them was a series of "Law Books" which established rules for draftsmen doing design work. These laws ordered design and production by mandating a range of standard design practices. While dimensional drawings promoted managerial control over the shop floor, the Law Books directed the draftsmen. Thanks in part to such controls, Baldwin had grown by 1872 to become America's largest capital equipment company, employing 2,500 men, and the biggest locomotive builder in the world, with a record annual output of 442 units.

In 1872, Charles Parry created another control device, the List System, to establish production schedules for all work in the plant. This system mandated a standard eight-week production timetable for all locomotives, regardless of their size or complexity. Under Baldwin's List System, each week the General Superintendent's office sent out "shop lists" to every departmental foreman in the plant, enumerating the orders to be built in the following two weeks. While foremen of the 1850s had told the superintendent when to schedule work, by 1872 these roles were reversed. Baldwin's List System bore similarities to the Shop Order system of production management, described in an 1885 paper by Henry Metcalfe, and credited by historians as an important first step in the systematic management movement. But such historians have only considered manufacturers. A Baldwin rival, the Norris Locomotive Works had employed a variant of the List System as early as 1855. It is not surprising that the builders of expensive, complex, and customized heavy machinery sought production management controls earlier than high-volume manufacturers who could count on their standard product designs and routinized production methods to provide some order and regularity.

Once Baldwin had developed these production management systems, it forever spurned the idea of producing only a standard product. Indeed its systems promoted further product variety. In the 1860s and 1870s, Baldwin adapted its design and productive capacities - which it had first created to meet the requirements of American mainline railroads - to fulfilling motive power needs in such new markets as industrial, mass transit, and export customers. This form of technological convergence, in Rosenberg's phrase, allowed the firm to grow by efficiently producing locomotives for a variety of markets.

My dissertation notes other unique characteristics of capital equipment firms, including the fluctuating terms of trade with customers and policies in labor relations. Rather than describing such issues here, however, this limited summary is better served by sketching the ramifications of those matters already detailed. Let me first note that, while I believe Baldwin was emblematic of the sector that it led, I am well aware that a single case study provides a perilously narrow base for generalizations. Although admittedly limited in its focus, this account draws broadly from related fields of technological, labor, economic, and business history. My integrated industrial study of a single firm offers some noteworthy findings for these fields, which heretofore have been dominated by issues in manufacturing.

For technological history, I show how manufacturers and builders could reach opposing goals - standard versus custom products - while sharing a common means - standard parts. While technological historians have detailed the standardizing efforts of American System firms, they have largely overlooked capital equipment where continuous, incremental change boosted sales as quality improvements (frequently advanced by customers) rendered older models obsolete.

Baldwin's pursuit of a variety of markets with differing motive power needs served as an alternate route to scale economies which economic historians may find noteworthy. In this connection, the locomotive builder suggests that technological convergence was common throughout the capital

goods sector. Economic historians have also noted a decline in the relative price of capital equipment circa 1860 which they argue was important to the spread of industrialization. This price drop suggests that Baldwin was not unique - that other capital goods builders of the era took similar steps in production management.

The company's battery of new managerial controls of the 1850s and 1860s dated fifteen to forty years earlier than the given origins of the systematic and scientific management movements - a finding of some import to business history. In establishing such systems, the locomotive builder sought optimization as well as efficiency in production, unlike manufacturers who generally focused on the latter goal alone.

These systems suggest that Frederick Taylor was a late entrant in the field of managerial reform, some revisionism that is particularly overdue in labor history. But in building a variegated product line, Baldwin remained far more reliant on a core group of skilled workers than were contemporary high-volume manufacturers. Labor historians should find that sensitivity to sectoral differences and to the differing demands of efficient and optimal production help explain the uneven advance of organized labor in the nineteenth century.

In the broad history of industrialization, this study underscores the unique importance of firms in the capital equipment sector - literal creators of the infrastructure of industrial America. My account shows that the manufacturers' model of managerial capitalism was only one of many formats which business leaders developed to cope with requirements and contingencies that varied across different product lines and sectors of demand. The builders' model of business organization arose from challenges whose character or extent were unknown in high volume manufacturing. Indeed the technical dynamism of the capital equipment sector was arguably the most important foundation for industrialization itself.

References

1. Count derived from table in Daniel Nelson, *Managers and Workers: Origins of the New Factory System in the United States, 1880-1930* (Madison, 1975), 7-8.
2. Joseph Wickham Roe and Charles Lytle, *Factory Equipment* (Scranton, PA., 1935), 1.
3. Nathan Rosenberg, "Technological Change in the Machine Tool Industry, 1840-1910," *Journal of Economic History*, 23 (1963), 416.
4. "Workmen," *The Engineer*, 1 (Sept. 27, 1860), 51.