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Design Rules, Volume 2: How Technology Shapes Organizations

Chapter 9 Organizing to Rationalize

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Working Paper 20-033

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Funding for this research was provided in part by Harvard Business School.

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Note to Readers: This is a draft of Chapter 9 of *Design Rules, Volume 2: How Technology Shapes Organizations*. It builds on prior chapters, but I believe it is possible to read this chapter on a stand-alone basis. The chapter may be cited as:

Baldwin, C. Y. (2019) "Organizing to Rationalize," Harvard Business School Working Paper (September 2019).

I would be most grateful for your comments on any aspect of this chapter! Thank you in advance, Carliss.

Abstract

The purpose of this chapter is to explain what the technologies of flow production with stochastic bottlenecks require and reward in organizations. I argue that organizations successfully implementing these technologies are likely to have unified governance and exercise direct authority over process design, job definitions and task assignments. As they come to employ more people, they will create hierarchical management structures as a means of managing information flows and delegating decision rights. Finally from the early 20th Century through the present, most of these organizations saw advantage in being legally organized as corporations, which could own assets, enter into contracts and employ individuals in their own right.

The result was a "paradigm" of mass production—a cluster of concepts that came to define both "big business" and "high technology" in the United States and elsewhere. Throughout the middle years of the 20th Century, many members of society took for granted the fact that successful businesses using advanced technology would be organized as large, vertically integrated corporations, exercise direct authority, and use managerial hierarchies to channel information and delegate responsibility.

Introduction

In a series of historical works, Alfred Chandler claimed that the "modern industrial corporation" spanning production and distribution and administered by a hierarchy of managers arose in the United States in response to the convergence of new automated flow technologies with opportunities to sell goods in large national markets.

> [T]he large managerial firm that integrated mass production and mass distribu-tion appeared in industries with two characteristics. The first and most essential was a technology of production in which the realization of potential scale economies demanded close and constant coordination and supervision of material flows by trained managerial teams. The second was the production of goods whose

> marketing and distribution in volume required investment in specialized, product-specific human and physical capital.[1]

Chandler's argument rests on three points:

1. The existence of mechanical technologies with a large cost advantage when operated at high volume (economies of scale in production);
2. The existence of markets where goods can be sold "in volume"; and
3. The need for "close and constant coordination and supervision of material flows" from start to finish of the process.

These characteristics of the environment and technology can be mapped onto three sets of inter-related investments: (1) investment in large-scale cost-saving capital equipment; (2) investment in marketing and distribution; and (3) investment in systematic management to find and address bottlenecks in a multi-step flow process. According to Chandler, "this three-pronged investment in production, distribution and management… brought the modern industrial enterprise into being."[2]

In the last chapter, I reinterpreted Chandler's three-pronged investments using the theory of supermodular complements.[3] Under a simple model of demand and profit maximization, I showed that more of any one of these investments increases the returns to the other two. Thus capital equipment is worth more in growing markets and market growth is worth more when capital equipment can be used to reduce unit costs. Finally the value of systematic management increases in the presence of market growth and/or cost-saving capital equipment.

The purpose of this chapter is to explain what the technologies of flow production with stochastic bottlenecks require and reward in organizations. I argue that organizations successfully implementing multi-step flow production technologies are likely to have unified governance and exercise direct authority over process design, job definitions, and task assignments. Furthermore, as they come to employ more people, they will adopt hierarchical management structures as a means of managing information flows and delegating authority. Finally, in the early 20th Century, most of these organizations saw advantage in being legally organized as corporations, which could own assets, enter into contracts, and employ individuals in their own right.

The result was a "paradigm" of mass production—a cluster of concepts that came to define both "big business" and "high technology" in the United States. Throughout the middle years of the 20th Century it was widely accepted by many members of society that successful businesses using advanced technology would be organized as large, vertically integrated corporations, exercise direct authority and use managerial hierarchies to channel information and delegate responsibility. The vertically integrated companies that

[1] Chandler (1986) p. 387.

[2] Chandler (1990) p. 8.

[3] Milgrom and Roberts (1990; 1995).

dominated the computer industry in the 1960s and 1970s (see Chapter 1) were examples consistent with the paradigm of mass production.

9.1 Organizational Mandates for Flow Production

At the end of Chapter 7, I argued that profit-seeking sponsors of large technical systems must manage their technical and organizational architectures in ways that solve four generic problems:

- Provide all essential functional components;
- Solve system-wide technical bottlenecks wherever they emerge;
- Control and defend one or more strategic bottlenecks; and
- Prevent others from gaining control of any system-wide strategic bottleneck.

Actions aimed at providing all essential functional components and addressing technical bottlenecks result in the largest possible surplus for the technical system as a whole. Actions aimed at securing strategic bottlenecks (and preventing rivals from doing so) allow the sponsor to capture a significant share of that surplus.

The question is: what forms of organization can achieve these goals in the context of multi-step flow processes in growing markets with opportunities to automate individual steps? In sections below, I address this question along the three dimensions of organizational architecture defined in Chapter 1: unified governance, the exercise of direct authority, and the use of managerial hierarchies.

9.2 Unified vs. Distributed Governance

Questions about the appropriate form of governance for a given technical system are essentially questions about the nature of complementarities within the system. Strong complements are essential to one another and uniquely co-specialized. Transaction cost economics and property rights theory both argue that a system made up of strong complements is best placed under unified governance, so that all of the components may be brought together with minimal recourse to defensive investments or holdup. Weak complements are not essential to one another and can be subject to distributed governance, linked by market transactions.

Supermodular complementarity, where more of any input makes the other inputs more productive, leads to mixed results. In Chapter 5, I showed that if three conditions are satisfied, then distributed governance can be sustained as a long-term dynamic equilibrium. In such cases, a network or cluster of autonomous firms will be the preferred way to organize the technical system. The question is, does distributed supermodular complementarity (DSMC) hold for flow production processes subject to bottlenecks?

The answer is no. Specifically, the presence of bottlenecks *scattered through the steps of a flow process* creates the need for unified governance. To find bottlenecks, systematic managers must gather and correlate information across the entire system. On finding bottlenecks, they must be empowered to take complex actions to change workflow and job content to eliminate the bottleneck. This sometimes entails local action—adding a person or a machine at a given point in the process. However the need for action can arise anywhere in the process.

A group of recurring bottlenecks may also have a single root cause that responds to system-wide changes. Centralized purchasing, inventory control, and order management systems as well as standardized information exchanges between different functional units are examples of systemic changes designed to address multiple bottlenecks in a single stroke.[4]

In the absence of bottlenecks, different parts of a multi-step process can be carried out with little or no loss of value by separate firms. I made this argument using the example of the smiths and the cooks in Chapter 8. To generalize the argument, let us imagine a flow production process in which the capacity of any step can be adjusted up or down without costs or limitations. For simplicity, let there be two firms, Upstream and Downstream. Upstream is responsible for production and can make labor-saving capital investments. Downstream purchases Upstream's output and is responsible for distribution and marketing: it can make investments that increase the size of the market.[5]

Now suppose Downstream invests in advertising and distribution to increase the size of its market. In the absence of bottlenecks, it will increase the quantity of goods ordered from its Upstream supplier. Thus Upstream will benefit from Downstream's market-expanding investment (an externality). The higher quantities ordered will then increase the value to Upstream of cost-saving capital equipment. Once that investment has been made, lower variable costs will lead Upstream to reduce the price of its intermediate good. Thus Downstream will benefit from Upstream's cost-reducing investment (another externality). It will then have even more incentives to invest again to expand the market.

In effect, Upstream and Downstream firms *are in a symbiotic relationship, but they can coordinate their actions in the market, via prices charged and quantities ordered*. Even though their choices display supermodular complementarity, market signals are sufficient to push both firms' investments in the "right" direction.[6]

The presence of bottlenecks scattered among the steps causes this type of decentralized decision-making to break down and rewards placing all steps under unified governance. For example, suppose Downstream sees an opportunity to increase the size of its market, but Upstream faces a bottleneck in production. Upstream will then not be

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[4] Yates (1989).

[5] I assume that Upstream and Downstream's assets are not co-specialized: each has other potential trading partners thus is not vulnerable to holdup by the other.

[6] One might object by noting that, each firm receives only a fraction of the revenue from end-product sales thus will not push its investment as far as if the two firms combined. But in a dynamic context, each will get an extra kick from the investments of the other, thus over time, will make heuristic adjustments to their investment models.

able to increase its production to meet Downstream's new demand, and Downstream's investment will not pay off. Symmetrically, if Upstream invests in labor-saving equipment and Downstream faces bottlenecks in distribution, then Downstream will not increase the quantity of goods ordered. Upstream may gain somewhat from lower costs, but it will not be able to grow, reducing its return on investment.

Unless both firms invest in systematic management *and freely share information about their respective processes*, it may be impossible to identify the location of the "true" production bottleneck. Thus finding and addressing production bottlenecks in a multi-step process is *easier* within a single firm than across two or more firms. Within a single firm, managers can gather the required information, and based on the information, redesign steps as needed. Lacking such authority, the process of finding and addressing the bottlenecks may be stymied by disputes and obstructed at every turn.

Indeed this was precisely the weakness of the so-called "inside contracting" system of production, which was used extensively in U.S. and British factories during the 19th Century. Under this organizational architecture, the owners of a firm provided space, machinery, raw material and working capital and arranged for the sale of finished products. But different parts of the production process were assigned to contractors who hired and supervised their own employees and received a piece rate for the output of their department.[7]

With inside contracting, governance of the flow process was distributed between the owners of the factory and the contractors. The process of finding and fixing bottlenecks was more difficult as a result. For example, at Singer's factory, when the "japanning" department[8] was known to be the production bottleneck, the manager in charge of the factory bemoaned the fact that "when the work does not come out of that department, and an inspection is attempted, one is met by such a flood of excuses, figures, and promises."[9] In another case, he reported that *his* standards for testing finished goods had been changed by the inside contractors *with the collusion of the inside contractor for inspection*.[10]

Time after time, at the Singer plant and others like it, the presence of inside contractors created confusion about who was in charge. In the early 20th Century, partly in response to the spread of systematic management techniques, inside contractors were replaced by employees in most American factories.[11] The historian John Buttrick describes how the transition from inside contractors to company-employed workers at Winchester Repeating Arms was linked to the adoption of Frederick Taylor's scientific

[7] Buttrick (1952); Landes (1969) pp. 58-59; Williamson (1973) pp. 323-324; Braverman (1998) quoting Maurice Dobb (1947) pp. 42-44.

[8] Japanning is a type of laquer finishing for wood.

[9] Hounshell (1985) p. 113.

[10] *Ibid.* p. 114.

[11] Englander (1987).

management techniques:

> During the early 1900s a modification of the Taylor system was successfully installed in the government arsenal at Springfield. … [T]he younger, technically trained officials were able to press with greater assurance for the elimination of the contractors. They could present concrete evidence … which showed not only that it was possible to replace the contractors but that the change would result in reduced costs.[12]

Even if Upstream and Downstream both invest in systematic management, the chance of holdup still arises. The production bottleneck, by definition, constrains the throughput of the entire process. The owner of the bottleneck thus controls an essential and unique asset on which the productivity of non-bottleneck assets depends. This is a case of one-way asset specificity, a kind of strong complementarity. Under the standard reasoning of transaction costs economics and property rights theory, the owner of the bottleneck can expect to be paid a signficant percentage of the value gain to the entire process that comes from fixing the bottleneck. The expectation of holdup, in turn, reduces the *ex ante* value of systematic management to the owner(s) of all steps.[13]

Placing Upstream and Downstream's processes under unified governance changes their incentives to address bottlenecks, to grow, and to make cost-reducing capital investments. Given unified governance, information can flow to a central authority who can take appropriate action without negotiating with a third party. Bottlenecks can be addressed wherever they arise. A single firm under unified governance thus has greater incentives to invest in systematic management, market expansion, capital equipment, than separate firms carrying out the same multi-step flow process within a supply network or cluster.

Conversely, any step or group of steps that contains no bottlenecks can be left out of the zone of unified governance. A step will not be a bottleneck if its capacity can be adjusted (upward or downward) to match the capacity of the rest of the process. Such flexibility is characteristic of goods traded in a liquid market—customers can purchase the good in any quantity with little or no effect on its price.

However, firms that are growing very fast can quite easily outgrow the capacities of pre-existing competitive marketplaces. As discussed in Chapter 8, when steps before and after the core flow process are subject to capacity constraints and/or volatile prices, they become potential bottlenecks. The owner of the core process then has incentives to manage the throughput of these adjacent steps via long-term contracts or direct control.

Is unified governance of all potential bottlenecks necessary to achieve efficient flow production? No, in fact, there are contractual methods of achieving the same goal.

[12] Buttrick (1952) p. 219.

[13] In effect, separately owned steps constitute an "anti-commons" as defined by Heller and Eisenberg (1998). See Chapter 5.

What is required is a high degree of information sharing among the autonomous contributors *and* the ability to act quickly to address the bottlenecks when and where they arise.

For example, in Chapter 4, we saw that information sharing and coordination among autonomous actors can be achieved via relational contracts, although these take time to build.[14] Commons organizations under distributed governance manage water flows (irrigation systems) efficiently by relying on mutual oversight and paid inspectors.[15] In Chapter 18, we will examine coordination of a modular production network by a systems integrator. Absolute transparency of information and the right of the integrating firm to intervene at any time are essential for this system to work. Finally, open source projects allow many autonomous developers to manage the flow of instructions within a software codebase: again absolute transparency and the right of any developer to change the code for his or her own use are central to the functioning of the system.[16]

In summary, separate firms carrying out a single, multi-step flow process subject to production bottlenecks have reduced incentives to invest in systematic management. By the property of comparative monotone statics, they also have reduced incentives to invest in market-expanding or cost-reducing technologies. In some cases, these barriers to efficient flow production can be overcome, leaving the process subject to distributed governance. However, if the costs of integration are relatively low, full transparency and the right to take timely action may be most easily achieved by placing all potential bottlenecks under unified governance. A single, *vertically integrated firm* will then be the most economical way of organizing the flow production process.

In fact, in the late 19th Century, across a range of industries, firms that vertically integrated, then rationalized their flow production systems, came to dominate their non-integrated rivals through a combination of rapid market expansion and impressive cost reductions. The result was the emergence of a new class of organizations, which Alfred Chandler labeled "modern corporations."[17]

9.3 The Exercise of Direct Authority

As discussed in Chapter 3, the creation of an organization under unified governance does not necessarily entail the exercise of direct authority within the organization. However, a notable feature of the organizations that emerged in the late 19th Century to implement flow production processes was the fact that managers, sometimes through delegates such as foremen, exercised direct control over the flow of work and the

[14] Gibbons and Henderson (2012).

[15] Ostrom (1990) Chapter 3.

[16] Open Source Definition (Annotated) https://opensource.org/osd-annotated (viewed 8/30/19). For further discussion, see Chapter 20 below.

[17] Chandler (1977).

actions of workers.[18] Bosses gave orders and were obeyed. Under the law, failure to obey a boss's order was grounds for discipline or firing.[19] The companies also consistently worked to expand their authority over internal practices, for example, by eliminating inside contractors and breaking unions.

Charles Perrow has argued that there are three types of control in organizations: (1) direct, fully obtrusive control where orders are given and obeyed and performance is closely monitored; (2) bureaucratic control where people are assigned to specialized roles (tasks), which they perform under looser supervision; and (3) control of cognitive premises where the individual learns to think and act voluntarily in ways that are consistent with the organization's goals.[20]

The question is, do multi-step flow processes require or reward the use of direct authority and "fully obtrusive" control of work? Or did the exercise of direct authority in corporations arise because of pre-existing social customs?[21] The owners and managers of the new vertically integrated corporations were generally men of elite standing in society. They were accustomed to giving orders and exercising authority over property, family, and servants. Foremen, for their part, were literally "big men," who "drove" their gangs. They would take direct, punitive action if their orders were not obeyed. These customary social relationships may have carried over to the newly formed organizations seeking to implement flow production technologies.

Thus we may ask, does the exercise of direct authority address the needs or constraints of flow production technologies? Arguably, direct authority may serve three different purposes in a flow production process. First, it may be used to synchronize actions. Second, it may be used to teach actors what to do. Third, it may be used coercively to force people to act in specific ways. Below I discuss each of the potential uses of direct authority in greater detail.

Synchronization

Flow processes in general must be coordinated in time: otherwise the flow will be subject to inefficient stops and starts. According to a given technical recipe, some steps may need to proceed in a fixed order, and/or the timing of steps may be precisely specified. For example, one cannot leave molten steel in a furnace for an indefinite period of time. However, even when the order and timing of steps are not specified by the technical recipe, the fastest end-to-end performance of the entire process minimizes material, labor and capital inputs, hence is most efficient. Thus throughput and profits will be higher if steps can be synchronized.

The important of synchronizing steps to achieve efficient operations was

[18] Langlois (1999).

[19] Masten (1988); Freeland (2016).

[20] Perrow (1986) p. 129. Emphasis in original.

[21] Stone (1974); Misa (1995) p. 270; Noble (1979; 1984).

emphasized by William Knudsen who left Ford to run GM's Chevrolet division in 1921. Explaining Chevrolet's flow production process in 1927, he wrote:

> [Every] time we build a car, we handle approximately one ton of material. Now, to handle successfully 100,000 cars per month, this immense burden must flow smoothly and without confusion to its destination. … [The] conveyor … carries the raw material to the machine, the finished material away from it, and gives the mechanic room to work. Any one of us who worked in shops in the old days remembers how piles of work to be done, or done, rendered confusion around the machine inevitable… . [The] conveyor … demands accuracy; more accuracy than was ever known on the bench.[22]

When several actors carry out a precisely timed sequence of steps, centralized authority is needed both to keep time (think of an orchestra conductor or the coxswain of a crew) and to design the sequence of coordinated actions (think of a choreographer or an engineer laying out an assembly line). Moreover, in high-speed processes, any slowdown for consultation or negotiation will create idle time for workers and machines, reducing the efficiency of the process.

Finally, it is generally useful to have someone outside the synchronized space, who can determine a feasible and consistent set of actions (the "plan") and then identify points of imbalance (bottlenecks) and address them. (According to Knudsen, "each plant has a production engineer responsible to the manager, who observes or coordinates production practice with engineering drawings."[23])

Education

Direct authority is also useful when one person knows more than another about the task at hand. A teacher can teach basic tasks and skills by giving orders, observing performance, and providing feedback and correction. When the tasks are programmed and the skills are physical, direct authority is an effective and natural method of instruction. It is only when trying to teach higher-level skills—e.g., judgment under uncertainty, problem selection, or emotional control—that the instructor needs to forgo direct authority for unobtrusive methods of control.

Coercion

Finally, direct authority can be a means of making someone take actions he or she would not choose to take on their own. A direct order backed up with enforcement can send someone into danger. It can put someone to work on boring, repetitive tasks. It can direct someone to perform actions that have no intrinsic value to the actor, or even are distasteful and repugnant.

[22] Knudsen (1927).

[23] Ibid.

Of course, other forms of control can also be used coercively, but direct orders and surveillance may be the most efficient way to obtain unwilling or grudging compliance in the short run. Thus some of the earliest and most successful uses of direct authority were in military settings. The Roman legions proved in their time that an infantry subject to direct authority and trained to carry out synchronized actions was militarily superior to loosely coordinated cavalry or hordes inspired by alcohol and plunder.

In the 18th and 19th Centuries, the principles of direct authority were carried over to commercial enterprises, beginning with cloth and lace factories, extending to railroads, and then to corporations engaged in large-scale flow production, such as steel mills, meatpackers and automakers.[24] All of these enterprises depended on synchronization of workflow for their success. Their production processes were also technologically advanced, and thus beyond the comprehension of many workers. At the same time, the processes required human laborers to carry out precise tasks in a strictly timed order. The tasks themselves were often strenuous, boring, repetitive, and even dangerous. Incentives to shirk were high, but a combination of direct surveillance and output measurement could be used to maintain effort and throughput at acceptable levels.

The multi-step flow production technologies of the First and Second Industrial Revolutions met all three criteria for the efficacy of direct authority. Direct authority, bosses, and modern technology thus came to be seen as inextricably intertwined. By the mid-20th Century, it was taken for granted that direct authority was essential to the way modern technology worked.[25]

9.4 Managerial Hierarchies

Small factories, local transport systems, and single-location service businesses can implement flow technologies under the supervision of a single manager working with foremen and clerks. However, in the late 19th Century, as the complementarity of larger markets, automated machinery and systematic management began to take effect, factories and companies began to employ a great many people. (See Section 8.9.) As firms grew larger, the possibilities for inconsistent action, miscommunication, and incorrect decisions grew apace.[26] Following the example of military organizations and railroads, most large companies involved in flow production adopted hierarchical methods of managing information transfers, delegating decision rights, and measuring performance.[27]

[24] Chandler (1977); Hounshell (1985); Landes (1986); Langlois (1999); Fields (2004).

[25] This view was actively promoted by Frederick Taylor, who wrote: "The work of every workman is fully planned out by management … and each man receives complete written instructions … [specifying] not only what is to be done, but how it is to be done and the exact time allowed for doing it." Taylor (1911) p. 63. According to Harry Braverman "Taylor raised the concept of control to an entirely new plane when he asserted as *an absolute necessity for adequate management the dictation to the worker of the precise manner in which work is to be performed*. Braverman (1974; 1998) p. 62 [Emphasis in original].

[26] Yates (1989).

[27] Chandler (1977).

The large modern corporations that emerged at the turn of the 20th Century were organized in a hierarchical fashion into functional departments. Each functional group was responsible for some portion of the flow process—procurement, fabrication of parts, assembly, distribution, and marketing. Proximate units were grouped together under the direct authority of a more senior official.[28] These hierarchies generally extended from the very top of the company down to the level of front-line workers. Most companies also employed financial, advisory, and research staff who worked across the functional areas.

Viewed strictly as a means of structuring communication linkages, hierarchy is an efficient way to filter large amounts of day-to-day, month-to-month, and quarter-to-quarter operational information. Indeed, as discussed in Chapter 4, this was the essence of James Thompson's theory of "boundedly rational" organizations: create groups that mirror the individuals' need to communicate and coordinate actions in real time; then create groups of groups according to declining interdependency. The groupings fostered timely mutual adjustments and the hierarchy also served as a means of conflict resolution "with each grade in the hierarchy specializing in resolving conflicts of the grade beneath it." [29]

In a flow process, the highest levels of interdependency arise between nearby steps, thus most of the necessary communication takes place locally. In a hierarchy, only selected information gets passed up to higher levels and then possibly back down to distant groups. The whole can be coordinated by setting consistent objectives for throughput within a given time period for the whole organization.

Groups at the lowest level of the hierarchy can manage to the plan, dealing with small deviations as necessary. This is "coordination by mutual adjustment."[30] Large deviations can be flagged and passed up to successively higher levels according to their magnitude. Such flags can cause additional problem-solving resources, e.g., expert specialists, to be sent to the point of disruption, and may cause a revision in the plans of other departments. If the functional units are buffered from one another, for example by intermediate inventories, then the effect of a disruption in one segment will be attenuated in the more distant parts of the enterprise. Thus a hierarchy is an effective way to match the scope of communication and the scale of responses to the magnitude of random disruptions, wherever and whenever they arise.

In summary, *as technologies*, large-scale, multi-step flow processes are well matched with organizations characterized by unified governance, the exercise of direct authority and managerial hierarchies. The need to address bottlenecks using the tools of systematic management calls for unified governance. The need for synchronization and tight process control creates a need for organizational control and may reward the exercise of direct authority. The sheer number of interdependent steps in a large system creates the need for hierarchy as a means of managing information flows and delegating

[28] Chandler (1986) Chart 1, p. 383.

[29] Thompson (1967) p. 60. See the discussion of mirroring in Chapter 4.

[30] Ibid. p. 56.

responsibility.

In the next chapter, we shall see that there can be significant variation in organizational practices across companies implementing similar flow production technologies. However, I shall argue that, notwithstanding this variation, the organizations tend to be similar in having unified governance (sometimes augmented with relational contracts); exercising direct authority (for purposes of teaching as well as control); and creating hierarchies of responsibility and information flow.

9.5 The Rise of Corporations

Organizations implementing large-scale multi-step flow processes became both common and powerful at the turn of the 20th Century. They dominated not only manufacturing, but also retailing, energy, transportation, and communications.[31]

The law regarding corporations, which in the United States took its current form at the end of the 19th Century, provided a legal framework that supported all of the properties "demanded" by flow technologies. By the 1850s, in most states, businesses organized as corporations had the ability to create zones of property ownership and direct authority that reflected the underlying technical processes and could last for indefinite periods of time. In contrast to proprietorships and partnerships, the technical processes carried out within a corporation would not be interrupted by the death or bankruptcy of an owner—they would continue under ownership of the corporation, and only the shares would change hands.[32]

In addition, assets not essential to the the technical process could be placed outside the corporation's ownership: if the corporation subsequently failed, those assets could not be seized by the corporation's creditors (limited liability). Finally, beginning in 1889, when New Jersey passed a law permitting holding companies, a corporation's zone of activity could extend across state boundaries.[33] These were all new and valuable features of corporations relative to the preceding legal forms of business organization.

As discussed in Chapter 3, legally constituted corporations are intrinsically hierarchical, since all decision rights are ultimately traceable to a single legal "person" whose actions are controlled by the Board of Directors.[34] This kernel of hierarchy can be elaborated into a hierarchical organization through the Board's power of delegation. However, delegated decision rights can be withdrawn at any time—they are "loaned and not owned."[35] Residual decision rights are vested in the Board of Directors and cannot be

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[31] Navin (1970).

[32] Hansmann, Kraakman and Squire (2006) call this feature "asset partitioning."

[33] Before 1889, states did not allow corporations to operate outside their boundaries. (Navin and Sears, 1955).

[34] Blair (2003); Freeland (2016).

[35] Baker, Gibbons and Murphy (1999).

transferred without transferring the ownership of shares.[36]

The laws governing the relationship of employers and employees also evolved in ways that confirmed the corporation's direct authority and close control of work processes. Indeed employment law in the U.S. and Great Britain was essentially adapted from prior laws governing master-servant relationships.[37] In contrast, contract law did not give managers rights of close control over how contractors (including inside contractors) performed their work.[38]

It is no accident that modern corporations have exactly the powers needed to rationalize a multi-step flow production process. There were enormous opportunities to create and capture value by rationalizing the many mechanized flow technologies that were invented in the latter half of the 19th Century. The limitations of the previous legal forms—including proprietorships and partnerships, trusts and single-state corporations—could themselves be viewed as a set of non-technical bottlenecks reducing the efficiency of these processes. The executives of the newly formed corporations could not "purchase" laws, but they could use their resources to hire lawyers and influence legislators by legal or illegal means.[39]

Thus during the late 19th and early 20th Centuries, lawyers employed by large enterprises and legislators in state governments worked to refine the legal form and powers of corporations. A great deal of money and effort was spent to address what were seen as deficiencies in the law. State governments in turn designed their legal systems to attract large companies into their territory. At the same time, the Sherman Antitrust Act, passed in 1890, made agreements *between companies* to fix prices, limit output, or share markets a federal crime punishable by fines and imprisonment. A corporation in contrast was considered a legal person, and not expected to compete against itself. Within its own boundaries, it could set prices, allocate output, and assign markets as it chose.

In the end, the modern corporation was the legal framework actively chosen by the owners of large modern enterprises as being most suited to their goals. Most of the companies that managed multi-step flow processes began as proprietorships or partnerships, but, by 1917, virtually all had opted to become corporations.[40]

The legal form was not without its problems and critics, however. In particular, the creation of management bureaucracies and the increasing separation of ownership from control created opportunities for rent-seeking and empire-building on the part of managers. Although the legal form enabled managers to pursue efficiency in flow

[36] Freeland and Zuckerman (2018).

[37] Coase (1937); Atleson (1983); Ahlering and Deakins (2007).

[38] Freeland (2016).

[39] Roy (1999); Blair (2003).

[40] Berle and Means (1932); Navin and Sears (1955); Navin (1970); Chandler (1977) Appendix A; Rosenberg and Birdzell (1986) p. 220; Roy (1999).

processes, large corporations were only as efficient as competition required them to be.[41]

Furthermore, in many corporations, managers abused their rights of close control in service of a theory of machine-like efficiency in production flows. Inside these companies, the right of close control over employees was used both to collect information and to redesign jobs. Systematic and scientific management pointed managers towards defining and assigning tasks in ways that caused deskilling, physical hardship, and devaluation of the workers' cognitive abilities. The common result was distrust, resistance and outright hostility between workers and management.

The characteristic response by managers was to resort to authority and to fight any attempt to organize the labor force. Over time, inside contractors were replaced by employees. Labor organizers and union sympathizers were summarily fired. A wide gulf opened up between a powerful and growing cadre of managers and an increasingly disaffected and distrustful workforce.[42]

Only later, with the advent of the Toyota Production System and other Japanese organizational innovations (discussed in the next chapter), did it become evident that even higher levels of efficiency could be achieved by making workers part of a system aimed at continuous improvement. However, that demonstration lay many decades in the future.

9.6 Conclusion—How Technology Shapes Organizations

In his book, *The Structure of Scientific Revolutions*, Thomas Kuhn defined a scientific paradigm as a set of principles and methods that are *taken as given* by a "mature community" of experts and practitioners in a given discipline at a particular time and place.[43] The paradigm acts as a cognitive filter for the analysis of problems. Problems for which the paradigm's lens is useful are recognized as important and valid. Phenomena that appear inconsistent with the paradigm are generally dismissed as unimportant. (They may be rediscovered when a new paradigm emerges in the wake of a "scientific revolution.")

Giovanni Dosi applied the concept of "paradigm" to technologies in an influential paper published in 1982. In broad analogy with the Kuhn's definition, he defined a technological paradigm as "an 'outlook', a set of procedures, a definition of the 'relevant' problems, and of the specific knowledge related to their solution."[44] He gave as examples (1) the internal combustion engine; (2) oil-based synthetic chemistry; and (3)

[41] See, for example Berle and Means (1932); Jensen and Meckling (1976); Roe (1991;1996); Roy (1999); and the large literature on agency cost and corporate governance.

[42] Braverman (1974; 1998); D. Nelson (1974); Montgomery (1976); Noble (1979; 1984); Piore and Sabel (1984); Halberstam (1986); Drucker (1946;1993).

[43] Kuhn (1962) p. 103.

[44] Dosi (1982) p. 148.

semiconductors.[45] It is noteworthy that all of these product technologies are implemented via large-scale, multi-step flow production processes.

The principles and methods used to build and manage large-scale multi-step flow processes in the mid-20th Century can be seen as a technological paradigm conforming to Dosi's definition. The technologies of flow production depend on a set of common procedures—specifying steps, ordering them, synchronizing the flow. Flow processes also have generic problems, including inefficiency, bottlenecks, and uncontrolled variability. The knowledge needed to solve the problems includes general scientific principles and experimental procedures, as well as knowledge specific to a given product or market.

Henry Ford coined the term "mass production" to describe the principles and methods applied at Ford Motors to make automobiles in large volume at low cost. The public quickly grabbed hold of the term and used it to describe all that was new, amazing and sometimes threatening in the economy. As Ford described it, the over-riding principle underlying mass production was efficiency, while the methods were an amalgam of systematic management, scientific management, and synchronized production lines. We have seen that these principles and methods were (and are) applicable to a wide range problems arising in multi-step flow production processes.

During the middle of the 20th Century, "mass production" also operated as a cognitive filter constraining the public's perceptions of both technology and business. In fact it is difficult to convey how dominant the "paradigm of mass production" was during its heyday. Large, vertically integrated corporations implementing multi-step flow technologies accounted for an ever-increasing share of GDP and employment.[46] Corporate R&D labs became the main source of new products and technologies.[47] Finally the Allied victory in World War II was made possible in part by the application of mass production methods to war production, largely supervised by executives from private corporations like GM and Kaiser Construction.[48]

Inset Box 9-1 provides a sampling of quotes that indicate the close association between technology and large, hierarchical corporations in the minds of informed observers in the decades after World War II.

[45] Dosi (1988) p. 1127.

[46] Kaplan (1964); Galbraith (1967).

[47] Mowery (1983a; 1983b; 1998); Nelson and Wright (1992); Baumol (2002).

[48] Chandler and Galambos (1970); Drucker (1993); Herman (2012).

Inset Box 9-1 Quotes from Various Observers on the Dominance of Mass Production Technology and Large Corporations after World War II.

Peter Drucker, *The Concept of the Corporation*, 1946

It has become obvious that modern industrial technology requires some form of big-business organization—that is large, integrated plants using mass-production methods. … Even to raise the question whether Big Business is desirable or not is therefore nothing but sentimental nostalgia. (p. 5)

[T]he war made clear that it is the large corporation which determines the economic and technological conditions under which our economy operates. (p. 8)

[T]he problem of the political, social and economic organization of Big Business is not unique to one country, but common to the entire Western world. (p. 9)

It [is] clear that most of the experts in this country, including the industrial engineers and managers, underestimated our productive capacity so completely in 1940 and 1941 precisely because practically all of us failed to understand the concept of human organization which underlies mass production. (p. 22)

Joseph Schumpeter, *Capitalism, Socialism and Democracy*, 1947

What we have got to accept is that [the large-scale establishment] has come to be the most powerful engine of progress and in particular of the long-run expansion of total output …. (p. 106)

The [entrepreneurial] function is already losing importance and is bound to lose it at an increasing rate in the future … innovation itself is being reduced to a routine. Technological progress is increasingly becoming the business of trained specialists who turn out what is required and make it work in predictable ways. … Bureau and committee work tends to replace individual action. (pp. 132-133)

William H. Whyte, Jr., *The Organization Man*, 1956

[College] placement officers find that of the men who intend to go into business … less than 5 percent express any desire to be an entrepreneur… . Most have one simple goal: the big corporation. (p. 68).

John Kenneth Galbraith, *The New Industrial State*, 1968

[The] modern corporation has the power to shape society. (p. 126)

[The] entrepreneur no longer exists as an individual person in the mature industrial enterprise. (p. 59)

Increased use of technology and the accompanying commitment of time and capital [are] forcing extensive planning on all industrial communities. (p.23)

[The] modern corporation [is] an instrument of planning that transcends the market. (p. 125)

Inset Box 9-1 continued

J.-J. Servan-Schreiber, *The American Challenge*, 1967

[Servan-Schreiber, founder and editor of the French newsmagazine *l'Express*, was alarmed by the entry by U.S. corporations into European markets. His book sold 500,000 copies in the the first three months after its publication, and was the topic of much debate and discussion among European businessmen and leaders.]

Europe has almost nothing to compare to the dynamic American corporations being set up on her soil. (p. 7)

[D]ynamism, organization, innovation and boldness … characterize the giant American corporations.

We know that 85 percent of industrial research and development funds in the United States are conducted by corporations that employ more than 5000 people. (p. 24)

What is most productive and decisive in the modern economy is the combination of the research factor with an industrial infrastructure, effective means of finance, and a large sales organization. The home office of a giant corporation coordinates all of these. (p. 43)

American industry has gauged the terrain and is now rolling from Naples to Amsterdam with the ease and speed of Israeli tanks in the Sinai desert. (p. 29)

William Baumol, *The Free Market Innovation Engine*, 2002

In this market form, in which a few giant firms dominate a particular market, *innovation has replaced price* as the name of the game in a number of important industries. (p.4, Emphasis in original)

[W]here huge firms dominate markets, … they have changed much of the economy's R7D into an internal, bureaucratically controlled process … . They have *routinized* it. (p. 4, Emphasis in original)

The oligopoly firms routinize not only inventive activity but the entire innovation process, thereby ensuring its long-run continuation. … it is the presence of the full innovation process, and not just its invention component that most directly differentiates the capitalist growth mechanism from that of all other economic arrangements. (p. 54)

Many dissenters criticized giant American companies and distrusted their managers, but almost no-one questioned their dominance of the global economy. Some scholars offered alternate models of "how the world might be," pointing to corporate abuses of market power and describing the benefits of craft production methods and industrial districts made up of networks of small firms.[49] Several argued that the replacement of human operators by machines in mass production factories was motivated, not by the goal of greater efficiency, but by the desire to fully control the workplace and "expropriate" the knowledge of workers and place it in the hands of

[49] Bluestone and Harrison (1982); Piore and Sabel (1986); Lazonick (1993)

managers.[50]

A paradigm by definition consists of several complementary elements that fit together to form a consistent picture of "how things work." Below, I list the elements of the paradigm of mass production, grouped under the headings (1) technology; (2) unified governance; (3) direct authority; and (4) managerial hierarchy.

Technology

At the core of the enterprise are multi-step, synchronized, automated flow processes designed to produce, transport, and sell goods and services in high volumes. Faster, more efficient flow is the technological goal. The technical and organizational architectures of the process are designed to identify and remedy bottlenecks in the flow using scientific understanding of the process and the tools of systematic management.

Unified Governance

The organization is vertically integrated. A single legal entity—a corporation—controls all critical steps that might become bottlenecks. The essential steps are subject to unified governance.

Inhouse R&D units develop new products and technologies to give the company competitive advantage in its product markets. These units give the organization a chance to control *future* technical bottlenecks which may become important strategic bottlenecks. Hence their creation is consistent with the principle of placing all potential bottlenecks under unified governance.

The legal concept of corporation was the means by which enterprises implementing flow technology achieved unified governance. Most of the companies that managed multi-step flow processes began as proprietorships or partnerships, but, by 1917, virtually all had opted to become corporations.

Direct Authority

The organization exercises direct authority in designing the technical architecture, defining jobs, and assigning tasks. Employees are legally obligated to obey the orders of their superiors within a pre-defined zone of authority.[51]

Managerial Hierarchy

Managerial hierarchies are used to channel information, delegate authority, and

[50] Braverman (1974; 1998); Noble (1979; 1984); Piore and Sabel (1986). The transfer of traditional knowledge from "the heads of the workmen" to managers was a strategy strongly advocated by Frederick Taylor: "All possible brain work should be removed from the shop and centered in the planning or laying-out department." Taylor (1903) *Shop Management*, quoted by Braverman (1998) p. 78.

[51] Simon (1951).

assign responsibility. Centralized planning, budgets, and financial controls are key tools of management, used to ensure consistency of action and accountability across the organization.

Unfortunately, in many corporations, managers abused their rights of close control in service of a theory of machine-like efficiency in production flows. Inside these companies, the right of close control over employees was used both to collect information and to redesign jobs. Systematic and scientific management pointed managers towards defining and assigning tasks in ways that caused deskilling, physical hardship, and devaluation of the workers' cognitive abilities. The common result was distrust, resistance and outright hostility between workers and management.

For most of the 20th Century, these elements constituted the dominant conceptual model of how modern technology and modern businesses worked. Details might differ across industries, but much of the world accepted Peter Drucker's premise that "modern industrial technology requires some form of big-business organization" using mass production methods.

However, in the late 20th Century, these assumptions were challenged in two ways: first, by the Toyota Production System which showed how flow processes might be managed more productively by engaging workers in a process of continuous improvement; and second, by the increasing importance of non-flow, platform technologies especially in the realm of information goods and software. I describe the Toyota Production System in the next chapter. The organizational needs of platform technologies are the focus of Part 3 of this volume.

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