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Contents

information technologies as a whole unit is that findings cannot be generalized to other technologies. As an alternative, they suggest a variable-based approach. This approach explicates the key characteristics of information technologies as variables. Individual technologies are conceptualized as sets of variables rather than as whole units. The resulting framework permits comparisons across different technologies.

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JAMES R. BENIGER

2. Conceptualizing Information Technology as Organization, and Vice Versa

About a decade ago, when personal computing briefly became a fad approaching a craze in the United States, many American reporters and commentators cast about for examples of important human tasks that would be difficult if not impossible to perform without computers. Because the so-called energy crisis was then still a vivid memory for many people, several writers independently decided to illustrate the computer's crucial role with a compelling example: the monitoring of the global movement of crude oil in ocean-going tankers.

Keeping track of tanker movements internationally may seem like a formidable data-processing task, but in fact it not only does not require a computer, but can be handled most effectively using only a pencil and a modest supply of 3×5 cards. Why? The explanation, as even cursory knowledge of information-processing and control technology would suggest, can be found in theoretical dimensions of the elements that organization and computers would control: the number of tankers, their speed, the complexity of their interactions, the predictability of their routes, and the probability and complexity of various contingencies.

Ocean-going oil tankers are relatively few in number, move extremely slowly, travel a small number of familiar routes known well in advance, and do not interact physically. What few simple contingency plans they have, for changes in political or weather conditions, are widely known and rarely used. All of these factors mean that the global movement of crude oil via tankers can be monitored quite effectively by merely reading a weekly trade paper and noting changes from the previous issue. Those reporters who wrote about such monitoring, presumably because little theory underlay their incidental knowledge of information technology and organizational control, were simply wrong in citing this example as something that could not be done without computers.

What example might have served? Consider again the basic theoretical dimensions of control: the number of at least partially independent elements, their speed, predictability, and interactions, and the probability and complexity of contingencies. This simple list would have led reporters to problems of controlling large numbers of high-speed objects (or rapidly changing variables) in real time—despite complex interactions of serious consequence—in a highly uncertain environment.

Transporting people from earth to the moon and back safely, for example, is without question something that could not be done without computers. Although sufficiently large and well-organized numbers of clerical personnel could perform the requisite calculations and other data processing, no arrangement of personnel could possibly execute these tasks fast enough to be effective (a conclusion which, because it hinges on the speed of communication among individuals, is actually subject to formal proof).

Similarly, air traffic control could not be maintained in anything like its present form without computers, although the airline reservation system could be, given modern telecommunications, although at a highly prohibitive cost. Centralized control of highway traffic, essentially the air traffic problem reduced from four dimensions (including time) to two, and confined to simple networks and to much slower speeds (though with proportionately tighter spacing), is clearly an intermediate problem—near the borderline of organizational control that might be effected (allowing for unlimited costs) without computers.

Computers and Organization

The question of what tasks would be difficult or impossible without computers might profitably be adopted as a general method for the study of organizations. It is introduced here to illustrate three points:

1. Theory is important to the practical understanding of information technologies in organizations (because lack of theory can lead, as we have seen, to seemingly plausible answers that are in fact quite silly).
2. Large-scale formal organization and computers have much the same practical functions in many applications (organization is often the most competitive alternative to computers, as we have also seen, in which case an economic tradeoff exists between the two).
3. To the extent that formal organizations and computers are homologous, understanding of the former can be informed by theories about information usually associated with the other, including those involv-

ing information processing, communication, decision, and control in the most abstract sense.

To appreciate the relationship between formal organization and computers, it is useful to consider the third major generalized information processor and hence controller available in even the earliest human societies, namely, the human brain. The unaided brain remains to this day the most awesome of all information-processing capabilities, a fact often overlooked amid the more recent adulation of computer technology. Undeniably computers can do many things better than can the brain, and many other things that the brain cannot do at all, as can also many organizations. Who amongst us, however, would want to replace the information-processing capabilities of our own brains with those of even the most efficient organization, or even the fastest and most powerful supercomputer?

Knowledge of the human brain, its capabilities and limitations, is crucial to the study of formal organization for at least two reasons: First, throughout history formal organization has emerged only as practical tasks involving information processing, communication, and control exceeded those same capabilities of the unaided human brain. Second, formal organization—itself a means of information processing, decision, and control—ultimately derives these capabilities from those of the individual brains of its human constituents, and thus cannot transcend their collective limitations and the constraints of their interconnectedness.

As expected from this perspective, the earliest known formal organizations arose (about 3000 B.C.) with the earliest known social systems that exceeded—in both scope and complexity—the information-processing capabilities of the unaided human brain. Best known among such early systems were the ancient nation-states of Mesopotamia and ancient Egypt and the later empires of Rome, China, and Byzantium. Until the industrialization of the nineteenth century, formal organization appeared only when collective activities needed to be coordinated by two or more brains toward explicit and impersonal goals, that is, needed to be *controlled*.

In terms of the various dimensions of control discussed above, however, preindustrial organization arose only when the number of elements, the scope and complexity of interactions and contingencies, or the volume of processing exceeded the capability of any one brain to control (as they did, most notably, in the early nation states, especially in their military operations). Preindustrial organizations were apparently never intended to control the *speed* of movements or flows, however, also expected from our perspective, given that organizations are much slower at processing information than is the brain. Only when speed is accompanied by sufficient volume of movements or flows do organizational capabilities exceed those of the brain.

In short, formal organization might be seen as the best known means to make a computer before the development of electronics, or as a prototypical computer that uses multiple human brains as components, or as the computer that results from the coupling of various brains by means of formal rules and channels of communication. Certainly many homologous relationships can be seen among formal organization, the computer, and the brain, or among the various constituent brains in an organization and the components of a computer, or among the varied applications of these three generalized information processors. Not until the nineteenth century, however, did advances in energy technology bring formal organization in the modern sense—and with it, ironically enough, the need for purely technological control that would eventually undermine the need for organization itself.

Industrialization and Organization

That formal organization did not begin to achieve anything approximating its modern form until industrialization can be seen in the growth of the U.S. government. As late as the 1830s, for example, the Bank of the United States, then the nation's largest and most complex organization with 22 branch offices and profits 50 times those of the largest mercantile house, was managed by just three people: Nicholas Biddle and two assistants (Redlich, 1951/1968, pp. 113-124). In 1831, President Andrew Jackson and 665 other civilians ran all three branches of the federal government in Washington, an increase of just 63 employees (10.4%) over the previous ten years. Fifty years later, however, in the aftermath of rapid industrialization, Washington's bureaucracy included some 13,000 civilian employees, more than *double* the total—already swelled by the American Civil War—only ten years earlier (U.S. Bureau of the Census, 1975, p. 1103).

Much the same organizational revolution occurred—at about the same time—in American marketing. As late as the 1840s, the staff of one of the country's largest importers consisted of the owner, his son, two or three clerks, and a porter; together they handled perhaps a quarter-million dollars in annual sales (Tooker, 1955, pp. 64-65; 225). Just a quarter-century later A.T. Stewart, then America's foremost dry goods distributor, had 2,000 employees and annual sales of $50 million; by 1873 the firm had a branch purchasing office in every major textile and apparel center in Great Britain and Western Europe (Resseguie, 1965).

Further evidence that a qualitatively new type of formal organization developed in response to industrialization can be found in the growth of concern about bureaucratization as a pressing social problem in the middle and late nineteenth century. The word *bureaucracy* did not even appear in English until the early nineteenth century, yet within a generation the phenomenon had become a major topic of political and philosophical discussion. As early as 1837, for example, John Stuart Mill wrote of a "vast network of administrative tyranny...that system of *bureaucracy*" (Burchfield, 1972, p. 391). A decade later Mill warned more generally of the "inexpediency of concentrating in a dominant bureaucracy . . . all power of organized action . . . in the community" (Mill, 1848, p. 529), followed in two years by Thomas Carlyle, who complained of "the Continental nuisance called 'Bureaucracy' " (Carlyle, 1850/1898, p. 121). The word *bureaucratic* had also appeared by the 1830s, followed by *bureaucrat* in the 1840s and *bureaucratize* by the 1890s.

Historians of formal organization also find qualitatively different organizational structures emerging with widespread industrialization in the middle and late nineteenth century. Harvard Business School historian Alfred Chandler, for example, hails the Western Railroad reorganization of the early 1840s as "the first modern, carefully defined, internal organizational structure used by an American business enterprise" (Chandler, 1977, p. 97). The first hierarchical organizational system of information gathering, processing, and telegraphic communication to centralize control in a manager's office (Erie Railroad) followed in 1853, formal line-and-staff control of an organization (Pennsylvania Railroad) in 1857, organizational structures (large wholesale houses) with a half-dozen or more operating departments controlled by a hierarchy of salaried managers in the late 1860s, and a centralized, functionally departmentalized corporate organization (General Electric) by the mid-1890s (Beniger, 1986, pp. 278-287; 390-399).

As final evidence that a qualitatively new type of formal organization developed in response to industrialization in the middle and late nineteenth century, consider that the first major theorist of modern organization, the German sociologist and political economist Max Weber (1864-1920), emerged during the same period. Those who have speculated about why Weber concentrated his attention on bureaucracy have tended to overlook—because of the ancient origins of formal organization—the possibility that he was simply attracted to the most revolutionary new technology of his age. If Weber were writing today, it follows, he might well apply much the same social analysis not to bureaucracy but to computers.

Technology and Organizational Control

Prior to industrialization, as we have seen, formal organization arose (prototypically in large nation states and their military operations) to control large numbers of elements, excessive scope or complexity of interactions and contingencies, or an otherwise unmanageable volume of processing—but never *speed* of movements or flows per se. We have already considered one reason: Organizations are much slower at processing information, other factors like volume held constant, than is the individual, unaided human brain. Consider now a second reason: Before industrialization, in effect the application of inanimate sources of energy (especially steam) throughout the material economy, few if any material processes—then driven by wind and water power, draft animal, and human muscle—could move nearly fast enough to exceed the capability of a single brain to control.

Seen in this way, industrialization, which at least potentially increased the speeds of most material processes 20 to 80 times virtually overnight, must have posed an unprecedented challenge and threat to formal organization, with its considerable disadvantages—relative to the individual brain—in controlling speed. Why, then, did industrialization not reverse the development of formal organization in favor of individual human control? Why, to the contrary, did industrialization in fact stimulate the rapid development of formal organization and corporate and state bureaucracies in their various modern forms (as we have just seen)?

The answer is that industrialization created both the need and the possibility for purely *technological* control (as opposed to either organizational or individual human control) of physical movements and flows. Control technologies, unlike formal organizations, can process at least highly constrained and routinized information faster than can the unaided brain. Because of the abstract and highly generalizable properties of control, however, technologies for the control of material flows can be readily adapted to the control of information and humans, and hence to control within organizations (computers being only one recent example). Thus by vastly increasing the speeds of material processing, industrialization created not only the need for modern organization but also both the need and possibility of control by technology, a factor that—ironically enough—would begin to erode the purpose of organization itself.

First Modern Organizations

To illustrate, consider the case of the railroads, already cited as the first modern organizational structures in American business. The earliest U.S. railroads, built between 1826 and 1830, used horses to draw cars along cast-iron rails. Steam power began to replace the horses in the early 1830s, thereby increasing operating speeds from 1 or 2 to more than 30 miles per hour literally overnight. Because early railroads operated for most of their length on only a single track, their most obvious control problem was to avoid head-on collisions. Lacking even the most rudimentary control technologies, early railroads adopted one of two solutions: On longer, lightly traveled roads (mostly in the rural West), all trains ran one way one day and the other way the next. Shorter and busier roads (mostly in the Northeast), for which this solution proved uneconomical or inconvenient, had the first of two trains scheduled to meet running in opposite directions wait on a siding until the other had passed.

The Western Railroad was—not incidentally—America's first intersectional line. With 156 miles of road connecting Worcester and Albany, the single-track Western was the first rail company forced, in order to maintain sufficient volume of traffic, to schedule as many as two passenger trains and one freight a day each way. This required nine daily "meets," times when trains had to wait on a siding for one going in the opposite direction to pass. On October 5, 1841, on a section of the road opened only the previous day, disaster struck: Two Western passenger trains collided head-on, killing two people, seriously maiming eight, and less critically injuring nine others. The public outcry, including an investigation by the Massachusetts legislature, reflected a preindustrial age not yet accustomed to travel at the speed of steam power, certainly not at the Western's operating speeds of up to 30 miles per hour—especially where horses had pulled cars only one-twentieth as fast less than a decade earlier (Salsbury, 1967).

As a result of the outcry and subsequent investigation, Western management instituted no less than America's first modern organizational structure: Control of the entire Western line and all of its various operations became centralized in a new headquarters in Springfield, Massachusetts. Because the Western was the first enterprise to extend beyond the span of a single manager's close personal contacts, a distance Chandler (1962, p. 21) sets for early railroads at roughly 100 miles, its headquarters was linked to three regional offices, each by three distinctly separate, carefully defined chains of authority and command. One chain passed through three regional "roadmasters" to control tracks, roadbeds, bridges, and buildings; a second stretched through three divisional masters and the various station agents to control all passenger and freight traffic; the third ran through master and deputy mechanics at each terminal and roundhouse to control all engines and rolling stock.

To command this new organizational structure, Western management reorganized its entire operations into a data-processing, communication, and control system that was, in effect, a prototypical computer. Innovations included regularity in data collection, formalization of information processing and decision rules, and standardization of communication with feedback. Responsibility for updating the three roadmasters on track conditions fell to conductors, enginemen, and stationmasters, who were required to pass a continuous stream of data along the regional hierarchies. Each roadmaster, in turn, was required to keep a journal of his operations and to make a formal monthly report to the chief engineer at headquarters. The company specified that "no alteration in the time of running or mode of meeting and passing of trains shall take effect until after positive knowledge shall have been received at the office of the superintendent that orders for such change have been received and are understood by all concerned" (Salsbury, 1967, p. 186).

Control of each train passed from the engineman, brakeman, and various other employees and became centralized in a conductor who had standardized detailed programming for responding to delays, breakdowns, and other contingencies. The conductor also carried a good watch, carefully synchronized with all others on the line, and moved his train according to precise timetables. He controlled all operations between origin and destination, including those of the engineman and brakeman, from his platform outside the first car of the train. Not only did he control the brake of this car, but he alone—except in sudden emergencies—determined when and where to stop and when to start, signaling his decisions by pulling a cord connected to the engine bell. The engineman, who formerly had exercised considerable control over his train, was reduced to little more than a programmable operator, dutifully following rules like "in descending grades higher than 60 feet per mile passenger trains are not to exceed 18 miles per hour and merchandise trains not over 10 miles per hour" (Salsbury, 1967, pp. 187-188).

To describe the conductor and engineman as "programmed" might at first seem anachronistic, a needless intrusion of contemporary jargon into the nineteenth century. In their control of trains, however, Western personnel might have been replaced in most of their functions by on-board microcomputers or, given modern telecommunications, by a more centralized means of computer control. Seen in this way, the Western conductors take on new significance: They are among the first persons in history to be used as programmable, distributed decision makers in the control of fast-moving flows through a system whose scale and speeds precluded control by more centralized structures, including the highly innovative organization of Western headquarters. This use of humans, not for their strength or agility, nor for their knowledge or intelligence, but for the more prosaic capabilities of their brains to store, retrieve, and process information, would become over the next century a dominant feature of employment in so-called information societies (Beniger, 1986, chaps. 7-9).

As illustrated by the Western Railroad and its early innovations in formal organization, the vastly increased speeds initiated by steam power and industrialization created the need not only for modern organization but also for technological control—a form of control quite distinct from that of either organization or individual human brains. Although second-by-second control of a Western train was largely independent of formal organization, at least before on-board telegraph, it might still seem highly dependent on human brains. Keep in mind, however, the new information technologies found on each train: the printed loose-leaf pages of rules and contingencies, the pocket watches synchronized throughout the system, the signal bell linking conductor and engineman, plus the various ways that the on-board employees had been made over into components of prototypical computer technology.

This final category, because it characterizes modern organization as well as most other technologies (at least before electricity) for controlling the speed of material movements and flows, foreshadows the technologies that would eventually begin to erode the need for organization itself. Just as microcomputers and telecommunications might replace many of the control functions of the on-board conductor, for example, so too might they replace many of the organizational tasks of workers in the Western headquarters. This equivalence of technological and organizational control, and ultimately of machine and brain, is one that Weber first identified as *rationalization*.

Rationalization and Organization

As mentioned, Weber must be considered among the first to establish that formal organization is itself a control technology, most notably in his *Economy and Society* (1922/1968). Among his defining characteristics of formal organization, he included several key elements of any control system: impersonal orientation of structure to the information that it processes, usually

identified as cases, clients, customers, or patients, with a predetermined formal set of rules governing all decisions and responses. Any tendency to humanize formal organization, Weber argued, would be minimized through clear-cut division of labor and definition of responsibilities, hierarchical authority, and specialized decision and communication functions. The stability and permanence of organizations, he noted, are assured through regular promotion of career employees based on objective criteria like seniority.

Because of the abstract nature of the concept *formal* in *formal organization*, much of what Weber wrote about the latter subject might well have been written about the computer (or indeed any formal information processor and controller). Certainly computers, by virtue of being machines, have relative stability and permanence and maintain an impersonal orientation to the information that they process. Their programming (firmware as well as software) constitutes the formal set of rules governing all their decisions and responses, a priori and without prejudice about individual cases. Like formal organizational structure, computer structure can ordinarily be characterized as at least partially hierarchical, with clear-cut lines of authority (or priority) and specialized communication and decision functions. Indeed, virtually the only ways Weber characterized organizations that do *not* apply to computers concern problems associated with engineering actual human beings into such impersonal structures (those involving criteria of promotion like seniority, for example).

A far more subtle control technology, closely associated with that of formal organization, Weber called *rationalization*. Although the term has a variety of meanings, both in Weber's writings and in the elaborations of his work by others (Collins, 1986, chap. 4), most definitions can be subsumed by one essential idea: Control can be increased not only by increasing the capability to process information but also by decreasing the amount of information to be processed. The former approach to control was what Weber defined as formal organization and is today increasingly realized through computerization; the latter approach was what he usually meant by rationalization, what computer scientists now call *preprocessing*. Just as rationalization complemented and increased formal organizational control, according to Weber, so too does preprocessing—the destruction or ignoring of information in order to facilitate its processing—serve computerized control today.

Formal organization and rationalization intersect in the regulation of interpersonal relationships in terms of a formal set of impersonal and objective criteria. The early technocrat Saint-Simon, who lived to see only the earliest stages of industrialization, described such rationalization as a move "from the government of men to the administration of things" (Taylor 1975, Pt. 3). The reason why people can be governed more readily *qua* things is that the amount of information about them that needs to be processed is thereby greatly reduced and hence the degree of control—for any constant capacity to process information—is correspondingly increased.

With sufficient rationalization, it is possible to maintain even the largest and most complex organizations, social systems and societies—ones that would be overwhelmed by a rising tide of information they could not process were it necessary to govern by the particularistic considerations of family and kin that characterize preindustrial societies. One example in formal organization is the development of standardized business forms, a major preprocessing technology. Because proliferation of paperwork is usually associated with a growth in information to be processed and not with its reduction, the development of business forms might at first seem to undermine control. Imagine how much more processing would be required of an organization if each new case were recorded in a completely unstructured way, however, and not limited to formal, objective, and impersonal information required by the standardized form.

Organizational Control Through Preprocessing

Industrialization and the development of information societies provide many examples of innovations in preprocessing—the destruction, filtering out, or ignoring of information in order to facilitate its processing—that have enhanced control by organizations. Major innovations in organizational control through preprocessing include:

Time zones. As long as transportation moved at only a few miles per hour, the fact that neighboring towns often had slightly different times (differences in so-called "sun time") posed no problem in information processing—travelers could adjust watches at their leisure. With industrialization, however, steam moved complex rail networks, extending over thousands of miles of track, at upward of 40 miles per hour, thereby threatening—through information overload—organizational control of transportation. In 1883, at the initiative of the American Railway Association, North America was divided into five standardized time zones, thereby defining away almost all information about differences in sun time among cities (organization of world time into 24 zones came the following year). With sufficiently cheap and powerful distributed computing, ironically enough, it may soon be at least feasible to return to a transportation system based on local solar time, thereby shifting control from preprocessing back to processing—where it resided for centuries before steam power pushed humans beyond the pace of the sun across the sky.

Standardized grading. With the increasing growth and complexity of the rail system, in the 1850s, and the greater speed and volume of rail shipments, it became increasingly difficult for transporters to keep track of farm produce "in separate units as numerous as there were owners" (Clark, 1966, p. 259). This control crisis eased only with innovations in preprocessing: the various standardized methods of sorting, grading, weighing, and inspecting farm products still familiar today. These innovations greatly reduced the information processing necessary to control shipments of agricultural products, in effect by defining away all but a limited set of differences among the harvests of individual farmers. In less-developed countries, by contrast, even humble commodities such as ice cream cones sold by street vendors are still individually weighed to determine price. Consider how much more expensive, say, grocery shopping would be if commodities such as eggs were sold by individual weight rather than in set numbers of standardized grades.

Fixed prices. In the bazaars of less-developed countries, sellers still bargain individually, asking prices based on each buyer's social position, apparent need, and manifest interest in an item. Imagine the information-processing problems such a system would pose for inventory and employee control, accounting and related investment decisions. It is hardly surpising that efforts to preprocess away these control problems through fixed prices followed closely the advance of industrialization in the West, led—as might be expected—by the first mass retailers, the department and chain stores. The pioneering Paris department store Bon Marché had a fixed-price, one-price policy as early as 1852; ten years later Stewart's department store introduced the policy in the United States. F.W. Woolworth, who adopted the idea in his first "Five and Ten Cent Store" in 1879 (it had become a chain of 59 stores by 1900), further rationalized the preprocessing technology in *price lining*, the mass production of items expressly chosen or designed to sell at a predetermined price.

Trademarks. Brand names, labels, and trademarks constitute one of the most important preprocessing technologies of the industrial era. Because they help goods (and increasingly even services) to "sell themselves," trademarks reduce the information and associated costs of advertising, marketing and promotion in control of demand—and make such activities more cost effective as well. The first U.S. trademark legislation, enacted in 1870, attracted no registrants for more than three months and only 121 during the year. As might be expected, interest in trademarks awaited development of sufficient mass production of consumer goods, with the resulting need to control demand.

In 1880, on the eve of continuous-processing manufacturing, when the old trademark law was declared unconstitutional, Congress quickly passed new legislation—and businesses raced to register (Smith, 1923). Economic value of the new technology was easy to chart: Within the decade, royalties to use the Baker Chocolate name and trademark reached $10,000 a year; by 1905 *Printers' Ink* estimated the value of Royal Baking Powder's trade name to be $5 million, "a million dollars a letter" (Pope, 1983, p. 69).

The concept of preprocessing as an information-processing and control option available to organizations helps to explain a recent anomaly—the growing importance of *brand equity*, which varies according to the associations and behaviors of a brand's customers that enable it to earn greater volume or margins of sales. Increasingly brand names have acquired values that actually may exceed all of a firm's other assets. Evidently trademarks, brand names and labels, even though they are nothing more than information (albeit information in the heads of possibly millions of consumers), now constitute a means of capital investment beginning to rival opportunities in more traditional capital forms.

General Classes of Organizational Control

As these and earlier examples suggest, there exist general classes of organizational opportunities, functions or requirements that are intrinsically information-processing, communication, and control problems—problems for which computers and other information technologies are likely to be useful. Because these are *general* classes of problems, they have not changed much since their earliest appearance under industrialization. Study of organiztional control problems as members of these general classes will argue the value of theory in understanding information technology as organization, and vice versa.

To illustrate, consider the following ten general classes of control problems that have confronted organizations, listed in the order of their first appearance in the United States (often the earliest in the world) with a recent manifestation included for comparison:

1. Control of independently moving objects to prevent them from colliding: Organization of railroads following the Western crash of 1841; air traffic control.

2. Control of a great many objects in a complex network to prevent them from getting lost: Organization of freight car traffic on the Erie Railroad, America's first great trunk line, in the early 1850s; similar problems of automobile and trailer rental companies.
3. Control of movements or flows of individually unique commodities among many buyers and sellers in complex markets in order properly to charge receivers and compensate senders: Rationalization of commodity markets—through standardization of methods of sorting, grading, weighing, and inspecting—in the 1850s; royalty compensation of multiple authors of works written on computer networks, or of authors whose works are distributed by means of rental libraries, photocopying, etc.
4. Control of movements or flows through complex networks so that control might pass—simultaneously with the flows themselves—to adjoining, autonomously controlled networks: Monitoring by railroads of the location and mileage of "foreign" cars on their lines, by means of car accountant offices and through bills of lading, in the 1860s; control of cellular telephone calls among various "cells."
5. Control to push movements or flows as fast as possible past fixed capital (both to maximize returns and to prevent capital shifts to other investments): Struggle of rail mills adopting the Bessemer process in the late 1860s to control increasing throughput speeds in the production of steel; organizational innovations to speed customers through fast-food restaurants and theme parks such as DisneyWorld.
6. Control to push as much inventory as possible past fixed retailing capital (again to maximize returns and to prevent capital shifts to other investments): Struggle by large wholesalers and retailers (such as department stores) in the late 1860s to maintain high rates of stock turn; similar problems in "just-in-time" inventory control in large mail-order operations.
7. Control of increasingly differentiated units of organization in order to integrate and coordinate them in a larger organizational structure: Struggle in the 1870s by the large wholesale houses, the most differentiated organizational structures in the nineteenth century, to integrate a growing number of highly specialized operating units; the control problems that constitute the central focus of organization and management theory, management information (MIS) and decision support systems.
8. Control of consumer demand to match production flows: Efforts after the 1880s by the first companies to adopt continuous-processing technologies—including producers of oatmeal, flour, soap, cigarettes, matches, canned foods, and photographic film—to stimulate and control consumption using national advertising of brand names directly to the mass household market; modern demand-driven manufacturing.

9. Control of multiple and diverse inputs to complex assembly or other value-added processing: Efforts after the 1880s by metalworking industries—from castings and screws to sewing machines, typewriters, and electric motors—to control throughputs at the volume and speed of the metal producers; PERT charting and related technologies in manufacturing and other large-scale organized projects.
10. Control of information processing itself as it expands in one of the above-mentioned applications: Efforts by large companies after the 1880s to contain the growing scope, complexity, and speed of information processing—including inventory, billing, and sales analysis—necessary for control of new organizational systems; airline reservations and billing systems following the explosive growth of international air travel.

As these ten classes of problems suggest, the opportunities, functions, and requirements of formal organization intrinsically involve information processing, communication, decision, and control. These factors, in turn, combine in a relatively small number of general control problems—problems which have changed little except in specifics since their earliest appearance under industrialization. This suggests, first, that formal organization will be most usefully understood in the broader context of the human brain, the computer, and other technologies (including rationalization and preprocessing) with which it might be substituted, in part or in whole; and second, that general theory about information, communication, and control will be indispensable for this broader understanding.

Summary

Like brains and computers, organizations are *controllers*, that is, they exist primarily to process information—and thereby at least partially to control external factors—toward some predetermined set of goals (which of course might be modified as this process unfolds). To the extent that all controllers are homologous with respect to information processing, decision, and control, understanding of either formal organization, the human brain, or computers and related information technologies might be informed by theory involving information usually associated with any of the others.

To the extent that all controllers are homologous, they can be expected to have much the same functions in many practical applications. Just as formal organization has often provided the most competitive alternative to the unaided human brain, especially following industrialization during the middle and late nineteenth century, computers and related technologies usually afford the most competitive alternative to organization in the so-called information societies of the late twentieth century. In general, technologies that fill homologous functions—by constituting alternative means to similar ends—must be considered as economic tradeoffs in relevant applications.

Thus we can see that the two major topics of this edited volume, namely organizations and information technology, are related at the highest levels of generality. As such, they merit joint study for theoretical as well as practical reasons. Guided by any good theory involving information processing, communication, decision, and control, we can expect that any insights gained from the study of either organizations or information technology will immediately inform our understanding of the other. Similarly, we can expect that such knowledge of both organization and information technology—as information processors, deciders, and controllers—will inform economic and other practical decisions in even the most mundane applications.

Here, then, are the rewards, practical no less than theoretical, that we might expect from the continued development of a general theory of information, communication, decision, and control, and from the corresponding conceptualization of information technology as organization—and vice versa.

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