Punched-Card Systems and the Early Information Explosion, 1880–1945

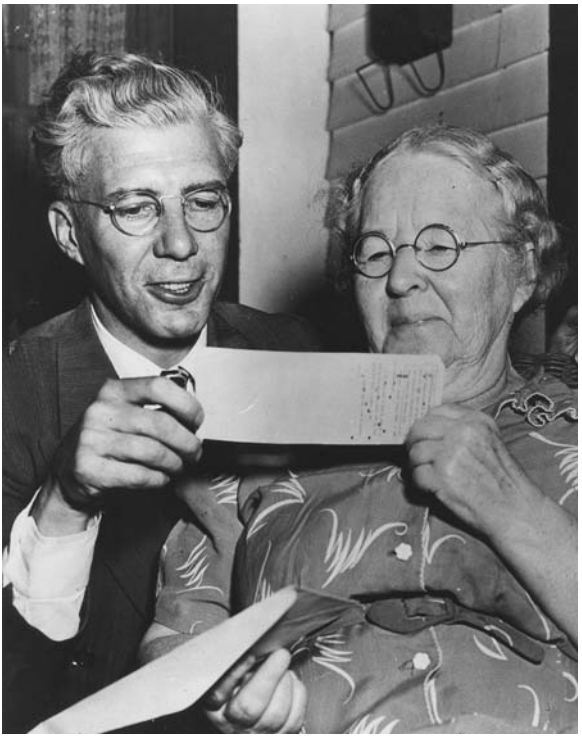
Heide, Lars

Published by Johns Hopkins University Press

Introduction

In the 1930s and 1940s, three large-scale registers of citizens that relied on punched cards were initiated in the United States, France, and Germany, demonstrating that industrial nations—whether democracies, autocratic states, or dictatorships—found use for and began to establish huge administrative systems from the 1930s onward. Punched cards, also known as punch cards, were the first technology to facilitate large, machine-readable registers that improved the abilities of the nation states to locate and control their individual inhabitants, for better and for worse.

In the United States, the Great Depression had caused severe social problems. Twelve million Americans had lost their basis for existence, as their jobs had vanished or their farmsteads had been ruined.[1] "Social justice through social action" was one of Franklin D. Roosevelt's presidential campaign promises in 1932. A major component of Roosevelt's policy of social action was the Social Security Act of 1935. This provided income for the elderly in the form of a pension, a program for unemployment compensation funds, and federally funded relief to the blind and to dependent children. As of 1937, twenty-one million citizens were entitled to an old age pension that was financed through compulsory payments from their employers. The salaries and wages paid were recorded under each employee's name by the Social Security administration in Baltimore, Maryland,[2] so that their pensions could be calculated, an operation that was depicted by a contemporary newspaper as "the world's biggest bookkeeping job."[3] This massive assignment was accomplished by the use of enormous punched-card registers, processed on machines operated by large numbers of government employees.



Ida Fuller, of Ludlow, Vermont, receives a Social Security benefit check in 1950 in the shape of a punched card. The message is that the Social Security cares for the individual and the punched card's role is underlined by turning its printed side toward us. The side facing the two individuals is blank. (Social Security Administration, Baltimore, Maryland)

Similarly, France used a military mobilization register made up of punched cards to bolster its government after capitulation to the invading Germans in the summer of 1940. The armistice had divided the country: three-fifths came under direct German military rule, while Philippe Pétain was to govern the remainder from the city of Vichy—the area known as Vichy France. Pétain was an aging hero from the First World War, and his autocratic regime was not content with the army of only a hundred thousand men permitted by the armistice, a figure determined by the Germans to minimize the threat of this potential opponent.

Shortly after the defeat, the Vichy regime quietly started to prepare

for a mobilization of an additional two hundred thousand men. They established a register of punched cards listing every male fit for military service. To conceal this project, a national register of all inhabitants in Vichy France was established, ostensibly to create a permanent tool to avoid gathering census information every five or ten years. The mobilization itself was intended to be kept quiet to avoid German detection—no radio announcements, no public notices on the squares to be studied by agitated citizens—as punched cards would allow each man's order to be mailed to his current address. The military mobilization register was destroyed after the German occupation of Vichy France in 1942 rendered the plan impossible. The national register, however, was completed.

In Germany, starting in 1941, several registers using punched cards emerged from the attempts by the Armaments and Munitions Ministry to make the war effort more effective. Two years later, the ministry initiated the development of a German national register, but by the end of the war this had still not been implemented.

The punched cards applied in these administrative systems in the United States, France, and Germany in the early decades of the twentieth century found their origins in more modest ambitions half a century earlier in the 1880s. The first punched-card system had been built by the engineer Herman Hollerith to process the United States population census in 1890, a job requiring only counting, not calculation. He completed this assignment with great success, but the market for counting-based processing of census data was small. To reach a broader market, during the 1890s and 1900s, the original numeric punched-card system was developed for other kinds of statistics requiring addition, in private business and in public organizations. Hollerith incorporated his business as the Tabulating Machine Company, which later became International Business Machines.

In the 1910s, the first bookkeeping systems using punched cards were designed, punched-card machines were launched that printed both the calculations computed by and the information stored on punched cards, and challengers to the Tabulating Machine Company emerged in the United States. During the 1920s, the punched-card machines gained improved calculation capability and incorporated letters as well. Improved calculation was required to compose an invoice with the numbers of the various items acquired and their item prices or to write

a pay slip based upon the number of work hours and the hourly rates. Punched cards and their corresponding machinery were improved to meet these growing needs.

Alongside these developments in the United States, punched cards spread to Europe. European companies adapted the original American technology and developed their own information systems and technologies; some of these were based on standards and basic patents from the United States, while others applied different ideas and principles. Though the European companies remained smaller than their American competitors or parent companies, they contributed significantly to the shaping of punched-card technology. The ways in which the punched-card business developed in the various European countries echoed differences in their technological cultures, business structures, and roles of government. The outcome was various nationally shaped machines with emphasis on different aspects of the technology.

In the 1930s, the scope of punched-card applications started to expand from business statistics and bookkeeping to include record management. Until then, punched cards had been a data-processing tool to be discarded once the process was completed. Punched cards became a storage medium. Several insurance companies, public utilities, and other businesses introduced registers of customers and wage earners in their punched-card-based bookkeeping systems. Various national governments adopted and developed this concept to make record-keeping the core of the system.

The ability to mobilize people proved essential in the interwar years. Roosevelt, Hitler and, later, Churchill accomplished this through their radio broadcasts. Building up large punched-card registers provided a supplemental, more tangible way to mobilize people. Punched cards were less charismatic than the nations' leaders, but, for the first time, they offered the nation an efficient technology, allowing direct access to the individual citizen. The major register projects in the United States, France, and Germany exemplified this. Through these and other large registers, punched cards came to contribute significantly to the shaping of modern societies. The press release photograph of an elderly lady receiving her pension check from the Social Security Administration in 1950 illustrated how the state cared for the well-being of each citizen. But these registers could also represent a threat, as with the possibility

that the national register in Vichy France could have been exploited to locate Jews for deportation.

Thus punched cards were developed from an ad hoc technology by the end of the nineteenth century into a pivotal technology for managing advanced industrial nations in the 1930s and in the Second World War. In this book, I first analyze the invention of the original punched-card technology to process the 1890 U.S. census. Then I explore the reshaping of the original technology and its manufacturing, which grew into a large industry. This process encompassed both the innovation and production sections of industry, as the users and customers who bought equipment and services contributed suggestions and ideas for inventions and improvements. In Western societies, the shaping and reshaping of punched cards shared the same general characteristics, though the process varied in the United States, Great Britain, Germany, and France.

This complex story aims at enhancing our understanding of technological and business developments in information management in these four countries, encompassing the shaping of the technology, the related dynamics of business, and the interaction of businesses among nations.

Analytic Framework

The punched card was the basis for the most advanced information technology from the 1920s to the Second World War. Punched cards facilitated storing information through combinations of holes in individual cards that various machines processed. Each job required the punched cards to be handled in a predetermined order. For example, in the 1930s, one card was needed for every entry in issuing invoices. The cards were punched on a key punch and the perforations verified by use of a separate device. Afterward, a sorter arranged the cards in a specific order, before their subsequent tabulation. The tabulator was a combined calculating machine and printer that performed the additions—and, in advanced versions, the subtractions—needed to figure the total amount due before printing the invoice.

Punched-card technology distinguished itself from the competing information technologies by facilitating more complex tasks, like producing statistics and printing invoices, with little human interference after the initial

setup of the machines. Further, machine processing of punched cards made it feasible to tackle large projects. In contrast, processing the same assignment by competing technologies, that is by hand or by the use of standard office machines, usually meant that the project had to be divided up into several individual tasks, which complicated management and was more labor intensive. From the 1920s, the advantages of punched-card machines increased as they acquired printing capability and gradually improved calculation capacity. However, it was not easy to introduce punched cards for a task. Their use demanded a high degree of standardization and formalization of the tasks to be processed, which, in turn, made greater demands on the user organization than did competing technologies.

Accomplishments and failures in applying technology in many installations ultimately were the basis for punched cards' success, as interaction with users enabled producers to develop and improve the equipment. This user-oriented approach makes the history of punched cards more complicated than would be an exclusively producer-centered approach. Therefore, theoretical and empirical studies are used in this book to select an appropriate set of concepts for its analytic framework.

The sociology of technology has produced essential concepts to describe a technology and its setting but, at the same time, provides only little guidance for analyzing why a particular path of development was chosen—and in many cases pursued for many years. In contrast, empirically based studies in the history of technology have focused on the dynamics of technological development and settings, but these studies write at a modest theoretical level that has curtailed their analytic contributions. A key problem in technological development is determining why one of several technical options is chosen in a development process and why a certain path of development is selected, changed, or terminated. These choices, which could be intentional or incidental, are made in both private companies and public organizations, and this makes understanding the interplay of technology and organizations essential.

Traditionally, sociologists viewed technology as an external factor in their studies of the nature and development of society and social behavior, and they focused on technology's social implications. In the 1980s, several sociologists broadened their studies to encompass the shaping of technology, and two approaches emerged: the *actor-network theory* and the *social construction of technology*. Originally, both approaches strongly empha-

sized social factors over technical in the shaping of technology, but they have since reduced this emphasis.[4]

The actor-network theory was developed by sociologists Bruno Latour and Michel Callon in the 1980s. They approached technology as a generalized network of the relations between the nodes constituted by essential individuals and technical components. In this way, they provided a basic symmetry to analyze both human and nonhuman components of a technology.[5] Latour and Callon's approach opens up for an extremely transparent analysis. However, it is based on an assumption of perpetual change that fits well with epistemological reflection but is less suited to empirically based studies of the development of a technology like punched cards, which became stabilized for long periods.

The development of punched-card technology was characterized by a combination of stable standards over long periods combined with infrequent reshaping of the technology and ceaseless smaller changes. Social construction of technology theory is related to a perception of technology as being reasonably stable for an extended time and supports distinguishing between minor changes and infrequent basic reshapings. Engineer Wiebe E. Bijker and sociologist Trevor Pinch developed this theory in the 1980s and 1990s.[6] They adopted the term *construction* in their social studies of the development of technology based on results from sociology of science. However, the meaning of "construction" seems somewhat obscure. In contrast to the laws of natural science, all technologies are undisputed constructs. They are made by people for people, which makes "social shaping" a preferable term.[7]

Wiebe E. Bijker has been the major exponent of the social construction of technology approach. Based on his study of the development of bicycles, Bakelite, and fluorescent lighting, Bijker classified the description of technological development into three phases.[8] The first phase is *genesis,* characterized by the interpretative flexibility of the nascent technology. Different "relevant social groups" or interested parties are formed through their diverse and hence flexible interpretations of this technology, which may develop in several directions or along varied paths.

The second phase is *closure and stabilization.* During this phase, the spectrum of possible interpretations narrows, and a "lock-in" takes place on a specific technological interpretation, with alternatives being scrapped. The term *stabilization* implies that the chosen interpretation or embodi-

ment of the technology subsequently remains unchanged for a period. Originally, the third phase was described rather vaguely as the "wider context," while Bijker subsequently used it to explain the closure and stabilization process.

The social construction of technology approach was a tool to describe technological development. This approach provided a method to identify the people and motives shaping a technology but offered no appraisal or critique of the development process.[9] The basic problem was the absence of explicit concepts to handle the various ways that power is exerted—ways that are crucial to understanding the dynamics of the important closure and stabilization processes. Bijker introduced the terms *micro-political* and *symbolic power* as a means for this understating, but he did not develop a theory of how they affected these processes. So, Bijker's approach needs to be supplemented with concepts and arguments to facilitate the understanding of the dynamics of the shaping process. Inspiration for this can be found in empirical studies of various technologies and business history.

Many scholars in the history of technology tradition have worked to gain new insights into the dynamics of the shaping of technology and the impact of technology on society. Thomas P. Hughes compared the histories of electrification in the United States, Great Britain, and Germany, which created one of the most important technological structures in the modern world.[10] As his unit of analysis, he introduced the concept of *technological system,* which addressed his technological and organizational aspects as a connected whole, composed of interacting components—technical, economic, and social. Hughes used this term in a pragmatic and fruitful way, but he did not offer an explicit definition, which limited its analytic power. Through his analysis, Hughes demonstrated the great advantages of the systems concept, which enabled him to move the research focus from individuals to organizations, while still leaving space for the individual person. "System builders" replaced lone inventors, and the co-workers of the system builders were appraised.

To analyze the dynamics of a technological system, Hughes borrowed the concept of *momentum* from physics, where momentum is determined by mass, velocity, and direction. In technological systems, mass consisted of several components, such as machines, devices, and other physical artifacts requiring considerable capital investment. Momentum also arose

from the people and organizations involved. Organizations that shaped and were shaped by the technology could be business concerns, government agencies, professional societies, and educational institutions.

Hughes' momentum concept further implied that social development shaped technology and was shaped by it, yet the interactions of technological systems and society were not symmetrical. Systems in creation were the most malleable. There could be several alternative solutions, both technically and organizationally. Social factors had a high degree of shaping impact but as the technological systems grew larger and more complex, gathering momentum, the systems became less shaped by and more the shapers of their environment. This suggested that it was easier to shape a system before it acquired momentum. However, a system with great technological momentum could be made to change direction or speed when its components were subject to significant forces of change.[11]

Hughes applied the notion of momentum to several growing technological systems. A basic question is what made momentum change. Hughes indicated that the cause was forces outside the system.[12] One of his examples was railroads in the United States, for they lost momentum as the competing automobile system acquired momentum in the early twentieth century. [13] But why did the automobile system gain momentum? Was it due to factors within that system, for example, the user's individual freedom? Or was it due to limitations within the railroad system? Railroads were able to carry from one railway station to another, but passengers and freight had to travel to the station of departure and from that of arrival. Two analogous examples are Atlantic liners and transatlantic flights and punched-card systems and computers. Did the old technology disappear, to be replaced by the new one? This appears to be the case for the punched card and computer example, but it was not the case for the two prior examples. Though not comprehensively, the momentum concept can facilitate complex analysis with human, organizational, and technical components, like the dynamics of Bijker's closure and stabilization, and it can help to explain why a stabilized technology can become subject to reassessment.

Business history provides a different perspective on industrial development. Business historian Alfred D. Chandler Jr. has made a fundamental contribution to understanding the crucial role of organizations in the development of industrial capitalism between the 1850s and the 1930s.

Since the 1950s, he has studied the strategies and organizational forms of big companies in the United States.[14] He showed that scale and speed were winning weapons when managed through efficient organizational hierarchies. Then in *Scale and Scope* (1990), he extended his analysis to encompass the largest industrial enterprises in Great Britain and Germany.[15] In this work, Chandler applied the economics of scope as the additional critical element in the evolution of the largest enterprises (economies of scope referring to the economies of joint production or distribution). Chandler offered an extended, structured comparison of the big industrial firms in Great Britain, Germany, and the United States.

Chandler considered his scholarship to be a contribution to the understanding of the emergence of modern industrial society. From this perspective, two limitations of his work are that he studied marketing, not users or consumers, and that he reduced the essential role of government to antitrust regulation and education. The history of the punched-card industry exemplifies these limitations and shows how productive it can be to go beyond them. The punched-card industry demonstrates the importance of moving beyond an aggregate approach to marketing and markets to one of looking at the users and their problems. This is needed to appreciate the shaping of the technology itself and its industry. Government was a formative, major purveyor that both nourished the emergence of both the first interpretation of punched-card technology and the establishment of the interpretation of the technology for managing large registers.

On a more general level, Chandler's scholarship focuses on documenting the history of business and not on analyzing its dynamics. His dynamic arguments were based on transaction economics, supplemented by the economics of scale and scope.

Economist Ronald H. Coase introduced the term *transaction costs* to understand the price mechanism, dismissing the classic economists' claim of free transactions.[16] Transaction costs became the theoretical stepping stone for Douglass C. North's development of an analytic framework to explain how the performance of economies was affected by institutions and institutional change in Western history since the sixteenth century. North analyzed the role of transaction costs in institutional development. Such expenses included the costs of paying for the exchange of goods, of measuring the valuable attributes of what is exchanged, and of protecting rights and policing and enforcing agreements. He argues that transaction

costs were the sources of social, political, and economic institutions. Classical economists extolled the benefits of specialization and the division of labor. They argued that output could be increased without increasing the number of producers, simply by reallocating production to those producers with the lowest opportunity costs. However, such a reallocation raised the number of transactions and thus increased total transaction costs.[17]

Extending the scope of analysis from classical economics to transaction costs provided an important new theoretical insight. Furthermore, for analyses based on empirical studies of companies and public organizations, the extension from simple costs to transactions is important to understand the dynamics of a prolific industry operating across four countries and two continents.

Analytic Strategy

I have selected Wiebe Bijker's construction of technology approach as the basis for this study of the punched-card industry, as it facilitates analysis of reasonably stable standards combined with infrequent reshaping of the technology, observed from the empirical material. However, "shaping" technology is preferred to "constructing" technology, as outlined above.

When using Bijker's approach to the shaping of technology, it is essential to enhance his concepts for understanding how one among several technological alternatives was chosen for the closure and stabilization phase of development. The empirical evidence shows that each alternative appears to have been related to a social group of users or customers. Even in some cases, one user seems to have been the exclusive focus of the producer, for example, the Census Office in the United States in 1890 for Herman Hollerith's development of the first punched-card and the French army's administration of conscription for the Bull company's format for bookkeeping in the mid-1930s. These were "prime users," while the concept of *prime application* is applied in cases in which the selection of alternatives focused on an application at several companies or public institutions, for example, operational statistics for the shaping of punched-card technology at the British Tabulating Machine Company and Deutsche Hollerith Maschinen Gesellschaft in the 1920s.

Further, understanding the dynamics of a technology-based industry

requires both the engineering activities of innovation and production—and the business contributions of management, marketing, and sales. Results from studies of business organizations facilitate the analysis of these aspects of the shaping of technology and industry.

The additional dynamic problem in the shaping of technology is explaining why and when an established technology closure was renegotiated, modified, or completely blown open for reshaping. For this end, the technology in a punched-card closure is perceived as technological system, as this was conceptualized by Thomas P. Hughes.

Analyzing the shaping of punched-card systems and Western society using this framework requires access to both corporate and engineering materials on the punched-card producers and information on the development of users. For most of the bigger punched-card producers, board-level material is preserved and provides the needed information on corporate decisions.[18] However, engineers below the executive level made most decisions on the shaping of technology. Only fragments of contemporary material on this kind of decision making have been preserved in any of the companies.

Unfortunately, very little material still exists from the small producers. This problem of the lack of contemporary empirical material has been alleviated by including sources from punched-card users and patents. A patent is informative because it contains a detailed description of the device and its expected applications. Patents proved particularly valuable for challengers to the punched-card trade's major producers, as they showed the facilities for and development of the challengers' equipment and provided essential information about related organizations, particularly in the United States, where the patent office recorded transfer of patent rights. Also, patents offered fruitful access to related information on the processing of the original application, litigation, and the variations of patent laws in different countries, which had considerable implications for the industry.

This book's objectives cover three levels of analysis with diverse dynamics: Individual actions involving the design and manufacture of the technology, company-level decisions and strategies, and conditions on national levels. The shaping of punched-card technology is the focal point. Individuals shaped technology—on the first analytic level—and they worked either alone or in organizations, companies, or the machine shop of the United

States' Bureau of the Census, which from this perspective resembled a company. For the individual inventor or innovator, the analysis focuses his acts, which correspond to the location of the shaping process.[19]

The situation on the second analytic level is more complex for individuals employed in a company, because the technology was also shaped by individuals whose acts were facilitated or curtailed by the company. A company managed established strategies that its inventors and innovators had to pursue, for example, the choice of primary users or applications for development. Moreover, management decided which new equipment was to be produced. Therefore, the ideal research strategy for developing and producing technology in a company would be to study the actions of every relevant individual. However, the preserved material does not, generally speaking, facilitate this research strategy. Consequently, the choice has been made to use company-level information as the main focus of analysis for the shaping of technology. This reduces detail, but the outcome still is a robust analysis of the main features of the development of punched cards, and it facilitates distinguishing the technology's main features.

The third level of analysis—the national level—enables a multi-society perspective and provides insight into aspects of its diversity. This book covers four major industrial societies—the United States, Great Britain, Germany, and France—and four successive punched-card closures. Two concerns contributed to the organization of the analysis. First, the narrative facilitates comparisons between the development in the four countries that would provide important insights into industrial and societal variations. To achieve this goal, the analyses of the various development paths in the four countries are kept separate. Second, the study presents a history of a technology in which the industry in the United States was dominant and the first of its kind, and yet where the shaping and production of punched-card equipment in Great Britain, Germany, and France made significant contributions to the overall development.

Topics Covered in the Book

First I investigate the dynamics of census processing in the United States, including Herman Hollerith's inventions and innovations for the first punched-card system for the 1890 census. I show how the original

punched-card system grew out of the organizational shortcomings caused by the absence of a permanent census office in the United States.

Next I analyze America's reshaping of the first punched-card system into a standardized, general statistics-processing system between 1894 and 1907. The application field was extended from the original processing of population data to encompass the compilation of general statistics, notably operational statistics. This opened up an extensive expansion of the trade.

Then I look at how the shaping of punched cards for bookkeeping tasks in the United States from 1907 to about 1933. Once more, this reworking of punched cards facilitated another substantial expansion, and several U.S. competitors emerged to challenge Hollerith's company.

Then the scene shifts the Europe. Already in the 1890s, Hollerith attempted to introduce and spread the use of the punched card for census processing across the Atlantic but had limited success. A discussion of the reasons for the cool reception in Europe compared with its success in the United States is presented followed by various transitions to punched-card-based bookkeeping in Great Britain, Germany, and France from 1920 to 1939. Causes and implications are analyzed for discernible national and technological distinctions. Relations are explored within the national structures and cultures, as these countries became mass societies. All three countries experienced opposition to the American version of the technology and the development of distinct national forms shaped by currency restrictions and growing national sentiments in the 1930s.

Punched-card use was expanded greatly to build large registers of people in the late 1930s and during the Second World War. Such registers' advantages for combating crises in diverse societies justified their design, but their implementation proved difficult and contained hazards.

I conclude my analysis of the invention and reshaping of punched cards with a review of the shaping of punched-card technology and business in the four countries. This complex story illustrates the scope of concepts needed for a comprehensive analysis of the interactive development of business organizations and their technologies. Further, it reflects basic changes in Western industrial society between the late nineteenth century and the Second World War.