Information Systems for Handling Manufacturing and Marketing Data in American Firms, 1880-1920

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As Alfred D. Chandler, Jr. [4, 5] and others have shown, the scale of manufacturing was transformed in the late 19th and early 20th centuries. The enormous increases in manufacturing throughput also motivated many firms to internalize the marketing function in order to effect comparable increases in sales. These developments would not have been profitable, however, without corresponding changes in managerial methods. Beginning in the late 19th century, the *ad hoc* management of the past gave way to more systematic methods of management heavily dependent on the collection and analysis of information.

Managers proceeded from compiling simple descriptive reports to performing increasingly complex statistical analyses, not just in specialized areas such as cost accounting, but throughout the manufacturing and marketing functions. The new emphasis on using large amounts of data required improved methods of information handling. This period saw a revolution in office equipment and methods. From forms to projecting lanterns, and from vertical files to the Hollerith machine, the new tools were predecessors of today's computerized information systems. Innovations in information technology enabled managers to use large amounts of data effectively and efficiently.

This paper uses published literature of the period and archival materials from two manufacturing firms-- E.I. du Pont de Nemours and Company and the Scovill Manufacturing Company-- to trace the evolution and use of information-handling systems in American manufacturing firms.[1] After briefly discussing the relationship between managerial methods and the uses of information, I will explore the new techniques and devices that emerged to support the collection, storage, analysis, and presentation of data.

Systematic Management and the Uses of Information

The small family firms that dominated the American manufacturing economy before 1880 recorded all external financial transactions (in double-columned accounts) but very little internal operating information [4, 24]. The owners directly oversaw production, and marketing was handled primarily by independent commission agents whose routine reporting was generally limited

[1]Some of this material has been presented in a different context in my book, *Control through Communication: The Rise of System in American Management* (Baltimore, 1989). The approach and part of the material, however, represent first, tentative stages of a new project.

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to semi-annual or quarterly accounts [21]. Some small factories of the early 19th century initiated minor changes in the use of information, including introducing a rudimentary form of cost accounting [4, 32], yet in most cases internal management methods were not "fundamentally different from what they had been in the craftsman's shop" [24, pp. 3-4].

Between 1850 and 1880 the railroads initiated important changes in their uses of information. The desire first for safety and later-- in the face of growth, diseconomies of scale, and competition-- for efficiency drove them to develop new managerial methods dependent on flows of information. Railroads established regular reports that drew quantitative and qualitative data up the hierarchy for use in decision making. The principles and techniques they developed anticipated, but had limited direct influence on, those developed by manufacturing managers beginning in the 1880s [4, 27, 35].

In manufacturing, too, growth followed by mounting inefficiencies and diseconomies of scale prompted a reassessment of managerial methods. Improvements in production technology, transportation, and communication spurred firm growth and the emergence of a managerial hierarchy in the final decades of the 19th century [4]. Initially, managers muddled along with the *ad hoc* methods of earlier generations. But coordination gradually broke down, creating disorder and leaving most of the power in the hands of the foreman on the factory floor [19, 20, 24, 33]. The resulting inefficiencies sent managers on a search for new managerial methods. Many of these methods depended on collecting and analyzing increasing amounts of information.

Beginning in the 1880s the emerging managerial community became more self-conscious about these changes. Articles on managerial theory and technique appeared, first in engineering publications such as *Transactions of the American Society for Mechanical Engineers* and later in newly-created management publications such as *System*, *Factory*, and *Industrial Management*. This literature built up a new managerial philosophy-- which Joseph Litterer [19, 20] was later to designate "systematic management"[2]-- designed to achieve efficiency through *system*. One of its key underlying principles was the need for each level of management to evaluate and adjust the performance of lower levels in order to achieve greater efficiency [16, 19, 35]. This principle dictated the use of operating information as a basis for ongoing monitoring and comparison both over time and among operating units.

Managers established increasing numbers of periodic reports that pulled information-- especially quantitative data-- up the hierarchy. The literature proposed systems for data collection and analysis in many areas of operations, from the factory to the marketing department [19, 20]. Systems were established to aid in production control, cost accounting, inventory management, sales, and office work. By the 1920s an extensive network of

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[2]Systematic management is a much broader and more pervasive, though also more amorphous, movement than the scientific management of Frederick W. Taylor and his followers. Although scientific management has received far more scholarly attention, it is, as Daniel Nelson [25, p. 480] has argued, "a refinement and extension of systematic management." Taylor's reforms on the factory floor presupposed the improved managerial methods of systematic management at higher levels of the organization.

information flows was found in most large companies. Of course, different companies adopted more systematic managerial techniques at different rates.

System came gradually and in three phases to Scovill, a manufacturer of brass products [35, ch. 6]. The first, tentative steps began in the 1870s with the institution of a primitive system of cost accounting that allowed managers to attribute profits to various units and to monitor them on a monthly basis. The second phase of systematization was initiated in 1905 by General Manager John H. Goss, who explicitly applied principles of systematic management to problems created by growth and structural change. During the next 15 years he introduced into manufacturing operations many of the principles and techniques of systematic management, involving greatly increased record keeping and reporting.[3] A final stage of systematization began in 1918 when E.H. Davis was hired to create a statistics office for the firm. From the start he focused on systematizing the reporting systems as well as on improving statistical analysis (Scovill II/34, Aug. 13, 1918). By the 1920s he had consolidated and rationalized the firm's use of data.

Du Pont, in contrast to Scovill, acquired the philosophy and techniques of systematic management rapidly in the early years of the 20th century [35, chs. 7, 8]. In the 19th century the black powder firm was conservative and unsystematic in its management methods. In 1880 the conservatism of the firm head, in refusing both to adopt a new product (dynamite) or to allow junior partners a larger role in decision making, drove one family member to leave the firm and establish the Repauno Chemical Company (partially financed by the Du Pont company but completely independent in management) to manufacture dynamite [6, 34]. Its executives sought systematic managerial methods, heavily dependent on routine reports, for managing production and sales [9, 10].

In 1902 the death of Du Pont's senior partner precipitated a crisis that ended with the reconstituting of the company under a new and progressive generation of the family [6]. This partnership bought up much of the explosives industry (including Repauno) by 1904, then proceeded to consolidate and systematize operations. In the next few years the principles and techniques of management initially developed at Repauno were introduced and further developed throughout Du Pont.[4] The High Explosives Operating Department (HEOD), which included the Repauno plant and was run by a previous head of Repauno, established an elaborate system of records and reports to pull operating information from the plants to departmental headquarters in Wilmington. Similarly, Du Pont's Sales Department adopted and adapted the system of sales reports earlier developed at Repauno.

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[3]See, for example, materials in Scovill, collection II, volume 333, Baker Library, Harvard Business School (hereafter Scovill II/333). Further references to Scovill documents will be indicated parenthetically.

[4]See, for example, materials in Du Pont Accession 500, Series II, Group 2, Box #992, Hagley Museum and Library (hereafter Du Pont 500/II/2/#992). Further references to Du Pont documents will be indicated parenthetically.

Techniques and Devices for Handling Information

By the early 20th century Scovill, Du Pont, and many other manufacturing firms were collecting massive amounts of operational data that needed to be recorded, stored, analyzed, and presented. From 1880 to 1920 managers adopted an array of techniques and mechanical devices for handling information efficiently.

Firms attempting to use increasing amounts of data first needed ways to reduce the burden of recording and consolidating it for transmission up the hierarchy. Printed (and later duplicated) forms with blank spaces for specified information were adopted to make "clerical work easier than would be possible if the blank sheet of paper were used" [17, p. 470]. Systematizers presented principles for designing forms to be as efficient as possible for the person filling them out [1]. Because forms standardized the position and nature of each piece of information, they also made it easier for compilers at the next level. Forms were seen as crucial to systematization, and the early 20th-century management publications were filled with articles suggesting forms for various purposes [29].

Many of these forms, especially those used for compiling data from other forms and basic records, were tabular. Firms had long used the lined and ruled accounting ledgers for recording financial transactions. It was a short step to recording data in printed or drawn tables. Tabs, which were added to typewriters beginning around the turn of the century, made it easier to use a typewriter to fill out tabular forms or create tables on blank paper [18]. Tables facilitated monitoring and comparing performance over time or among units and were important tools in the shift from simple description to comparative analysis [11].

When Scovill adopted its primitive cost accounting system in the 1870s, it created several printed forms for gathering data and for compiling monthly and yearly cost statements. The second phase of systematization that began with John H. Goss's efforts in the first decade of the 20th century brought a further proliferation of forms and tables. A form designated "Employee's Order Sheets," for example, both systematized the approval process for and recorded data on employee purchases of company products (Scovill II/34). Goss's monthly tabular "Cost Analysis Sheets" (initially hand-drawn but later on printed forms) compiled and categorized manufacturing costs (Scovill II/333, 328). The monthly figures were then compiled into a yearly table with a column recording the previous year's figures for comparison.

By Scovill's final phase of systematization over 200 different reports, generally on forms and often tabular, were sent regularly to the general superintendent's office (Scovill II/26). E.H. Davis's Statistics Office initially focused not on statistical analysis, but on "a general survey of the existing statistical or record situation in the plant as a whole through a study of printed forms now in use" (Scovill II/34, Aug. 13, 1918). He proposed that his office serve as a "clearing house of reference." Thus Scovill used forms and tables extensively in collecting and compiling data.

The collected and compiled information was only useful to managers when it was stored in a manner that made it readily accessible for later

reference. Vertical files, such as those still used in most offices today, provided the first big improvement in this area. As I have discussed elsewhere [35, 36], growth in external and internal communication towards the end of the century strained pressbooks, pigeonholes, and box files. Bound press books fixed copies of outgoing documents in chronological order, separated from related incoming and internal documents. Vertical filing, used with carbon copies or loose press copies, was introduced as a storage system that combined all related documents regardless of origin. Filing cabinets, manila folders, and tabbed dividers made vertical files more efficient than previous storage systems, and organizing and indexing schemes made it possible to store documents by subject, name, geographical region, or number.

Vertical files improved accessible storage for records and reports drawing data up the hierarchy [12, 15]. While Du Pont itself was still using older storage methods, at the turn of the century the more progressive Repauno adopted vertical files organized numerically by subject, with an alphabetical card index (Du Pont 500/II/2/#986). When the new partners took over and expanded Du Pont, they also adopted vertical files to keep essential information and reports readily accessible to the executive committee.

Another popular form of information storage was the card file, a variant of vertical files with pre-printed stiff cards replacing paper and folders. Around 1900, several systematizers suggested replacing bound accounting ledgers with card ledgers to allow reorganization and purging of dead accounts [14, 22]. Others soon suggested using card files throughout firms for compact and accessible storage of frequently consulted data [7, 23, 30].

Subsequent developments of the card file provided an important advance in the retrieval of data. For example, metal tabs in a variety of shapes and colors clipped to designated positions on the top edges of cards enabled clerks to retrieve all cards with a particular set of characteristics. A later version of this method used clips attached to the lower edges of cards and a specially designed card file with several rods running the length of each drawer, attached to keys on its front [21]. When a key was pressed, the rods raised all cards with a clip in the corresponding position, thus making it easy to consult or remove them. One proponent of card files noted that "the need for extensive cross-indexing which would otherwise be necessary for close and analytical utilization of the data, is by this method successfully eliminated in nearly every case" [28, p. 136]. These systems served as primitive data bases that greatly facilitated analysis of the data.

One type of card file, the group segregator, went a step further in combining storage with preliminary analysis by allowing the user to segregate groups of cards that shared more than one characteristic [18]. This feat was accomplished with perforated cards, a special filing drawer, and metal rods. Rods were inserted through the perforated front of the drawer in the desired locations, and slots in the cards between certain holes caused those cards with all of the desired characteristics to drop down below the others when the card tray was inverted. Office systematizer William Henry Leffingwell noted potential applications for such systems in the modern (1920s) office:

> This finding and filing system is an important aid to the keeping of sales records when used to classify customers and prospects by alphabetical arrangement, geographical location, branch office, salesman handling, class of trade, line of business products used or bought, credit rating, terms, and so forth. It is also well adapted to statistical, historical, and research records, as well as other numerous applications, such as new business, personnel records, stock control, and ledger records [18, p. 727].

All of the card files, from the simplest to the most elaborate, played an important role in making data more retrievable and thus more usable.

By 1913 Du Pont had established a Sales Record Division with extensive records in the form of tabbed cards. The function of this system was summarized as follows: "Our sales records are entirely a sales proposition comprising as they do *all* information concerning the smallest unit (customer) in *one* place for *Quick reference*,-- and *Follow-up of trade and salesmen*" (Du Pont 500/II/3/#127/1914). In 1913 alone the Sales Record Division responded to 23,000 routine requests from various divisions of the Sales Department as well as "numerous special requests of value to territorial and division heads."

While the ability to retrieve information by category could be said to provide the first stage of analysis, going beyond this elementary stage required more powerful quantitative tools. Graphic analysis became popular during this period. Graphic techniques for representing statistical data began to evolve in the late 18th century but were not commonly used to represent managerial data in American firms until much later [37]. Graphs often were introduced to managers by engineers who used them for analyzing and displaying experimental data, but engineers who became systematic managers in the 1880s also promoted their application to managerial data [31]. Often they were used to present rather than to analyze data, but they also served an analytic function for "a class of work which would be extremely difficult to understand if the graphic method were not used" [3, p. 184]. In Du Pont, for example, the head of HEOD's Safety Division graphed the number of injuries on the same chart with the number of payroll employees and pounds of powder packed for a five-year period (Du Pont 500/II/2/#581/ 1912, p. 307). He used the graph to analyze (as well as to present) the relationships between accidents and these other variables.

Machines that sped calculations were even more useful. In accounting, specialized bookkeeping machines had been developed to post entries and calculate running totals [17]. But when systematic methods of management came to manufacturing and marketing, extensive calculations were no longer limited to accounting departments. A variety of adding machines, calculating machines, and statistical tabulating machines developed during this period were adopted throughout firms. Leffingwell dates the development of the "modern" adding and calculating machines to the patents registered by William S. Burroughs in 1888 [18]. By the 1920s at least 25 different companies manufactured adding machines (listing and non-listing models) [17].

Calculating machines, especially the electric ones available by the mid-1920s, multiplied and divided much more rapidly than did adding machines.

The most powerful of the new office machines designed to process data were the tabulating machines (actually composed of several devices). They combined the sorting function of card files with rapid tabulation or calculation. The Hollerith tabulator initially was developed to process the data collected for the 1890 U.S. Census [17, 18]. Information was stored on cards in the form of punched holes. The cards were then electromechanically sorted by characteristics and tabulated as desired. Other tabulating machinery followed the Hollerith, including the mechanical Powers machine. These powerful new devices for analyzing statistical data found many applications in business: "Wherever the classifying and analyzing of statistics or the compiling of reports is part of the daily routine of any business enterprise, there the tabulating machine can be of invaluable service ... because it will serve more economically and with greater speed and accuracy than a large clerical force" [18, p. 176]. The much greater efficiency of these machines made feasible more analysis of the data.

E.H. Davis's first major purchase for Scovill's Statistics Office was a Powers Accounting Machine, consisting of a card punch, sorting machine, and tabulator, along with files to hold the punch cards (Scovill II/34, Oct. 10, 1918). Although the Cost Office already had a Hollerith Machine (Scovill II/34, Dec. 12, 1918), Davis justified his need for a separate Powers system:

> The Powers Machine will open up a large field of statistical investigation and presentation. A certain amount of preliminary experimentation is necessary in handling data susceptible of treatment in any one of several ways. This machine will make possible a series of provisional experiments now prohibitive on account of the time and labor required, and will facilitate actual operation along the lines eventually adopted (Scovill II/34, Nov. 8, 1918).

Davis's desire for his office's own tabulator reflects the magnitude of the data to be analyzed. Just one routine analysis to be taken over by the new Statistical Office, the hospital accident report, had used 17,000 Hollerith punch cards in 1917 (Scovill II/34, Dec. 12, 1918). The clerical work required to process that much data by hand would be prohibitively expensive.

With the aid of the techniques and mechanical devices already described, firms collected, stored, and analyzed increasing amounts of data. This data still had to be presented to managers for decision making:

> After a person has collected data and studied a proposition with great care so that his own mind is made up as to the best solution for the problem, he is apt to feel that his work is about completed. Usually, however, ... his task is only half done. The larger and more difficult part of the work is to convince the minds of others that the proposed solution is the best one [3, pp. 1-2].

Executives could be overwhelmed with the masses of information now available to them. Tables, though handy for gathering and consolidating statistics, required detailed study before they yielded their information. Graphs as well as some display devices were widely adopted during this period to aid in presenting information [35, 37].

Systematizers noted the advantages of graphs over tables: "There is ... no doubt that a graphical chart, correctly made, shows tendencies much quicker and impresses the mind more accurately and emphatically than do figures" [17, p. 205]. Graphs were particularly effective in displaying the comparisons so central to systematic management [3, p. 107]. Moreover, graphs more readily would gain the attention of the busy executive [13]. As early as 1909 one systematizer noted that graphics had become the accepted way of handling enormous quantities of data:

> [The executive] must have reports of his costs, his sales, his profits or his losses, but he must have them in such forms that he can interpret them instantly and draw conclusions for future guidance. ... In a modern organization the executive obtains this information through a system of graphic records, a simplified summary of countless departmental statistics and itemized reports [26, pp. 214-215].

Many systems of graphs designed to aid executives monitoring some particular function were presented in the management publications of the day [2].

Du Pont developed an interesting graphic system of its own [37]. From the Executive Committee's formation in 1902 through Du Pont's growth and product diversification of the war years, the committee struggled with increasing information overload [35]. The solution came through a major reorganization of the firm, aided by a new graphic presentation system. When the firm adopted a multi-divisional structure in 1921, the committee's function shifted to evaluating the divisions' financial performances and allocating resources among them, using the return on investment (ROI) formula developed during the war [5]. At about the same time the Chart Room was established to display divisional ROI data [37]. This Executive Committee meeting room was equipped with ceiling tracks from which were suspended 350 large graphs designed to trace trends in each division's return.

Scovill's E.H. Davis also was concerned with presentation mechanisms. One of his earliest acts in the Statistics Office was to establish standards for regularly used charts and to create new graphic compilations (Scovill II/34, Aug. 13, Oct. 12, and Nov. 18, 1918). He ordered a reflecting lantern (the 1918 equivalent of an overhead projector) for "illustrative conferences" to publicize his results, whether graphic or not (Scovill II/34, Nov. 18, 1918). He clearly recognized that presentation of statistical data to executives in as accessible a form as possible was part of his job.

Conclusion

Using mid-19th century office techniques, early 20th century firms would have been hard pressed to handle the increasing flow of information rapidly and inexpensively. In response to this problem, solutions emerged to facilitate all stages of this process, from collecting and storing to analyzing and presenting the information. When E.H. Davis outlined the goals of his Statistics Office at Scovill in 1918, he stated his intention to use "standard forms, and labor-saving devices" for efficiency (Scovill II/34, Aug. 13, 1918). By then, an array of such aids were available to him.

In the *Office Appliance Manual* that Leffingwell compiled and edited for the National Association of Office Appliance Manufacturers in 1926, he explained the growth of the office machinery industry as being built on the new uniformity of methods engendered by systematization:

> When business method was individual and self-centered and business aims narrow and secretive, there was little incentive for inventive genius to burn the midnight oil in the search for business machinery. The demand for mechanical office appliances did not exist because there was no similarity of method. But as similarity of method spread through the exchange of ideas, the possibilities for mass production attracted some of the keenest minds in the country, who turned to making machines and devices that would simplify the mass of problems crowded into the business man's day. As a result, an immense industry has been created-- an industry which produces office machines and devices for the entire world [18, p. 18].

The prospect of a wide market of businesses facing similar information-handling tasks made the development of new office products such as adding and calculating machines an attractive prospect. In other cases, however, the firms adopted available devices or techniques (e.g., forms, graphs), adapting them to the firm's information processing needs.

Whatever their origins, these devices and techniques (we might call them hardware and software), along with many others, were widely adopted in the forty years surrounding the turn of the century. They created a revolution in the office without which managers might have been forced to look for less information-intensive methods of executive control.

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