

Information Systems and Internal Organization: A Study of the Dow Chemical Company, 1890-1914

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My dissertation examines the relationship between innovation in information processing and innovation in management organization and strategy. Economists and historians have for years credited new information systems and new accounting techniques with providing necessary support for the growth of the large firm. More recently some have taken to blaming these same innovations for the decline in competitiveness and short term vision of American manufacturers. Frequently, however, little reference is made to the actual content of these changes and their implications for management decision-making. My dissertation attempts to evaluate these claims by examining the managerial demands placed upon the information system of one manufacturing firm during a period of organizational, technological, and strategic change.

This case study draws on the Herbert Dow papers, which include company correspondence, financial statements, factory reports, lab books, etc. These records were formerly kept in boxes in the Company vault, protected by the secretary to Herbert Dow's successors (his son and then his son-in-law) whose diligence prevented their destruction. They are now housed in the company's archives: a one room schoolhouse where Mrs. Grace Dow taught before she married Herbert Dow.

Before submerging myself in these voluminous records, I surveyed the literature on accounting systems in manufacturing firms during the late nineteenth century. Based on studies of the paper, nail, ice, textile, boat, auto, and machine tool industries, I propose a new periodization of changes in information systems. This periodization focuses less on changes in accounting technique than on changes in the function of information systems over this period.

The first formal information systems were introduced to monitor people and processes. In firms where there had been increases in labor input

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or the separation of ownership from management, the emphasis of the new information system was on monitoring people. Where technical change led to increases in raw materials inventories or the introduction of continuous process machinery, the emphasis was on monitoring processes. Where people or processes were within the boundaries of the firm, we observe the introduction of new "cost accounting" techniques. Where it was important to monitor relationships with outsiders to the firm, as was the case when firms began to market their own output, existing mercantile techniques were relied upon.

In the second stage these data, originally collected for monitoring purposes, were adapted for use in short term planning. This was the case when, as a result of either technical or strategic change, firms faced a new and wider variety of choices.

A third stage, in which managers used formal information systems for long term planning decisions was rarely observed during this period. This may reflect the early stage in the usage of these systems, as has been suggested by Alfred Chandler, or the small size of capital investments compared to post World War II firms, as suggested by Thomas Johnson. I argue, however, that it primarily reflects an unwillingness to rely on inherently retrospective data for making decisions that, for innovative firms in a period of rapid structural change, are necessarily prospective and non-routine. Thus the information system's function is intimately connected to the firm's strategic posture.

I then turn to a more detailed study of the relationship between strategic and information system innovation at Dow. The dissertation presents a history of the Dow Chemical Company, and its immediate predecessors, from 1890 to 1914. This history focuses on strategic shifts and the implications of these shifts for organizational structure and the design and use of the information system.

I divide the Company's history into three phases. In the first phase the Midland Chemical Company (the Dow Company's immediate predecessor) pursued a relatively "adaptive" policy of living off of a single technological innovation, consistent with a "disintegrated" vertical structure and participation in output restricting cartels. In the second (though chronologically overlapping phase) the Dow Company adopted a more innovative strategic posture. In the earliest years of the Company this meant sustained investment in improvements in the Dow bleach process. In the third phase, following the 1900 merger of the Dow and Midland Chemical Companies, we observe innovation in both products and processes. The firm integrates forward into the distribution of its products, frequently disrupting existing market division arrangements. The internal organization of the firm provided incentives for continued innovation.

The dissertation then reconstructs information systems used at Dow during this period. While particular accounting techniques and report forms at Dow were often unique, the *functions of the information system* were similar to those in the periodization presented above. New stages in the development of the information system correspond to shifts in firm strategy.

Dow's Strategy

Dow extracted its primary products, bromine and chlorine, from underground salt water brine. Other trace elements - such as magnesium and calcium - remained after the removal of bromine and chlorine. After the 1900 merger the Company continually engaged in research to find new, inexpensive ways to extract these elements, and to find or create new sources of demand for their consumption. The Company engaged in research, to find new uses - such as water purification - for the bromine and chlorine which it could produce in much greater supply than could be consumed by existing markets. The Company pursued research in product areas related to its existing customer base - for example, developing bromine based dyes for sale to its textile customers. Once the firm integrated forward, salesmen provided information about potential new products to the research chemists back in Midland.

The effect of this strategic position - emphasizing the development of new products - can be seen in its decisions about internal organization and vertical integration. Because of the economies of scope in marketing and research and development, the firm did not adopt the multi-divisional structure soon to be seen at DuPont. The gains from the M-form, in economizing on bounded rationality, were outweighed by its costs in firm innovativeness.

The Dow Company instead retained a highly centralized internal organization. The Company did not make clear "line and staff" distinctions. Rather than assigning individuals to line or staff positions, the distinction enforced was between routine and innovative activity. Individuals were expected to cross that boundary on a regular basis. Hence, most production managers were college trained chemists, and those most closely identified with research activity also supervised plants at different times. While individuals were not boxed into one activity, Herbert Dow insisted on the strict separation of managerial responsibility for innovative and routine activities. By retaining final responsibility for all innovation himself, he promised his Board of Directors an accountability which is hard to obtain in as amorphous an activity as technological innovation. He also assured that innovative activity would remain a high priority. It would not fall into the technological stagnation of the earlier Midland Chemical Company, not because of recalcitrant investors this time, but because of preoccupied or bureaucratic managers. His emphasis on the creation of an internal labor market and long term employment, and the introduction of profit sharing schemes, both for managers and production workers, encouraged cooperation among those responsible for innovation and routine production.

The degree of forward integration was a subject of frequent consideration. When founded, the Dow Company, like other nineteenth century firms, did not have its own sales organization. Continued innovation in its production processes gave the company access to technologies with economies of scale. Continued innovation in product development led it into new markets and encouraged it to develop closer ties to the final consumers of its products. In each case, Dow's strategy of technological innovation

increased the returns from vertical integration.

The costs of forward integration were not the diminishing of "high-powered" market incentives or diseconomies of size. Neither did the loss of the large wholesaler's economies of scope factor large in Dow's decision making. The costs Dow faced in establishing its own sales organization were the disruption of the traditional roles wholesalers played in maintaining price fixing restriction agreements in virtually all of Dow's markets.

While such an innovative strategy demanded investments in forward integration and research and development, those investments were riskier, and in the case of R&D, relatively unusual for firms of the period. The decisions to make sustained investments in innovation and its own sales organization were not made quickly. To the contrary, they were made only after a decade of internal debate among the Company's management and the departure of investors unwilling to accept the risk that Herbert Dow's more innovative strategies required. That decade, in turn, gave the Company the time to smooth out problems in its production processes and establish the reputation that made a more innovative strategy viable.

Changes in Information System

I identify three distinct phases in the evolution of Dow's information system, corresponding to phases in the firm's strategy. In the first phase, the Midland Chemical Company's strategy was essentially adaptive. Corresponding to this strategy was an undeveloped information system that provided little data on firm costs or profitability.

The Midland Chemical Company's accounting system during this period was typical of nineteenth century manufacturing firms. The general manager produced a weekly report to the Company Treasurer. This report mimicked the account statements prepared for outsiders to the firm; it is identical to the form used for suppliers' accounts. Thus, while it was the only systematic communication to the Company's executives on the internal activity of the plant, the form permitted only the most basic monitoring of the manager for honesty. It was useless in monitoring performance or making planning decisions. Given the strategic posture of the firm and the collusive market in which it operated, this information sufficed to sustain a very profitable enterprise.

In the second phase, the firm pursued an innovative strategy with regard to improving its product and process, but remained both single product and vertically disintegrated. The information system regularly and frequently produced data on quality of product, technical efficiency, and average input and product costs.

The Dow Process Company (1895-1897) initiated these changes. In general, the "mercantile" procedures of the Midland Chemical Company continued. However, daily time cards, which gave both plant and executive management more detailed information about internal plant activity, were also introduced. When the Dow Chemical Company was founded in 1897, the general manager's "personal" account report was dropped. It was replaced by a report that included measures of technical efficiency and product cost. For

the first time, the firm's formal information system was used by the Board of Directors to monitor and evaluate plant management (that is, to monitor for effort as well as honesty), and by plant management to make short term planning decisions.

Finally, in the third phase, the firm encountered new informational problems when it became multi-product and vertically integrated. New informational forms aided long term planning. These included the periodic calculation of profits earned by individual products and accounts to monitor R&D expenditures on potential new products.

The firm faced new problems measuring cost because its products shared inputs. Both accounting "standards" and the firm's own economic and strategic considerations influenced its resolution of the joint costing problem.

As suggested by Johnson and Kaplan, the firm adopted cost based inventory valuation at the urging of professional accountants. However, that practice did not determine which overhead costs were allocated to products. The firm allocated some indirect costs, but not imputed fixed plant costs. This decision reflects the firm's desire to "do it right" and the informational demands created by the innovative, multi-product strategy of the firm.

R&D expenditures were sometimes allocated to individual products. These costs constituted the costs of the firm's innovative strategy; their handling both created incentives for innovation and allowed the Board of Directors, responsible for long term strategic planning, to monitor these expenditures.

The firm did not use these cost measures in making short term decisions. The firm continued to use *avoidable* costs in short term decision-making. In the long run, however, the question for the innovative firm was not simply how to avoid costs but how to transform them, how to transform the firm itself and the environment in which it operated, in ways that would gain for it a competitive advantage and greater profits.

While many factors influenced the firm's decisions regarding the collection and calculation of cost data, including the recommendations of professional auditors, the most important determinants were firm strategy and the organization of the markets in which the firms' products were distributed. The firm's accounting records evolved during this period from a fairly haphazard affair, used rarely in the management of the firm, to a complex system which produced daily, weekly, and monthly reports used actively by both plant management and the board of directors that monitored plant managers and made long term capital allocation decisions. As the firm evolved from one that produced only one product, sold in a cartelized market, to one that produced many joint products sold in increasingly competitive markets, the information system also changed, from one designed simply to monitor the honesty of its general manager to one that provided information for short and long term decision making and created incentives for continued innovation.