ORGANIZATION OF THE SYSTEMS FUNCTIONS IN ENGINEERING AND CONSTRUCTION

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For the management information system field, the full-scale charge of the minicomputer has rekindled the flames of controversy over centralization versus decentralization of the data processing function. This paper first examines the general arguments for and against centralization which are found in the literature. We then analyze some of the weaknesses of these generalized arguments. Finally, we report findings concerning the centralization/decentralization question from a survey of one particular industry -- engineering and construction.

We start by summarizing the major arguments pro and con centralization on data processing. The half-dozen most cited arguments in each are noted.

ARGUMENTS PRO CENTRALIZATION

The advantage of centralization most often discussed by authors is economies of scale.[5,9,15] Some examples are that the larger the computer, the bigger the jobs that can be handled; the bigger the machine, the smaller the excess capacity required to maintain a given level of service; the bigger the machine, the shorter the waiting line or better the turn-around; and finally Grosch's Law -- that hardware capacity is proportional to the square of price.

A closely related advantage is accessibility and rapid access to all data bases by all who need them and who are authorized to use them.[5,15,24]

Depth of good personnel is often listed as an advantage of centralization.[5,9,20] It is argued very often that large staffs and large computers attract better personnel. Standardization is considered by many to be an important advantage of centralization.[9,20] If everyone in a company uses the same systems, then transfers within that company are easier, and customers see the same product regardless of the division doing the work. Information can flow readily from division to division. In addition, when computers play an important role in the company's business and projects are larger than a division can handle and must be shared between divisions, this can be accomplished if systems are standardized. Finally, the costs of startup of new offices or new divisions are minimized if one standard package is used for all offices.

Synergy is also an advantage of centralization. This results when many users of the same information system contribute ideas to the betterment of that system so that all are benefitted in a total greater than the sum of the parts.

Centralized systems seem to enhance the achievement of integration. It enables lowest level transactions to flow automatically and easily to highest level summaries within one machine without human intervention or data communication between files.

ARGUMENTS PRO DECENTRALIZATION

Decentralization of computers and information, on the other hand, is desirable because it leads to a maximum of local control.[5,20] Local control means the setting of computer priorities to suit the needs of a particular division. It also means maintaining profit and loss responsibility for the division entirely within the grasp, and accountability of a single individual. Decentralization puts the computer and computer personnel closest to information needs. This enables computer personnel to have the maximum familiarity with local needs and, hence, should lead to more effective application systems.[5,20]

There seems to be a general consensus that, in either system development or in machine usage, a division will get quicker response to its needs if the organization is decentralized.[5] Streeter, however, does make the counter argument, using queueing theory, that a large central computer will provide all its users a better average turnaround than the multiple small computer alternative.[21]

Decentralization also leads to simplicity.[24] An oft-quoted remark by those who favor decentralization is that there is a limit to the size of a central organization. Larger installations are becoming so complex that some feel that, overwhelmed by technical demands, they are reaching

the point of burgeoning bureaucracy, ineffectiveness, and unresponsiveness to user needs.

Local personnel motivation is best when computers are decentralized.[12,21] This is perhaps the most significant item mentioned by authors in the literature. It is really the behavioral consideration that, in order to centralize, there must be a great deal of cooperation between the central and the remote office. Since remote offices would prefer to be decentralized, that cooperation is difficult to achieve.

Finally, operating computer decentralization both allows and forces top functional DP management to focus on the forward-looking tasks that they should be facing, since top management is unburdened from day-to-day matters.

In contemporary literature, two polar camps exist regarding the centralization issue. Albrecht and Glaser, for example, appear to lean toward the advantages that can be seen for centralization. At the same time, Canning and Chen are representative of the camp that foresees decentralization resulting within a few years from the impact of the minicomputer. Table I summarizes the views found in the literature regarding the centralization question.

ISSUE	AUTHORS FOR CENTRALIZATION	AUTHORS FOR DECENTRALIZATION
Scale	Glaser, Grobstein, Lowe, Streeter	Canning & Chen
Accessibility	Glaser, Lowe	
Attraction of qual. staff. Depth	Glaser, Frederick, Albrecht	
Standardization	Fredericks, Albrecht	
Synergy		
Integration of Systems	Head, Glaser, Fredericks	Peck , Canning
Local Control		Glaser, Albrecht
Communication & understanding local needs.		Glaser, Albrecht
Responsiveness	Streeter	Glaser
Simplicity		Canning
Personnel Motivation		Chen, Streeter
Unburdens top mgt.		Albrecht

TABLE I

Summary of Views from the Literature Regarding Centralization

TWO PERSPECTIVES CONCERNING THE GENERAL ARGUMENTS

The debate about centralization has, however, so far been in the general terms noted above and has been less than illuminating along several dimensions. We attack two of them in this paper. These are (1) the need for a clear and agreed-upon definition of what is to be centralized, and (2) the need for evidence from industry to support the contentions of either camp. Arguments pro and con, in the main, have been made on a generalized, qualitative plane without supporting quantitative evidence. This paper works toward remedying these weaknesses by first providing a useful partioning of the problem and then offering quantitative evidence concerning the problem drawn from one industry.

CENTRALIZATION/DECENTRALIZATION -- A THREE DIMENSIONAL PERPSECTIVE

Some articles discuss centralization of DP as if it were a monolithic organization. Others differ as to the components of DP. Albrecht defines the principal dimensions of the systems function as: systems research, systems operations, systems methods, systems planning, systems design, systems development, systems maintenance, and systems implementation.[20] Glaser defines the elements of DP as equipment, staff, and decision authorities.[5] Canning's elements include processing, communications, data bases, and system-wide rules.[24]

Canning has divided DP into two actions, one resource, and a set of policies. Glaser's division suggests two resources and a governing body. Albrecht takes the point of view of the functions being performed for the institution which DP is supposed to serve and breaks the function into its component parts. Albrecht's functional analysis seems to be more consistent with a normal view of an organization and is also appealing since it stresses the purpose of DP rather than the resources required to carry it out. However, the division is too fine to allow a quick conceptual grasp.

The authors of this paper have chosen to take Albrecht's point of view, but to put Albrecht's elementary functions into three conceptual groups in which these elements would normally be found. That is, systems methods, systems research, and systems planning are grouped and called "systems management:" systems design, systems development, systems maintenance, and systems implementations are grouped and called "systems development:" and "systems operations" is then left as the third group.

Systems operations utilizes the resources of the hardware itself as referred to by Glaser, as well as part of Glaser's staff -- the staff responsible for the hardware. It is the function which is responsible for the operation of the processing, communications, and data base referred to by Canning. Systems development uses the other part of Glaser's

"staff" -- the portion which performs this function. Systems management is responsible for Canning's system-wide rules and represents Glaser's decision authorities. It is clear that, in the discussion of centralization or decentralization, any of the three segments (operations, systems development, or management) can be centralized or decentralized -- with differing results. Often the three travel together -- but not necessarily.

SOME EVIDENCE ON THE DEBATE

The second aspect of the debate on centralization and decentralization with which this paper deals is the need for quantitative analysis of available evidence to shed light on the problem. A limited, but robust sample of companies in a single industry was selected in an attempt to better understand the implications of centralization or decentalization of computing in a particular industry setting. To this end, the authors of this paper surveyed , through interviews and questionnaires, a set of leading firms in the engineering and construction industry. The general characteristics of the applications in this industry that tend to lead to centralization or decentralization of the three principal functions noted above were examined and the results of the centralization or decentralization policies being pursued were quantified. The results of the study are noted in the following pages.

THE STUDY

ENGINEERING AND CONSTRUCTION COMPANIES

Companies chosen for study were the larger engineering and construction (E & C) companies which perform turnkey design-construction contracts both nationally and internationally. These companies require and have reasonably large to very large computer installations. Companies were selected from those listed in the annual listing of major construction companies published in the Engineering News Record.[31]

An engineering and construction company performs the functions of engineering, design, project management, procurement, construction management, and construction for an owner of a facility. A single company may perform all of these functions, or only a part of them.

There are, of course, any number of ways by which engineering and construction companies might be classified. For the sake of simplicity, four categories were chosen to serve to clarify somewhat the segmentation of the engineering and construction market and the principal means by which the engineering and construction companies differentiate themselves from their competitors.

The four categories chosen for classification of engineering and construction companies were: size, function specialty, type of product, and geography served. Table II lists the major categories.

SIZE	FUNCTION SPECIALITY	PRINCIPAL E&C PRODUCT	GEOGRAPHY COVERED
Revenue	Design	Heavy Civil	U.S. Only
Sales	High Technology	Power Plants	U.S. + Foreign (non-socialist)
Number of Employees	Project Management	Industrial Plants	U.S. + Foreign (including socialist)
	Construction Management	Waste & Sewage Treatment	
	Construction		

TABLE II

Categories of Engineering and Construction

INFORMATION SYSTEMS IN ENGINEERING AND CONSTRUCTION

This section briefly describes and classifies the major MIS application groups in the engineering and construction industry utilizing Anthony's framework as a structuring device.[37] The desirability of centralization is discussed for each application group.

The major application groups which are used by engineering and construction companies are noted in Table III. They are broken down by Anthony's four categories of strategic planning, management control, operational control, and financial accounting.

Strategic Planning According to Anthony,

> "The word strategy is used here in its usual sense of deciding on how to combine and employ resources. Thus, strategic planning is a process having to do with the formulation of long-range, strategic, policy-type plans that change the character or direction of the organization."

Information systems that have been used by E&C companies to aid the process of strategic planning include econometric and systems dynamics models, as well as venture analysis systems. As in any other company, the purpose of these systems is to aid top management in their assessment of the present value and risk associated with a new venture or with acquisition of new resources. Little is published on this type of system, but clearly its nature is such that centralization of systems development is called for.

TABLE III

Engineering & Construction Company Systems

STRATEGIC PLANNING				
Econometric & Systems Dynamics Models				
Venture Analysis				
MANAGEMENT PLANNING & CONTROL				
Simulation Models				
Property Management				
Human Resources Management				
Cash Management				
Planning and Budgeting				
Management Accounting				
Bidding Strategy				
Project Monitoring				
OPERATIONAL INFORMATION, PLANNING & CONTROL				
	Phase of a Typical Project			
Function	Planning	Initial Engineering	Production Engineering	Construction
Engineering	Modeling	Design	Drafting	Rigging
Scheduling	Schedule	Diagram	Progress	Productivity
Procurement	Vendors	Bids	Purchase	Expedite
Cost	Estimate	Control	Trend	Trend
Accounting	Budget	Report	Payables	Billing
Construc-tion	Logistics	Site Prep.	Exc. & Fdn.	Fabr. & Erect
FINANCIAL ACCOUNTING				
General Ledger and Financial Reporting				
Shareholder Records				
Tax Reporting				

Whether the systems are run on a computer located at corporate or whether a terminal is used to run such systems at a remote site is not important given sufficient security, reliability, and responsiveness. In general, however, a very large computer system is necessary -- therefore this set of applications tends to be either centralized or run on a large service bureau time-sharing computer.

Management Planning and Control Considerable effort has been expended in E&C companies to apply computerized information systems in the area of management planning and control. Again, according to Anthony,

> "Management control is the process by which managers assure that resources are obtained and used effectively and efficiently in the accomplishment of the organization's objectives."

Several systems which have proven useful in this process to engineering and construction companies are listed in Table III.

In general, it is important that the management and development of these systems be centralized. For example, it would be awkward to have different property management systems in different divisions if there were ever a need to consolidate the company's property records. Certainly there are some economies to be achieved for the company if property can be viewed for the entire company and moved between divisions. Similar logic applies to centralizing the other management control systems.

Since these systems tend to be data base oriented and viable distributed data base systems are not yet available, it is probably best to also centralize systems operations.

Indeed it may be feasible to develop the systems by coordinated task forces and perhaps even eventually to operate the systems on distributed minicomputers but, to be effective, these systems should be integrated, standardized, and accessible to all divisions in the company. A considerable degree of centralization is desirable at the present time.

OPERATIONAL INFORMATION, PLANNING AND CONTROL

Anthony describes operational control as:

> "Operational control is the process of assuring that specific tasks are carried out effectively and efficiently."33

He goes on to say:

> "Information is used for other purposes in an organization; indeed the great bulk of information is not primarily used for planning and control but is generated in connection with necessary operating activities within the organization.
>
> "Operating information provides the raw material for much management control information, and to the extent that management control information can be derived from operating information, its cost is low."33

The typical E&C company processes an enormous amount of operational information associated with each construction project. This information ranges from highly technical data regarding the process or system to be used by the plant to a large amount of detail regarding the thousands of pieces of hardware that make up the plant. It is not surprising, then, that engineering and construction companies have developed the largest number of computer applications in the operational control area. The following paragraphs provide an overview for the reader of the typical operational functions performed in this industry -- and the information systems necessary to support these functions. Inferences can be drawn for the needs of centralization or decentralization of hardware systems development and systems management in this industry.

Planning The planning phase of a typical E&C project involves consideration of alternatives in selection of the basic process, sizing of the major units, and determination of the approach for the remainder of the project. Plant modeling is an example of the simulation systems often used in this phase of a project. Models cover the range from empirical to linear programming. In general, they involve the characterization of a plant as a number of modules. The simulation then allows the consideration of various operating conditions and unit specifications. Clearly, it is important for these systems to be standard throughout the E&C company and to be comprehensive and of high quality. Running these systems requires very large computers. Centralization of the development and operation of these systems would seem to be mandatory.

At the same time that engineering modeling systems are being used in the project planning phase, use of scheduling, cost estimating, and material control systems are also initiated. PERT arrow diagrams are laid out for the remaining phases of the project. Cost estimates previously based on very rough data during the contract negotiation period are refined based on the selection of major items of equipment performed in the preliminary engineering. Here again, standardization of systems is desirable. In addition, these systems are very expensive to develop and duplication can be ill-afforded.

Initial Engineering At some point in the project more people are added and initial engineering begins. During this phase, major items of equipment are selected or designed, and foundations and other structures are designed -- all either through the aid of the computer or in many cases today, automatically by the computer.

Production Engineering When initial engineering is complete, a design review is conducted with the client. After his approval, production engineering begins. Production engineering includes the detailed design of the plant. The computer is heavily used here, both in terms of design and layout and drafting, and in terms of selection of items. The material control systems are in full swing at this point, producing drawings and material lists which are sent to the field for fabrication and erection and requisition of materials from the field warehouse. PERT charts are fine tuned. Cost trends are estimated and some accounts paid.

Construction Finally, construction begins. Construction and production engineering overlap for a portion of the project and then engineering is completed and construction carries on to the completion of the project and the start-up of the plant. As shown in Table III, with the help of other information systems, schedules are checked for productivity, purchased materials are expedited, cost trends are estimated, and project billing is initiated.

Anthony and other authors suggests that to the extent practical, integration of operational information and planning and control systems is desirable and cost effective. The foregoing discussion of E&C systems indicates that large volumes of data and large numbers of systems are involved. Large project data flows from one application subsystem to another (e.g., scheduling to purchasing to payables). Integration of operational systems in engineering and construction is important. The savings to be achieved through integration are significant. A need for integration implies a definite benefit from centralization of systems management and coordination of systems development.

In addition to the need for integration, two other factors lead to the conclusion that centralized systems are important for the engineering and construction company for operational control.

First is the trend toward sharing projects between divisions. The size of today's projects has become so large that more and more companies are forced to divide work between two or more of its offices. Clearly,

management of such a project can be considerably enhanced if the offices sharing the work for the contract use the same systems.

Second, clients of engineering and construction companies ask for standard reports and documents on all of their projects. This implies that different projects of a particular client handled by different offices of the same contractor are required to use the same programs at the very least.

It would appear, then, that some degree of centralization is called for with operational systems because of benefits to be derived from the efficiency of large scale computers, the need for systems integration, standardization, and accessibility.

FINANCIAL ACCOUNTING

> "Financial accounting is the process of reporting financial information about the organization to the outside world."[33]

Demands on the engineering and construction company for financial information are not very different than those on most other firms. In fact, during the survey to be discussed several companies indicated that they were using shareholder records and general ledger packages purchased from software houses.

Perhaps the only special requirement of E&C financial reporting is that for clients. Financial records must be kept for clients if any government or cost-plus constracts are handled by the E&C firm. This often requires a certain flexibility in the financial system since clients may dictate the grouping or breakdown of data.

Economies can be achieved by integrating the financial accounting systems with operational and management systems. For example, the project accounting system can be designed to flow summary level information into the general ledger system.

Financial accounting is necessarily a corporate process and points to a natural centralization of financial systems management, and financial systems development. Furthermore, large data bases and significantly large printing requirements favor centralization of processing on this class of application.

SURVEY OF CURRENT PRACTICE

Our survey had three major purposes. These were (1) to gain a better understanding of current practices in the organization and application of computers in this industry, (2) to get a composite of the view of the future held by engineering and construction companies, and (3) to attempt to empirically relate the efficiency and effectiveness of computer application to centralization.

A questionnaire was used as the basis for determining current practice in the engineering and construction industries, and for collecting the thoughts of computer department managers about the expected impact of future computer technology on their work.

The questionnaires for this survey were directed to the managers of computer services in thirty-one of the largest engineering and construction companies on the Engineering News Record list of 1974.[31] Fourteen responses were received.

Of the thirty-two billion dollars of new constracts awarded in 1973 to the companies on the ENR list, the fourteen that responded to the questionnaire represented over nine billion dollars, or approximately 30% of the total industry sales.

The type of construction engaged in by the companies responding to the questionnaire included almost every type of industrial construction. However, companies which design and construct process plants were predominant. Ten of the fourteen respondents were primarily design constructors of process plants such as oil refineries, petrochemical or chemical plants. Annual revenues of the respondents ranged from under 100 million dollars to over one billion dollars. The companies ranged in number of employees from 400 to over 10,000. Dollars spent on data processing for information systems ranged from $400,000 per year to over ten million dollars per year.

The analysis was confined to the ten process plant companies. The other E&C companies were dropped because of the variability introduced by type of plant constructed. For example, it was indicated that companies that emphasize power plant construction, in general, use more computer resources for a given number of employees and heavy civil E&C companies use less. By limiting the analysis to process plant builders, the ten companies remaining the summary, and discussed in this section, are fairly homogeneous and the results are more reliable.

The respondents were categorized by size of company measured by total company employment. The data for the companies falling in each category were averaged. Four size categories were apparent and utilized for data analysis. The categories were "small" companies with 400 to 700 employees, "medium" companies with 2,500 to 3,000 employees, "large" companies with 5,000 to 6,000, and finally "very large" companies with over 10,000 employees.*

As Table IV shows, as the size of the companies increase, so does the degree of centralization or data processing. The percent of geographically dispersed offices relying on the central computer for their primary data processing grows from zero to sixty percent as company size grown from "small" to "very large."

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* It is true that our sample is statistically <u>not</u> significant. Yet we think the data discussed here does have meaning - and is indicative of significant factors of interest in the centralization/decentralization discussion.

MEASURES OF EFFECTIVENESS AND EFFICIENCY

Since centralization and size travel hand in hand, all of the data reported in this section can be seen as a function of either. However, we believe the casual variable which leads (as will be shown) to increased effectiveness and efficiency is centralization of data processing. So do the computer managers to whom we spoke. They indicated the reasons which have been noted and/or will be cited later in this paper.

Company Size	Average # of employees	# companies	Average # geog. dispersed offices	Typical computer location	Average % other offices using the central computer
Small	560	3	2.7	one small computer per office	0
Medium	2550	2	3.5	one midi computer per office	.29
Large	5500	2	6.5	one large computer at corporate HQ.	.40
Very Large	10,700	3	14.7	several very large computers, in one or two central locations	.60

TABLE IV

Key Company Data

There are several indications in the survey data that the amount of computer service provided increases as the size of the company and the degree of centralization of the computer installation increase. Figure 1 shows the number of computer jobs per employee per day, the number of major application systems (sales accounting, project planning,

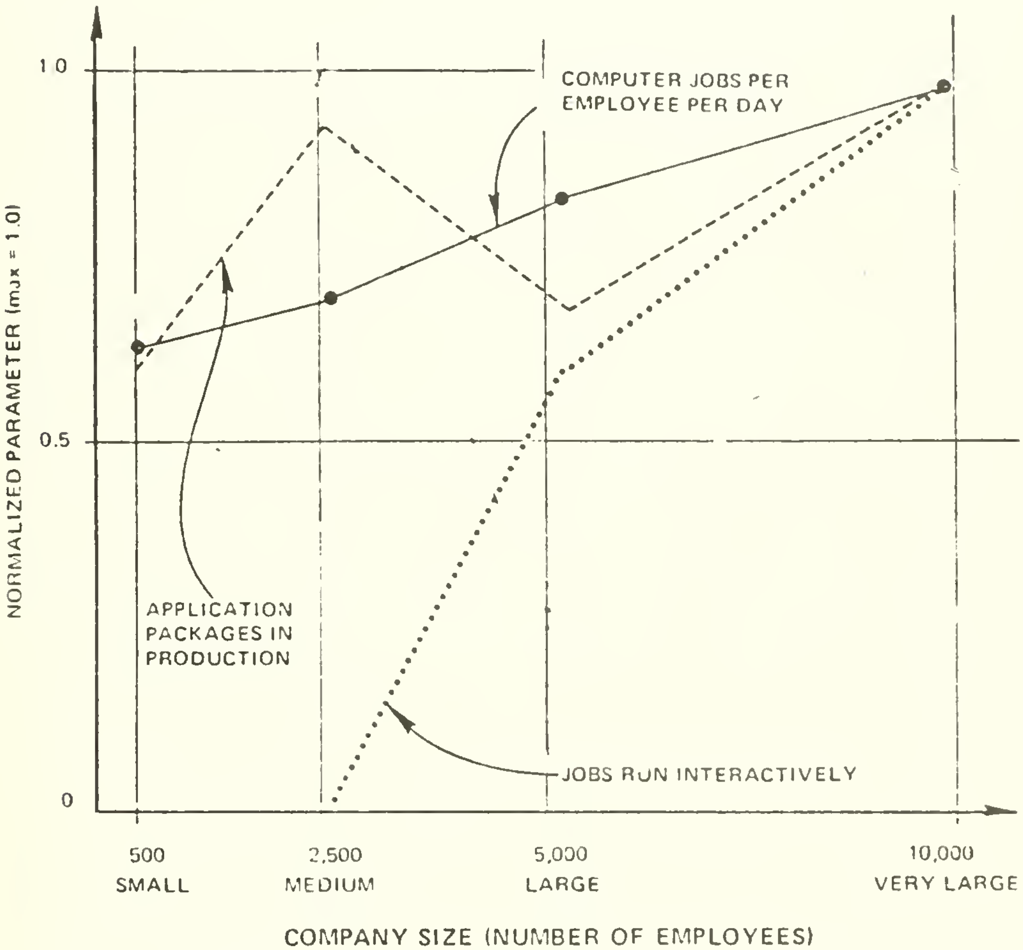

FIGURE 1

Services Provided as a Function of Company Size

design engineering, etc.) in production,[1] and the percent of jobs run interactively as a function of company size. Points on the graph are normalized as a percentage of the maximum in each category.

It also appears that, by additional measures, the effectiveness of the computer increases with the size of company. Figure 2 shows several such indicators as a function of size, including integration (number of application systems which "feed" each other) and a standardization of systems (the degree to which programs used by differing offices are the same), the number of different services provided to jobsites, and demands for new programs by users. The last category is included as a measure of the perception of users of the value of puting activities onto data processing.

However increasing size and centralization does not lead to increased effectiveness on all measures. Turnaround time for batch jobs appeared not to be related to installation size. And, except for medium-size companies, mean-time-between-failure on the central computer configuration as a measure of realiability worsens with size of company. In addition, the "demand for new programs" can be interpreted either positively (DP doing a ggod job, therefore increasing demand) or negatively (central DP as a bottleneck).

[1] The decrease in the number of application systems "in production" from medium to large companies appears temporary. When one includes the number of systems reported in the final development stages by each set of companies with those near being run, this line also takes on a constantly increasing slope from small to very large companies.

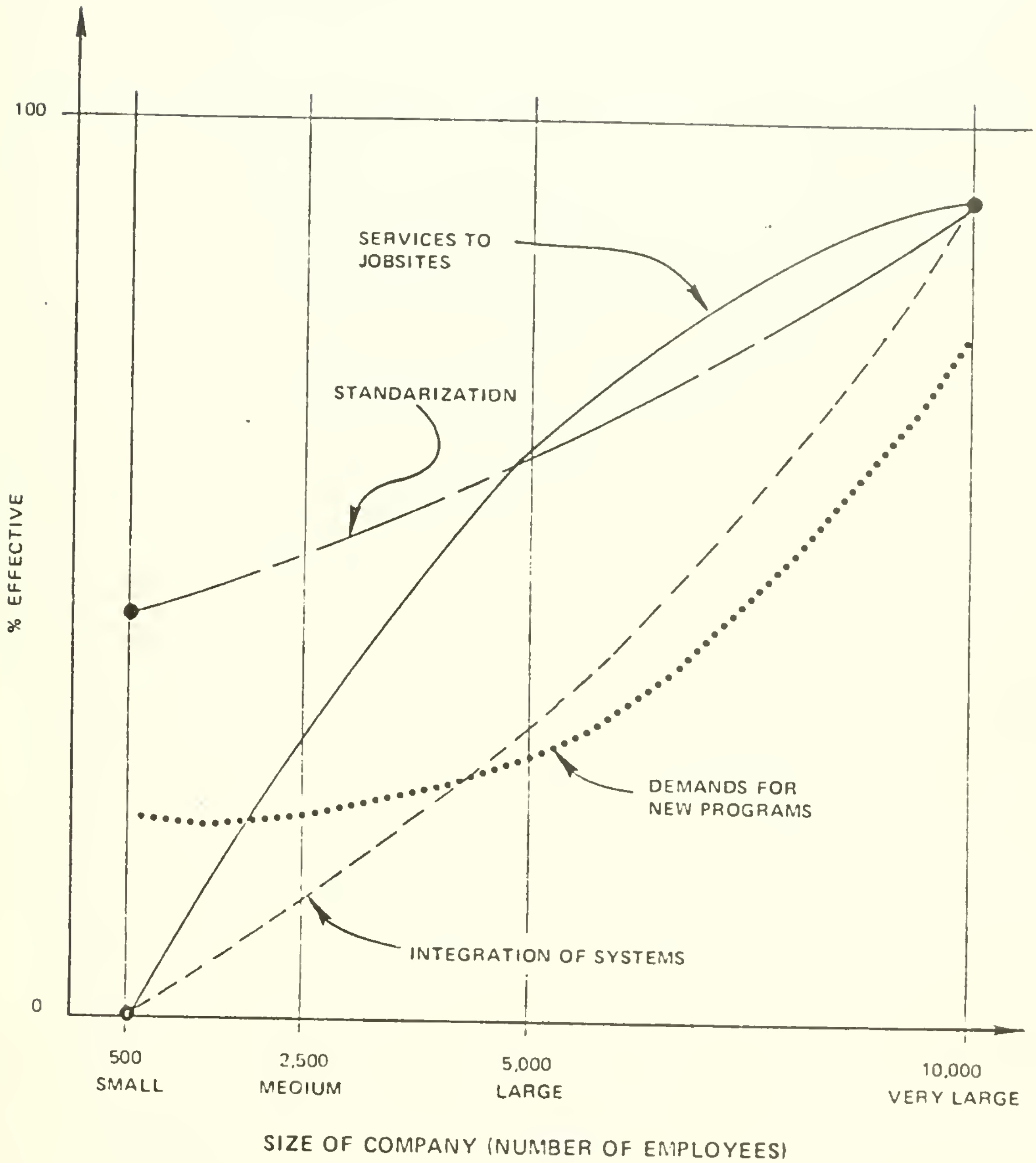

FIGURE 2

Effectiveness as a Function of Size of Company

Perhaps the most interesting indicator of computer efficiency is total hardware cost per employee, i.e., hardware plus data communications plus service bureau costs incurred by the company per employee. This indicator ranged from $700 per year per employee for small companies down to less than $300 per year per employee for very large companies as shown in Figure 3. This is particularly interesting in the light of the increased services provided to the employees of the very large companies when compared to the small companies. Total DP costs, due to increased personnel in the larger installations, to develop these additional services, do not decrease as rapidly -- but they do decrease with size.

VIEWS OF THE FUTURE BY DATA PROCESSING MANAGEMENT

A final section on the survey instrument enquired into DP management's view of the future. Answers to some of the more significant questions, by company size, are noted in Table V.

There was rather uniform agreement among the DP managers of small companies that their management was applying increasing pressure for them to centralize. The medium-size companies were also continuing to centralize DP most emphatically with regard to the computer management function, but also with regard to hardware. Large and very large companies apparently had matured with regard to centralization, and, in some cases, were discussing the possibility of decentralizing certain functions.

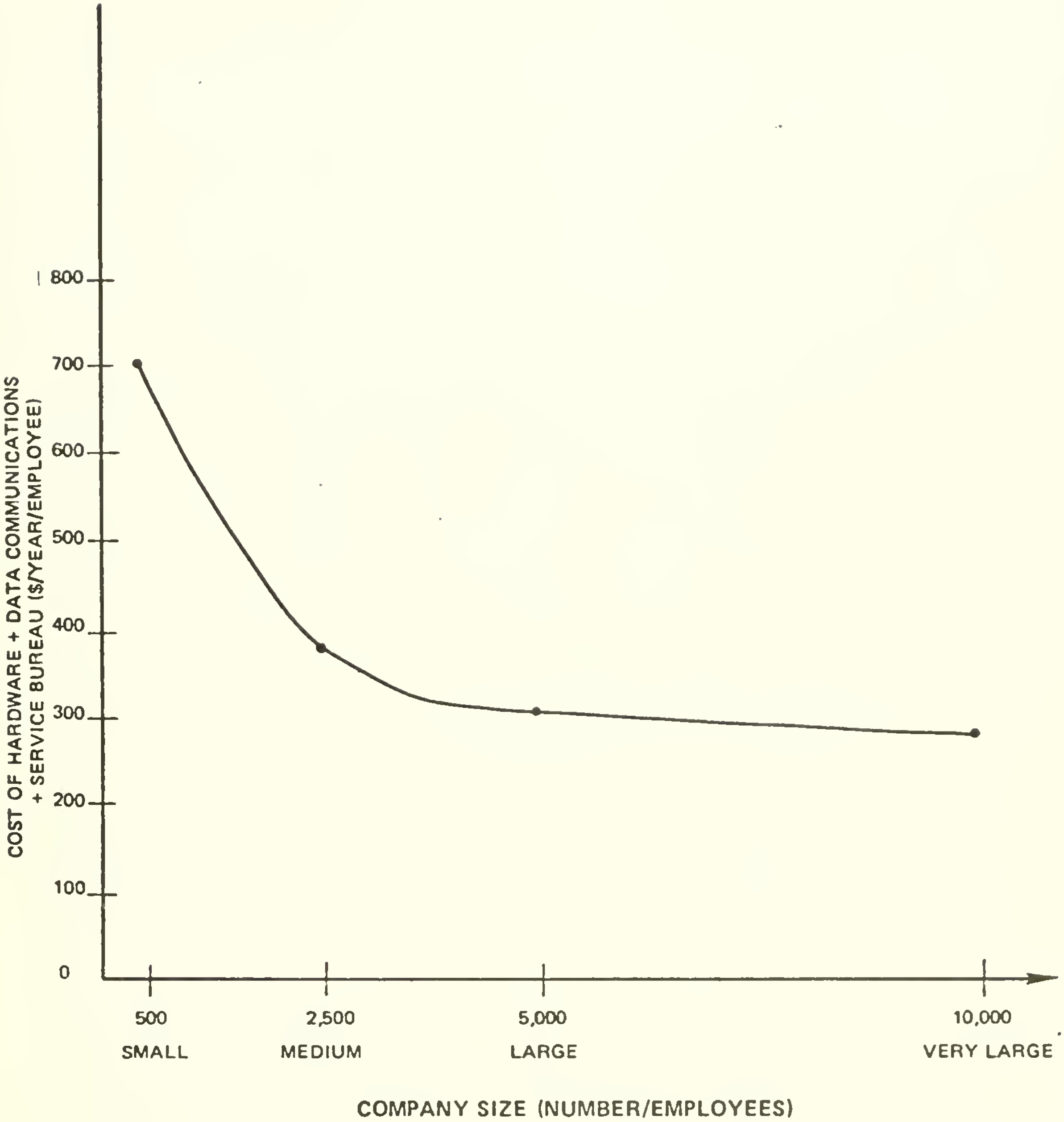

FIGURE 3

Hardware Scale Advantage Process Plant E&C Companies

TABLE V

Composite Views of the Future by Company Size

		SMALL	MEDIUM	LARGE	VERY LARGE
A.	Current and future use of minicomputer.	No plans for use.	Now used for graphics. Will be used for many things.	Now used for network processors. Will be used for graphics and remote jobsite DP.	Now used for network processors, graphics, and process control. Jobsite processor and hierarchical network in future.
B.	Future organization of computer management.	More centralized.	More centralized at top management request.	About same or more centralized. Top mgt. wants overall planning and better information. Leads to better qual. sys. and more standards.	More centralized for more standard systems. May decentralize some functions for better responsiveness.
C.	Future placement of comp. hardware.	More centralized to reduce costs.	Probably about the same. However, some will centralize more for economy and others may decentral. more via cheaper mini.	About the same except special purpose mini's and some general purpose use of mini's.	About the same except for special purpose mini's and some general purpose use of mini's.
D.	Future standardization of systems.	More.	More standard because of bigger contracts requiring more than one office and to allow overall planning and uniformity of performance measurement.	More standardization for better control, to meet client demand, for less duplication, better qual. systems, and better format.	More. Big jobs require more than one office, company procedures are getting more standard. Also, standardization leads to a better quality systems & docu., provides backup and gives mgt. assurance.
E.	Future trend in data communications.	More. To enable centralization.	More. To provide service to jobsites & to enable some possible decentralization of hardware.	More. Lower costs thru centralization, better info. to mgt., more timely info., & to handle new offices & jobsites.	More. Handle jobsites, new offices, and graphics. Increasing need for communication of all kinds.

All except the smallest companies expressed <u>plans</u> for use of mini-computers in the future. All had firm plans or were currently using minis for applications involving graphic displays, and network processing. Interestingly, none of the companies which stated plans for using minis for distributed commercial functions (e.g., remote jobsite payroll, ineventory, etc.) had thought these plans through to the point of commitment. Personal follow-ups were made to each company expressing this particular "future view." In no case, did the DP manager indicate expected efficiencies for such a move, nor major effectiveness gains. However, it was felt that "inexpensive" mini-computers may enable giving managers who desire it "their own" computer for motivational reasons.

All companies indicated an increased need for standardization of computing systems throughout the organization. Increased needs for multi-office coordination on major jobs, overall planning, improved quality of systems, and improved standardized outputs for major customers were cited. To allow increased standardization, increased data communications were also seen as necessary in all cases.

The cost of data processing to engineering and construction companies as a fraction of their earnings before tax has grown to become a significant number decreasing from 38% for small companies to 24% for large companies, and rising somewhat to 28% for very large companies.

THE PAST AND THE FUTURE

The results of this analysis imply that centralization of decision making and control, of systems development, and of systems operation has been desirable for engineering and construction companies. The larger companies which had larger systems staffs were able to develop a greater number of systems that were generally more integrated than those of the smaller companies and were more standard throughout their companies. Also, the larger companies now operate their systems for a smaller dollar cost per employee than the smaller companies.

So much for the past, now what on the future? The following two sections explore the tendencies toward and away from hardware centralization based on forecasts of technology developments and what was learned from the survey.

Toward Increased Hardware Centralization Centralization has tended to improve the effectiveness of computing in the engineering and construction company. The survey conducted for this paper indicated that bigger computer shops provide more services to the company at lower unit costs.

As mentioned previously, the information processing demands in the state of engineering and construction industry demands standard systems. Control of standards is easier on one computer than on several. This implies centralization.

Streeter's article points out the importance of reliability to centralization of hardware.[21] Current hardware is more reliable than recent models and Withington's report indicates that future models will be even more reliable.[28] These two factors taken together would indicate that future hardware can support a greater degree of centralization than the present.

Perhaps the most important force of all which is tending computer organizations toward centralization is data base accessibility. It is true that data base systems are available for minis, but these appear not germane in this industry. The survey showed that very large engineering-construction companies have data bases in excess of two billion characters. Sophisticated tools are required to manage such large data bases. A need for coordination of construction projects between jobsites, standardization of company data, integration of systems and the normal considerations of economies of scale all imply centralization of the data base.

Withington[28] and others forecast that the data base management packages coming will considerably reduce the work required by programmers to manipulate and assure the reliability of data bases. However, these packages will be very large and will require a large computer to operate. This need for a large computer and expensive software packages again implies a balance toward hardware centralization.

Toward Hardware Decentralization There are, however, a number of forces acting simultaneously with those described above which tend to push the hardware organization toward decentralization.

There is efficiency and increased effectiveness in centralization, but it may have an upper limit. Canning sees the limit qualitatively through the complexity he sees in large shops.[25] Some respondents to the survey from very large companies indicated that reliability and system complexity were their biggest problems. There are several plausible reasons why a limit might exist. Canning would attribute it to complexity. Streeter might attribute it to the reliability of current hardware, telecommunications and operating systems. Or, it might simply be the constraint of the largest computers available. Our evidence suggests that there is a point where economies of scale disappear. At this point decentralization (at least to two or more sites) becomes managerially useful for all the reason that underly management decentralization.

Effective "fast response" is gaining ascendency over efficiency in some industries. Managers and other users of computers are demanding simplicity. Most are willing to give up some degree of computer power to be able to quickly solve their problems. Minicomputer manufacturers have so far been careful to keep their computers simple to use while maxicomputers have become increasingly complex. As long as minicomputer manufacturers provide simplicity, managers may give up some advantages of

centralization in order to get simplicity and "fast response" to their needs.[24,28] We found evidence of increased consideration of this tradeoff during our survey.

In addition, standard application systems can be developed with central coordination, but implemented on a decentralized basis. And there clearly are some response time, reliability and queueing factors which make local data entry and edit desirable. One must look at hardware decentralization on an application by application basis, and a function by function basis. There is no single overwhelming all-inclusive answer which is possible.

It should also be noted that our respondees were primarily DP managers. A poll of users might have elicited a different set of responses on some dimensions.

Toward Increased Centralization of System Management Early in this article, we referred to the three major areas which must be considered with regard to centralization and decentralization. These are hardware, systems development, and systems management. The usual discussion is on the question concerns hardware -- and it is on that that we have focussed above. As has been noted, although past centralization success is clear, these are some interesting tradeoffs for the future. The focus of software development is a complex issue which we have let alone in this study.

It is in the area of systems management, however, that we find the clearest evidence -- and have the strongest personal conclusions. Many of the most significant benefits of centralization (the development of standard systems, reduced program maintenance, compatible hardware, effective documentation standards, improved personnel selection and training) arise from centralized systems management, not centralized hardware. The strong desirability of increasing standardization in all of these areas was undoubtedly the most completely agreed upon -- and most strongly voiced by all respondents (see Table V) in the survey. It is a point with which we concur for this industry.

SUMMARY

In summary, centralization of hardware and systems management, which have occurred as DP departments have increased in size in larger companies, has served companies well in the past by the efficiency and effectiveness measures used in our survey in the engineering and construction industry. Exactly what part of the benefits have occurred through sheer size -- as opposed to centralization -- is unclear. The fact remains that the two variables have followed each other and the result of increased centralization in larger companies is positive.

As far as hardware centralization is concerned, this will differ from industry to industry, but we believe the application structure of this industry suggests that increased centralization is logical from an

efficiency viewpoint for small and medium sized firms -- and for many of the larger firms. The largest firms may well have passed the point -- given current hardware technology -- where increased centralization has a further yield. For this reason, we expect some decentralization of hardware in these very large firms. In addition, for political and human motivational reasons, there will probably be some hardware decentralization in other firms.

Yet the real challenge which is evident is to further develop and maintain system management centralization. This can lead to the benefits of standard application systems, decreased program maintainence costs, and the other benefits noted just above. Significantly, the proliferation of noncommunicating hardware, multiple software systems, and incompatible data elements which was true prior to the last decade's move toward centralization can be avoided. It is in this area -- the focus on systems management that the most significant question of centralization or decentralization lies for the management of data processing.

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