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AN ANALYSIS OF COMPUTER DECENTRALIZATION

CECILIA R. D'OLIVEIRA

OCTOBER 1977

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The results indicate that (1) strong decentralization forces do exist in many organizations. The forces derived from these particular case studies are classified as either functional, economic or psychological. (2) The drop in hardware costs allows decentralization to occur at the initiative of lower level managers.

The consequences could include disintegration of the organization's information system. Decisions by lower level managers may overlook the technological constraints of decentralization, especially the problems of networking loosely coupled computers. This could result in a future inability to share data or programs among organizational units. Because of the many functional advantages it provides, ~~we do not feel that~~ top level management should discourage decentralization. However, top level management must be aware that ~~the~~ technological constraints require that decentralization occur with their guidance and their perspective of the entire organization.

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AN ANALYSIS OF COMPUTER DECENTRALIZATION

by

Cecilia R. d'Oliveira

This Technical Memorandum is based upon a thesis submitted on July 25, 1977 in partial fulfillment of the requirements for the degree of Bachelor of Science in Computer Science and Engineering at the Massachusetts Institute of Technology.

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Cecilia R. d'Oliveira

Submitted to the Department of Electrical Engineering and Computer Science

on July 25, 1977 in partial fulfillment of the requirements

for the Degree of Bachelor of Science.

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This thesis is concerned with the recent trend towards decentralization of the computer facility. We conjecture that there are strong forces in many organizations leading towards decentralization, which have been held in check by technological and economic constraints that are beginning to relax. This conjecture is explored by analyzing approximately forty case studies of decentralization decisions.

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INTRODUCTION

1.1 Overview

Currently, there is much discussion regarding the issue of centralization versus decentralization of an organization's computer-based information system. While a centralized computing facility continues to be the norm, there appears to be a recent trend towards decentralization. This thesis is concerned with determining and examining the forces behind these decentralization decisions.

1.2 History of Computer System Organization

The question of how to match the computer-based information system to the organization has plagued management for years. Traditionally the first computer was acquired and used by the accounting department, because accounting functions were well suited to computer processing. As other departments became interested in applying this computer to their tasks, problems often developed in establishing priorities for the use of the computer. In most cases these organizational conflicts were resolved by establishing a separate data processing department [1].

At the time centralization began, it was considered infeasible to allow separate departments within a firm to acquire and maintain their own computers. First, costs for hardware were prohibitive. Second, there was a severe shortage of technical personnel. Third, management saw the computer as a means of centralizing records that were formerly collected and maintained by individuals or groups. A centralized information system would allow consolidation of reports that had been difficult or impossible previously [2].

The trend during the late 1960's was towards more and more centralization of the information system [3]. First, economies of scale in computer hardware became a widely accepted idea [4]. Second, the combination of centralized systems and the new technology of time-sharing seemed to make a "Total Management Information System" for the organization a possibility. At that time one might have predicted that by 1977 there would be very little debate or concern about how to organize a computer-based information system.

1.3 Why the Concern Today?

And yet, there is more discussion now than ever before. There appear to be several reasons for continuing management interest in this area. First in spite of decreasing hardware costs, EDP (Electronic Data Processing) budgets continue to climb and represent an increasingly large part of an organization's expenditures. Second, organizations as a whole are increasingly dependent on their information systems. Third, because information systems have become an important part of management many individual managers are demanding more control over their own systems. Fourth, technological developments, such as minicomputers, offer new alternatives in computer system organization, because of their low entry costs and increasing capabilities.

It is assumed that a decentralized, user-controlled, environment will impact issues that concern management differently than will a centralized environment. For this reason and because they represent the extremes of computer configuration, discussion of computer system organization has focused on centralization versus decentralization. A quick scan of any computer community journal reveals that centralization-decentralization is one of the most heatedly debated issues in the management of information systems today.

1.4 What is Computer Decentralization?

The concept of decentralization is not a new one in the computer community. The earliest computer installations in business firms were excellent examples of decentralized computing. The end user, in most cases the accounting department, was responsible for developing applications, maintaining and managing the system. Both the computer and the technical personnel required to support it were located in the accounting department [i].

It was not until other organizational units became interested in this new electronic tool that the trend toward centralization began. The result was that the machine, support personnel and responsibility moved out of the user department to a new and separate unit--the data processing department.

It is obvious that computer system configuration is not limited to either a totally decentralized or totally centralized system. For example, an organization may maintain an otherwise totally centralized EDP department but "spin-off", i.e., decentralize one particular function. In fact some authors [5,6] point out that there are three major activities involved in the information system function, any or all of which may be centralized or decentralized or somewhere between--making the variations between totally centralized or decentralized almost infinite. These activities are:

1. systems operations--the process of receiving input, updating files and generating reports.

2. systems development--the process of designing and implementing new systems and applications.

3. systems management--the process of planning and establishing policy for the data processing function.

Another term referring to decentralized computer-based information systems is "distributed processing." While it has been defined in many ways, its basic meaning is that processing power is moved out of the central computer room to local sites. The only distinguishing characteristic between distributed processing and decentralization is that distributed processing implies central planning. Decentralizaton may or may not be the result of central planning.

This thesis will use loose definitions of the terms centralization and decentralization. As has been noted, there are many variations of computer organization. It is unlikely that any two firms will organize computer resources in exactly the same way. For this reason it makes sense to deal more with the concepts rather than with precise definitions. The concept of centralization is that processing is carried out by a specialized, central group for an end-user community. The concept of decentralization is that the processing power is acquired and administered by the end user.

1.5 Related Research

There is an abundance of literature related to the role of the computer system in the organization. To some extent, all of this literature relates to or is background to this thesis.

As early as 1957, several authors conjectured about the probable effects of computers on organizations. These authors explored questions about how the ability of the computer to store and consolidate large amounts of information would impact organizational structure. Some authors felt that management would become much more centralized because of the ability of top executives to access large amounts of information through the computer. Other authors saw the computer as a vehicle to further management decentralization [7].

Many authors have explored the various alternatives available in computer system organization, and the use of computers in organizations. In The Real Computer: Its Influences, Uses and Effects, Frederic Withington presents numerous case studies citing the use of computers in organizations as well as the alternative structures that these systems assume [3].

Recently, much literature has been addressed to the debate between centralization-decentralization of the organizational computer system, in an effort to determine the "best" structure. This discussion has centered on the advantages and disadvantages. Rockart has developed a bibliography of this literature [8].

Herbert Grosch, in the 1940's, was the first to present views that economies of scale existed in the use of computers. This became known as Grosch's Law and has been the major argument for and reason behind centralization of the computer facility. Various authors have tested Grosch's law during the past twenty years [9,10,11,12,13]. Selwyn explored whether users feel that economies of scale exist.[14]

The Center for Information Systems Research at the M.I.T. Sloan School of Management has developed a model for decision-making regarding computer system organization. This model is presented in a 1976 working paper from CISR [8]. The model is partly based on information obtained through case studies from the literature. The findings from the case studies are summarized in the CISR paper.

1.6 Scope of the Thesis

A more enlightening approach to this issue may be to determine the forces that are actually significant in decisions regarding decentralization. The goal of this approach is not to define the "best" structure for a computer system. Rather we try to discover why decentralization decisions are made by managers at either a corporate or operational level. This is done by examining case studies and analyzing the forces at work in the organizations studied.

The conjecture is that there are strong forces in many organizations leading towards decentralization that have been held in check until now by technological and economic constraints. If this conjecture is true, it is significant for two reasons. First, it will be difficult in the future for an organization to suppress strong forces from within, even if the philosophy of the organization favors centralization of the computing facility. The economic constraint is vanishing as hardware costs drop. The technological constraint refers to the difficulty of sharing information among loosely coupled computers. This is a significant constraint at present but it is not unrealistic to assume that the technological problems will be solved in the future. Second, these forces may result in decisions that ignore, overlook or underestimate the present technological constraint. For example, it is now possible for computer acquisitions to occur at low organizational levels because of the drop in hardware costs. The result of these localized decisions could be difficulties in the future for organizational units desiring to share data or programs. Therefore some thought should be given now to overall system integration.

PRELIMINARY DISCUSSION OF FORCES

Decentralization decisions may be initiated at different managerial levels. It is apparent that some decentralization occurs at the initiative of operations (department) level managers who opt for acquiring a small computer, which they dedicate to their application, rather than sharing in the use of a large central system. Decentralization decisions are also made by corporate level management. It is likely that there are different forces behind decisions made at different managerial levels because different perspectives are involved. The operational manager is more concerned with the day-to-day aspects of running a department. The corporate level manager is concerned with the long-range aspects of running the entire organization. This thesis examines the forces behind decisions made at both levels.

Preliminary study of the literature suggested specific forces that might be significant in decentralization decisions. These evident forces seem to fall into three categories: functional, economic and psychological. These categories are broad and it is not always clear in which category a particular force should fall. However, the categorization provides a conceptual framework which was helpful in analyzing the forces behind decentralization decisions.

> A <u>psychological</u> force is one whose source is an emotion, a philosophy, a preference or a perception.
>
> A <u>functional</u> force is based on the ability of a particular configuration to accomplish its task. This collection of forces seems to parallel many formerly noted advantages and disadvantages.
>
> <u>Economic</u> forces are those based on costs.

This thesis does not present forces as advantages or disadvantages of decentralization since we do not attempt to define the "best" structure of an information system. It may be true that many "advantages" of decentralization are in fact "forces" behind user decisions to decentralize. However, advantages and disadvantages reflect an "objective" view of the decision in terms of its ultimate effect on the organization. One might assume that managerial decisions are more complex than this.

RESULTS

3.1 Method

The purpose of this thesis is to determine forces significant to user decisions regarding decentralization. The most reasonable way of determining these forces is through examination of actual case studies.

Over forty case studies were collected as part of this research. The most available source was the literature. Many cases were obtained from articles in Computerworld, Datamation or other computer community journals. In some instances additional information was obtained from the organization after initially reading about the case in a journal. Additional sources include other authors' experiences and case studies related by the marketing department of a computer manufacturer. (Because they were obtained under an agreement of confidentiality, the latter case studies are disguised here.) Appendix A contains a listing of the case studies used in this thesis. This listing consists of the name of the firm, or a description of the firm's activities, the source of the case study, and the sections in this thesis that refer to that case study. Each case study has a unique alphabetic code which is used whenever that case study is referred to. This code may be used to cross reference through Appendix A.

Because of the stated purpose of this thesis most of the case studies examined concerned decentralization decisions. However a few case studies were examined and are presented because they represent typical centralization decisions.

Some of the case studies involve corporate level decentralization decisions. Other cases involve decisions made or initiated by the end-user departments. The available case studies are quantitatively weighted in favor of the former. This may be because most of these decisions are made by corporate officers. Another possible reason is that end-users are not usually interested in publicizing their computer acquisitions. For example, one case was related by a user whose department had acquired an in-house computer. This user refused to identify himself or his firm. This desire to remain anonymous may stem from the fact, as the case study relates, that the central data processing department had not approved this acquisition.

A few of the case studies used involve decisions to convert from a service bureau system (i.e. a commercial supplier of computer services) to an in-house system. These decisions may involve many of the same forces that are present in end-user decisions to convert to a local computer from a central department.

Most of the case studies involve business organizations. However, a small number of government and university based cases have been included.

A danger in conducting this type of research is the reliability of the data. In some cases, one suspects that the person relating the case study to the computer journal may conciously white-wash the facts or even portray a distored version of the real situation. In addition the presentation of a case is highly dependent on the perception of the manager relating the story.

This problem constrains the thesis in a number of ways. The most crucial constraint is that it is possible that the forces that are revealed through this type of research are not those really significant to decisions. It is possible that many significant forces will not appear in print, especially the conjectured psychological forces. Therefore, it is necessary to "read between the lines" in some cases. However, when this is done it is acknowledged.

3.2 Functional Forces

Functional forces refer to those forces that are based upon the ability of a computer system to accomplish some desired function.

Many of the forces behind the decentralization decisions examined were functional forces. Although these forces were significant in the decision-making process, nothing is implied about the eventual performance of the system in the case study.

Table I lists the functional forces that were found to exist in the case studies examined.

TABLE I.

<u>FUNCTIONAL FORCES FOUND</u>

Flexibility
Availability and Accessibility
Ability to Set Priorities
Ability to Regulate Response Time
Ability to Regulate Hardware and Software Upgrades
Avoidance of Overhead on Mainframe
Shorter Development Because Less Complexity
Privacy and Security Issues
Reliability

3.2.1 Flexibility

The word that best sums up functional forces is flexibility. The vice-president of manufacturing of a small firm (case A) that switched its inventory and production control system to a mini from a service bureau said, "Outside services are not tuned to the needs of a small operation. If you want real flexibility you have to control the computer yourself."

Local control of operations gives the user the flexibility to regulate response time and time of availability, set priorities and schedule system upgrade. It also allows easy accessibility to the system. Each of these was a major force in decentralization decisions.

3.2.2 Availability and Accessibility

An insurance firm's actuarial department (case B) obtained a dedicated minicomputer system. According to the anonymous user they wanted additional availability in order to do more research.

> Before, we rejected jobs because they would have taken too much time on the time-sharing system. Nowadays we don't mind letting the mini run four or five hours.

An engineering firm (case C) was considering switching from a service bureau to an in-house computer. The decision was between acquiring a central mainframe computer or investing in separate minicomputers for each regional office. The decision was to decentralize. One of the reasons given was that local engineers could then be encouraged to use the computer freely. The corporate officers felt that this would be especially useful if a specific job or proposal required a large amount of engineering calculations.

Another case involved Lowe's Companies Inc. (case D), a group of 140 building materials stores spread throughout the Southeast United states. Its decentralization decision is a total one, involving both store level and corporate level decentralization. One of the principles behind the design of the corporate system is that it is dedicated to the user. The company management wanted the system available to users on a full time basis to provide them with the capability to do what they want, when they want.

Ricardo Consulting Engineers of Shoreham, England (case E) is a former user of a time-sharing service. One reason that the firm purchased an in-house system was that "availability of machine time, particularly for large jobs was restricted" on the service bureau machine.

3.2.3 Ability to Set Priorities

The ability to establish priorities is important to an operational manager. Local control of a computer system allows the manager of the unit to determine what is crucial and what deserves priority in terms of computer time or development time. A central department must set priorities among a variety of users and if a crucial situation arises in more than one unit, one user must be given preference. If an operational manager thinks that he does not receive enough priority then he may seek local processing power. This force is apparent in the following examples.

The controller's division of Atlanta's First National Bank (case F) acquired its own minicomputer system in order to automate much of its clerical work. According to the manager of accounting services, what the division felt was high priority did not seem crucial to the central data processing department. If the division wanted this new capability it had to develop it. This disagreement was the major force towards decentralization.

A representative of Deere and Company (case G) related his firm's experiences with small computer users within the organization at the recent Spring 1977 National Computer Conference in Dallas. The firm uses six mainframes as a corporate computing utility. Since 1975 the central computer department has conducted an annual survey of users to determine where small computer systems were being used within the company as computers rather than remote job entry terminals. In 1975 the survey uncovered 35 small computers, in 1976 the second survey revealed 102 small computers and in this year's survey 150 small computers were reported.

Although the company representative did not mention the forces behind these computer acquisitions he did say, "An added item of interest was that some of the applications examined took only days to implement, after sitting in the request queue in the Business Systems Department for months."

Closely related to the ability to set priorities is the ability to regulate the response time of the system.

3.2.4 Ability to Regulate Response Time

The turnaround time, i.e. the response time, of a computer system is a major determinant of effectiveness of the system in many applications. Response time may refer to actual machine time, which is important in on-line applications. It may also refer to total turnaround time which includes computer time, transportation of data to the centers and reports from the center. The ability to regulate response time is related to the ability to set priorities in that decentralized computing allows the manager to determine what response time his department's various applications require and this really involves setting priorities. A slightly different perspective regarding response time is that dedication of a minicomputer to interactive use gives better response than a general purpose machine. Glaser states

> the need of operating managers for rapid turnaround of operating information may transcend any economies that might be provided by sharing data processing facilities located at some distance and time from the local area [6].

Dedication of a machine to an application allows better response time and decentralization allows the manager to regulate the response time. Both of these seem to be major forces towards decentralization.

An insurance firm's actuarial department (case B) obtained a dedicated minicomputer system to perform actuarial simulations. The department considered using the firm's data processing center mainframe but a benchmark job took 45 minutes of machine time as opposed to 17 minutes on the dedicated minicomputer. We assume that this is because the central computer is processing many applications at one time (i.e. multiprogramming) while the minicomputer is dedicated (i.e. processing a small number). The better response time of the dedicated implementation was one reason that the department chose to decentralize.

The corporate division of a service company (case H) was faced with the decision of whether to implement an on-line system using a mini or by placing the system on a portion of a large batch-processing machine. The company realized that the peak loading periods for both the on-line system (however it was implemented) and the mainframe would occur at about the same time. For this reason a separate machine that was under the user's direct control seemed to have great value for this new application. This was a major reason for implementing the system on a dedicated machine.

In a case study mentioned previously (case E) Ricardo Consulting Engineers of Shoreham, England, switched its data processing from a time-sharing service to an in-house computer. The firm found that it was "approaching the limit of the capabilities of time-sharing systems. In particular, turnaround time was considered excessive,. . ." Rather than reprogram for a more powerful time-sharing service they acquired an in-house computer.

Office Canteens of Manhattan (case I) recently acquired a small in-house computer. According to the controller, "Before we installed our small business computer, we were sending all our data out to be processed by an IBM System 3 owned by another division of our corporation. But we weren't getting the information needed for management decisions." Fast response to the profit and loss picture at each cafeteria unit was essential to this firm. This need for fast response seemed to be a major force behind the decision to acquire an in-house system.

Chrysler Corporation (case J) decided to implement an interactive graphics system for computer-aided design. Adding this capability to the central machine would have compromised the response time of both the old and new systems. To protect the response time of both the new and old applications Chrysler implemented this system on a mini.

Other case studies mentioned the slow response time of a batch oriented central system as being a decentralization force. A subtle issue in these cases is that the organizations have made a decision not to attempt upgrade of the central system so that it is capable of on-line real time response. In many of these cases there is no mention of the alternatives the organization considered before deciding to decentralize. While response time needs are the most apparent decentralization force in these particular cases, the desire to avoid system upgrade may be an unstated but major underlying force in these decisions.

3.2.5 Regulating Hardware and Software Upgrades

Service upgrades of both hardware and software occur with some regularity in centralized processing departments. The reasons for the upgrades may be: expansion to more powerful hardware, replacement of a failing unit, installation of a new application or replacement of the operating system with the latest edition. These service disruptions may have no obvious benefits to some users but all are forced to suffer the inconvenience. A local system will experience less service disruption for upgrades because the system is less complex and serves fewer users. Less complexity implies that upgrades will be less difficult and therefore less time-consuming. Fewer users means that there are fewer applications which will require upgrade. Service disruptions that do occur will have obvious benefits to those users. In the extreme case of one user to a system, this user will install an upgrade only if he perceives a benefit. The following cases are examples of the force of regulating upgrades.

A large commercial bank (case K) decentralized operations in its money desk department (which keeps track of reserves, and transfers money to accounts when needed) by dedicating several minis to separate applications. This approach was taken because it would allow the department to automate one step at a time. Expansion or upgrading of functions would result in minimum interference with total operations.

Software upgrades tend to experience further problems than service disruption during installation. New software may result in the sudden appearance of "bugs", which must be tracked down and corrected. These "bugs" will tend to affect service for a longer duration than a temporary disruption for upgrade. A report dealing with software reliability [15] states, "Following a new release software failures can lead to a considerable reduction in serviceability." The report documents the average extent of the reduction in service found to occur in several computer installations that were studied.

The wide variety of uses of mainframe systems means that many "bugs" show up in some applications and not others. The same report says

> The diversity of software problems. . .indicates that different users experience different problems and software errors have high applications dependency.

These application-dependent bugs may necessitate changes in software systems. The new software may impact another user who was not aware of or affected by the initial problem. This is the "interference" problem. A decentralized system minimizes the impact of one user on another because there are fewer users and therefore fewer upgrades of software are required. Decentralized systems therefore tend to avoid this problem.

A case involving a wholesale manufacturing company (case L) points out an interference problem. The company has a central facility that serves on-line order entry, production scheduling, corporate accounting, inventory, customer billing, etc. - all of which share a large data base. The central computer was formerly exclusively batch operation. However two years ago the computer was upgraded to provide on-line order entry. The company system has had numerous problems with the mix of batch and on-line applications. Formerly, the batch process ran smoothly but now it is beset by software problems. The result is that applications are delayed or not run, which makes users unhappy and managers frustrated.

3.2.6 Desire to Avoid Overhead on Mainframe

It appeared that the major force to decentralize in some case studies was the need to install a new application and the desire to avoid any upgrade of the mainframe. Although the reasons that these organizations wanted to avoid upgrade were not stated explicitly we conjecture that they involved the desire to avoid overloading the mainframe.

For example, the Retail Installment Loan Department of Wachovia Bank and Trust Company of Winston-Salem, N.C. (case M) acquired a dedicated minicomputer to preprocess installment loans for each of the bank's offices in North Carolina. In 1971 the department was using the bank's central computer to process these loans. They had at various times used keypunching, OCR and key-to-disk for data entry but had experienced problems with each of these methods. Efficient data entry required an interactive system, which conceivably could have been implemented by upgrading the central system. Although the article did not address this point it appears that they decided against this kind of upgrade.

Olinkraft, Inc. Mill Division (case N) installed a dedicated mini to support an on-line system. This decision was made to eliminate the overhead on the mainframe that would be associated with upgrading it to handle on-line systems. The mini accumulates transactions during the day and communicates these transactions by batch mode once a day to the central computer which processes and stores large amounts of data relating to all the Olinkraft industries.

A railroad company (case O) wished to automate waybill preparation. (The waybill is documentation accompanying every freight shipment and contains information on source, destination, customer, rate, etc.) Corporate management considered a centralized system using remote on-line terminals but discarded this idea because of the high overhead that it would require of the central computer, simply to handle the communications. They chose instead to install mini computers at each of seven agencies. These agency systems will send updates to a master file on the central computer at corporate headquarters but will maintain appropriate subset files locally.

Industrial Nucleonics, Inc., (case P) implemented a production and inventory control system on a dedicated computer. The firm initially attempted this system on a central computer. However it experienced data preparation inaccuracies with the central approach because the keypuncher was not familiar with manufacturing terms. This problem might have been solved by decentralizing personnel responsible for data entry and introducing an on-line data entry system, but it appears that this approach was not considered. Perhaps because the company wished to avoid any upgrade of the mainframe, it decided to decentralize the entire operation.

3.2.7 Shorter and Easier Development of Less Complex Systems

Development of a system to run on a local dedicated computer may be faster and easier to accomplish than expanding the central system to incorporate the new application. This savings in time and ease of development may encourage decentralization.

A commercial bank (case K) decentralized operations in its money desk department, by dedicating each of several minis to a different application. This approach was taken after initially attempting to automate operations through a centralized system. With a central system, program development was complex and therefore a lengthy process, and by the time an application was developed it was obsolete. After years of problems they decided that through decentralization each application could be developed in six to nine months compared to the typical two to three years for a central system.

A large chemical division (case Q) consisting of several remote profit centers in addition to a corporate headquarters gave most responsibility for handling information needs to these remote locations. At some point, central management recognized a widespread need for an on-line transaction oriented system. The company considered tying the profit centers directly into the computer at corporate headquarters. However, they felt that adding an on-line capability to the central system could take two years to implement. The decentralized approach was used because they expected that the development time of this implementation would be six months. This was one reason that the company chose the decentralized approach.

3.2.8 Privacy and Security Issues

Privacy of information stored in computer data bases has been a major cause of concern in the past five years, most noticeably in government computer systems.

As early as 1972 the FBI (case R) established a security regulation requiring that any computer that handles criminal histories be dedicated to law-enforcement use and under the control and management of law enforcement officials[cw20]. This regulation was reaffirmed in a 1975 ruling by the Justice Department, which called for states receiving federal funding to operate criminal justice information systems on dedicated computers.

In Hiroshima, Japan, in 1975 the Central Congress for Privacy Protection (case S) protested the city's plan to place the health records of victims of the 1945 atom bombs into a central data bank. Other Japanese data banks had been established without privacy objections. It seems, however, that the idea of centralizing a data base brings privacy considerations to the foreground. People seem to be more comfortable with the idea of decentralized data bases.

In 1975 Arizona's governor (case T) opposed consolidation of the Arizona state government computer systems into a central system because he felt it threatened the privacy rights of Arizona citizens.

The Georgia State Crime Lab (case U) uses a minicomputer to keep track of evidence used in criminal trials. The lab chose a mini over other methods because it needed "the security of an individual system."

Lockwood-McDonald Hospital (case V) formerly used a terminal connected to a service bureau computer to serve its data processing needs. The hospital administrator, explained why the hospital decided to obtain its own small computer. "The major advantage in having a small compact, easy-to-use computer right here in our own business office is the ability to enter and retrieve information in a timely, completely accurate, totally secure environment."

3.2.9 Reliability

There are circumstances in which a single centralized computer facility is not sufficiently reliable to provide required levels of availability. In these circumstances a distributed system comprised of several nodes individually capable of stand-alone operations may provide a configuration that continues to operate as a whole if one or more of the individual nodes fails [16].

In a distributed or decentralized system, service continues to most of the system if one particular node fails. The failure of the mainframe computer in a centralized system results in total loss of service throughout the system. A central system's reliability may be increased by using a redundant processor, which serves as a back-up to the front processor. However, this redundancy may not decrease vulnerability to disaster (such as fire, flood, etc.) or sabotage because the two processors are usually located in the same area.

Several case studies seemed to show that the reliability of a decentralized or distributed system is a force in decentralization decisions.

Inter-Provincial Pipeline Company (case X) is a Canadian-U.S. company that uses a distributed network of mini computers to monitor and control pipeline and pumping stations. Reliability was cited as the major reason for choosing this structure.

The ARPANET is a computer network that ties together the computer systems of major universities and research laboratories from across the United States. The Inter-Message Processor (IMP) system (case Y) is a network of small computers dedicated to the task of handling communications between host computers (i.e. the university or laboratory computer) in the network. The IMP computer acknowledges to the source computer that its message has left the communications subnetwork and has reached the destination host computer. The IMP is not subject to service interruptions which a host computer is subject to because it serves only one function. These interruptions may appear as a crash to the source computer because its message isn't immediately acknowledged, when in fact the message has been received and will be processed at a later date. Because the IMP is not interruptable, i.e. it is dedicated to one function, "its negative acknowledgement is a more reliable indication of message non-delivery than is a timed out host level acknowledgement. In addition the special purpose IMP machine can be made more reliable than a general purpose host which must manage failure prone mechanical devices."

Southern Bell Telephone and Telegraph Co. (case Z), with headquarters in Atlanta, uses seven clusters of minicomputers in its service order application. One of the major considerations in this decision was the requirement for high reliability.

3.3 Economic Forces

In the 1940's Herbert Grosch argued that the power of a computer system increases with the square of the cost of the system [9]. In other words, if you pay twice as much for a processor you receive four times the processing power. This argument became known as Grosch's Law and has been the center of much debate and study. Among those who empirically tested Grosch's Law were Knight [10,11], Solomon [12] and Littrel [13]. Knight and Solomon concluded that economies of scale did exist. Littrel's study indicated that the law held for scientific calculations but not for commercial data processing.

The original Grosch's Law referred only to economies of scale in the hardware that provides the processing power. Supporters of the argument have extended it by pointing to the existence of economies associated with the operations of large systems and shared development costs. Multiprogramaming, usually found only in large systems has also been mentioned because it seems to provide another economy by ridding the system of non-productive idle time.

The economies of scale arguments, especially Grosch's Law, have been increasingly opposed in recent years. The decreasing cost of hardware and the emergence of sophisticated minicomputers have produced many opponents of economies of scale. Arguments against economies of scale often mention the high overhead found in most large systems due to multiprogramming and security support. In discussing diseconomies of scale Selwyn states,

> It was learned, for example that the sharing overhead components in one major time sharing system then under development would be about 65% of total hardware costs [14].

The overhead costs associated with large central systems seemed to be a major reason that the city of Boise, Idaho (case AA) acquired their own minicomputer to service municipal needs rather than sharing a larger system with another city or the county. A report published by the city stated,

> The third limitation of large centralized systems is the cost associated with large sophisticated computers. For Boise City this was a major limitation. While, initially, the large computers were subject to the benefits of economies of scale it seems that the largeness and complexity of such systems have spawned even greater diseconomies of scale. The overhead encountered in multiprogramming, virtual memory, telecommunications and data bases is far greater than anyone, except possibly the hardware vendors expected it to be.

Arguments against economies of scale also include (1) decentralized systems composed of uncomplex, dedicated computers can be supported by fewer experts thereby decreasing operating costs [17]; and (2) development time of a smaller (therefore less complex) function will be shorter and therefore more economic.

From the controversy that exists today over economies of scale we might conclude that hardware costs have dropped to the point that there is no significant economic advantage to either a centralized or decentralized environment. The case studies examined seemed to indicate that the decision as to which configuration is more economic is dependent upon the particular application, the environment and the prior experiences of those making the decision regarding economies of scale. Economic considerations in decentralization decisions today seem to involve more subtle issues than absolute economies or diseconomies of scale. The considerations include such things as communications costs, entry costs and the initial investment required. The following chart lists economic forces that were significant in user decisions regarding decentralization.

TABLE II.

Economic Forces Found

Low Entry Cost

Low Initial Investment

Fixed Cost of Own System

Lower Communication Costs

Smaller Investment Than Upgrading

3.3.1 Low Entry Costs

A decade ago the capital required to install a computer system ranged from $150,000 up to the millions. Today the low end of the range is below $15,000 and is still dropping [18]. Many decentralization decisions made today would not be made if the systems acquired required capital in excess of $100,000. Although low entry costs are not explicitly stated as a force towards decentralization they are a precondition to many of these decisions. Smaller capital investment requirements also make the acquisition of computer systems more possible at lower organizational levels than was possible before. This is because in many organizations capital acquisition decisions are less centralized for smaller capital amounts. The conclusion is that lower entry costs remove the economic constraints that once prevented decentralization decisions and also enable these decisions to be made at lower managerial levels.

3.3.2 Low Initial Investment

Many centralized data processing systems are based on mainframes that cost anywhere from \$500,000 to \$12,000,000 [19]. Many organizations may find it difficult to obtain the capital required to acquire these mainframes. In addition corporate management may be hesitant to invest this amount of money in a system that (1) will not be developed and functioning for some time and (2) does not allow a step by step analysis to determine if the system will be effective. A decentralized or distributed system may be much easier to sell to management.

In 1969 a group of experts from a large systems house participated in a study of process control requirements for a large chemical plant (case BB). The study showed that the resulting improvements could support an expenditure of at least two million dollars. A large redundant process control system was presented to management. The cost of the system would be \$1.8 million. Management accepted the results of the study but would not invest the money in this large central system.

In 1972 the same management group accepted a proposal for a distributed process control system. The distributed system could be installed in a step-by-step manner over a period of two years. The initial capital investment required to determine the overall system's economic feasibility was less than $100,000 (cost of first step) compared with the $1.8 million required in the 1969 proposal. The management decision was much easier, because the system would be partially functioning and paying for itself in six months and because the initial investment was low.

3.3.3 Fixed Costs

The fixed cost of acquiring a minicomputer system seemed to be preferable to paying out variable service charges in two case studies that were examined.

The first case (case B) involved the actuarial department of an insurance firm. The department used a time-sharing service but wanted to do more research involving actuarial simulations. A user in the department said

> The idea of having our own minicomputer with fixed cost, no matter how much time we used it, had a lot of appeal. Now we don't mind letting the mini run for four or five hours.

A theoretical chemist at Berkeley (case CC) experimented with the feasibility of using a dedicated minicomputer for very large scale theoretical chemistry computations. The chemist and his graduate students had been using the CYBER 7600 central processor at the Lawrence Berkeley Laboratory but felt that their annual budget for computer time was buying them a negligible amount of cpu time on this large machine. The chemist acquired a minicomputer and began to run many of the applications on this machine. His conclusion was that it was feasible to invest the annual budgets for computer time of two university scientists in a minicomputer. He attempts to show that the minicomputer provides him with three times more computing power per dollar than the CYBER 7600. This calculation is debatable, however it appears that the idea of obtaining a dedicated computer for a fixed and affordable price was preferable to him than paying for cpu time on a central machine.

3.3.4 Lower Communication Costs

In many situations remote terminal capability will satisfy the needs of a user department functionally and psychologically. However remote access requires communication capability and this entails an additional expense that seems to be becoming more significant. One author states that of all the elements of computing cost the smallest decrease in recent years is represented by the communications portion[da4]. Communication costs seem to make up more and more of the costs of remote computing. This has been mentioned as a major force towards decentralization, which requires significantly less communication facilities.

The jewelry firm of Lisner/Richelieu of Rhode Island (case DD) sought to reduce costs incurred by financial data processing. They had formerly used data entry terminals connected by telephone lines to the firm's central computer facility. These terminals were on-line eight hours a day and telephone costs were high. This was a force in their decision to seek an alternative method of processing which eventually resulted in the purchase of a dedicated mini.

A large corrugated container manufacturer (case EE) wanted to totally automate a formerly manual inventory control system. In deciding whether to install remote terminals at the individual plants the company was faced with the question of communication costs. Their conclusion was that a central system connected to remote locations by communication lines would incur large communication costs and this was a major reason for their eventual decision to organize the inventory control system in a distributed way.

3.3.5 Smaller Investment Than Upgrading Central System

In many cases upgrading a mainframe for a new application is difficult to do and may cause interference problems. In addition this upgrading may be more expensive than implementing the new application on a dedicated minicomputer.

In a case study involving the corporate division of a service company (case H) the decision was whether to implement a new on-line data entry system on a mini or on a portion of a large batch machine. Their analysis indicated that the upgrading of the batch would be more expensive than development of a dedicated system. The smaller investment required to implement the system on a dedicated minicomputer was a major force in the decision to decentralize this function.

3.4 Psychological Forces

A psychological force is one whose source is an emotion, a philosophy, a preference or a perception. We conjecture that as hardware costs continue to drop and as technological advances allow sophisticated networking of computers, psychological forces may be the deciding factor in decentralization decisions. Decentralized systems will be able to accomplish the same tasks as centralized systems at a comparable cost. The appearance of the "user-oriented computing" concept seems to indicate that psychological forces are emerging that will be significant forces in computer acquisition decisions.

However, psychological forces still represent a special category of forces. Most of the forces mentioned in the case studies examined were functional or economic in nature. It appears that forces in these categories are still more acceptable as reasons for decentralization of business computer systems. Psychological forces remain hidden in these decentralization decisions and we conjecture that they are at least as significant as economic or functional forces.

The following list contains psychological forces that were found to exist in decentralization decisions.

TABLE III.

Psychological Forces Found

Bad Experiences With a Central System

Insures Greater User Acceptance

Fewer Political and Priority Conflicts

Philosophy of the Organization

3.4.1 Bad Experiences With the Central System

Case studies seemed to indicate that many decentralization decisions are made specifically because of former experience with a central system. Like many kinds of business decision-making, decisions are sometimes made in reaction to previous experiences.

Some users acquire local dedicated computer resources because they have found the central system unresponsive, inflexible, slow-reacting or expensive. This experience with the central system forces them to consider other alternatives. George Glaser says

> if a user has a problem and is determined to solve it, and if he cannot get an acceptable solution to his problem from the 'legal' source of help, he will seek (and find) illegal sources [6].

Industrial Nucleonics Corporation (case P) formerly used a central batch computer for planning production and handling inventory. The problems they experienced with this system were:

1. lag time between inventory change and report receipt
2. priority conflicts at the data processing center
3. data preparation inaccuracies because keypuncher was not familiar with manufacturing terms

These problems forced them to consider other alternatives and eventually led to the acquisition of a dedicated system for production and inventory control.

First National Citibank of New York (case FF) was one of the most public in their decision to decentralize computer operations. In the 1960's Citibank automated many of their applications with large computers controlled by a central department. The following is a Citibank description of their experiences with a central computer system.

> To support this automation, we built large data centers with sophisticated hardware. We talked at the time of the economies

> of hardware centralization and economies of scale. We staffed our data processing organization with sophisticated technical resources to program and run these computers. Data processing became an institution with its own culture, jargon and management process. Over time the data processing people developed a new language separate from the line manager. Communication barriers resulted--the line didn't speak computerese and the data processer didn't speak business.

According to Citibank's Vice President of Data Processing, things had gotten so bad with the large central department that a simple request for information had to go through a dozen people and took ten days to complete. "If I didn't have ten days I would write it off to a tape and take it to a service bureau." [source 2] It appears that bad experiences with the central system were the major force in Citibank's decentralization decision.

A large commercial bank (case K) attempted to automate money desk operations using a centralized system. Because of the complexity of program development, functions were often obsolete by the time they were developed. After years of attempting to develop a central system the bank began to search for other alternatives. This led eventually to the implementation of a decentralized system.

Many case studies, mentioned in previous sections, involved organizations that were former users of central systems. Their decentralization decisions often resulted from a dissatisfaction with their central systems. The point is that in some cases it is possible that with certain modifications or changes in policy and personnel, the central systems would have been satisfactory. However, in many cases the former experiences preclude any consideration of this alternative. For this reason, bad experiences with a central system are considered a psychological force.

3.4.2 User Acceptance

An advantage often noted of decentralized computer systems is that they insure a greater degree of user acceptance. The reasons for this may include (1) the system can be closely tailored to the user's needs (2) the user has responsibility and will not be able to blame anyone else if anything goes wrong and (3) the user is assured that data processing performance is measured by how well his business performs.

In the following two case studies, corporate management's desire to achieve a greater degree of user acceptance was mentioned as a prominent force in their decision to decentralize.

A major railroad (case GG) wished to develop a system to keep track of freight car location both between and within freight yards in order to improve utilization. They initially used a central system with remote terminals located in each yard. Local yardmasters did not fully utilize this system however and the system was considered unsuccessful. In an effort to implement a system that local personnel would accept, central management replaced the central system with a decentralized one. They installed dedicated minicomputers in each freight yard and this allowed the system to be tailored to the needs of the personnel in each yard who would actually use the system. The railroad company seemed to feel that this system would insure a greater degree of user acceptance.

Boise City, Idaho (case AA) first experimented with the idea of a decentralized computer system when they installed a minicomputer in the Boise Public Library. The results of this installation seemed to have an impact upon their eventual decision to acquire their own municipal computer system rather than sharing a large central system with other cities, which is typically the case with small city governments.

> ....it can be anticipated that the installation of minicomputers will improve user acceptance of such systems. The circulation system installed in the Boise Public Library is thought of as the Library's computer. When the system goes down it is still the Library's system, not a system belonging to the data processing department. This attitude is a result of the fact that the hardware is close to and under the control of the people who use it. This has been an important factor in the success and overall user acceptance of the library system.

3.4.3 Fewer Political and Priority Conflicts

In an article entitled "Power, Politics and DP," Joseph Rue points out

> It does not take long for a dp manager to realize that users are not really "departments", "functions", or "projects" but rather certain people who are pursuing personal purposes within the organization's power structure [20].

Data processing involves information, which is of major importance to an organization. There seems to be a certain amount of power related to control of information in organizations. This, according to Rue, is why a dp department experiences conflicts and difficulties in its relationship to other departments in an organization. Other departments or people require the information that dp provides and these people are competing with each other for priority. Avoidance of the politics of the centralized data processing function was mentioned in the following case study of a decentralization decision.

The Data Tech Division of Penril Corporation (case HH) has a minicomputer for manufacturing operations but uses a service bureau for financial applications. According to the controller the functions are split primarily because "the service bureau can do a better job." However, he also mentioned "there are no conflicts between the needs of accounting and manufacturing. This means, in essence, that there's not time wasted with politicking or empire building. Priorities are always clearly drawn: get the job done for the company as a whole."

3.4.4 Philosophy of the Organization

Several authors have noted that centralized data processing in a decentralized management environment is contradictory and dangerous[5,6]. A decentralized management philosophy gives profit and loss responsibility to organizational units and provides unit managers with all the resources required to accomplish the task. To overlay a central data proccessing facility on an organization of this sort may result in conflicts and confusion. In several of the case studies examined the organization opted for a decentralized computer facility because it was more in line with management's philosophy than a central facility.

An engineering firm (case C) formerly used service bureaus to serve the needs of its offices across the United States. The firm has very decentralized management and gives much responsibility to division managers. The company decided to acquire an in-house system and they considered both a central computer implementation and one with minicomputers installed in the various offices. Their decision was to implement the decentralized system because it gave them the opportunity to maintain their decentralized operating philosophy.

A European division of a large multinational manufacturer (case II) decided to implement a distributed data collection system. This system, which spans the continent, includes eleven minicomputers and a central machine. One of the major reasons they implemented a distributed system is because they felt that distributed data processing would fit well with the autonomous nature of their different divisions.

W. R. Grace Corporation (case JJ) is a very decentralized company managerially. In line with this the company gives major control of computer systems to their various divisions. The central department approves computer purchases, attempts some standardization to allow transfer of staff and programs and is responsible for conducting a yearly survey of all data processing operations. However, each division maintains responibility for all other aspects of its own computer system.

First National Citibank of New York (case FF) decentralized their computer operations in line with a corporate philosophy that managers should have complete control over all aspects of the process for which they are responsible. In 1970 Citibank reorganized its management structure in hopes of reducing operating costs brought on from the tremendous growth of the financial services sector. The bank broke up large functional organizations into product groups and gave line managers full responsibility for individual products. A manager's performance was measured by his unit's cost performance. However, in the midst of this move to decentralized management Citibank had maintained a central computer system. By 1974 the bank realized that a central processing system meant managers did not have control of the necessary resources to meet their responsibilities. In 1974 the company began a decentralization of its data processing function which continues today.

3.5 Significant Centralization Forces

3.5.1 Economies of Scale

The argument for economies of scale in computer use was a significant centralization force in the 1960's and in many cases it continues to be today. It is unimportant whether these economies do in fact exist. What is important is that many organizations continue to believe in and support the existence of economies of scale. This force is most apparent in arguments that first arose in 1972 between state and city governments and the Federal Bureau of Investigation.

An FBI regulation (case R) issued in 1972 required that any computer handling criminal histories "be dedicated to law enforcement purposes and be under the management control of a law enforcement agency." This would require that states maintain dedicated computer systems for law enforcement. State and city governments objected strongly to this regulation on the grounds that it would greatly increase their data processing costs to operate anything but a central system and that this would have serious fiscal impact.

An article in Computerworld in 1975 noted the trend in various states towards centralization of their data processing systems. Kentucky reported saving $2.4 million/year since consolidating their data processing onto one large machine. This consolidation was aimed at lowering costs and was achieved in spite of severe opposition from user agencies which maintained their own machines. Mississippi's Central Data processing Authority reported to have saved $500,000 annually since centralizing [21].

In 1975 the state of Arizona (case KK) consolidated from sixteen to six cpu's "to do something about excessive spending."

Acme Markets, Inc. (case LL), wished to reduce data processing costs which led them to centralize operations. Previously equipment was decentralized but the company felt that this approach led to no standardization of applications software and little control over data processing costs. According to the manager of DP operations they installed a remote batch network because

> We wanted to reduce the total costs at the remote locations and eliminate duplicating people at each location.

Selwyn conducted a study of 10,000 computers installed at firms in manufacturing industries (case MM) to determine whether or not the experience of users was that economies of scale did exist. He concludes "Users did operate computers as if there were significant economies of scale in their use." He used a complex model to estimate the computer capacities required by an arbitrary firm given the size of the firm. He then compared this estimate to the actual acquisition patterns of the firms in the study and determined that many users acquired computers much larger than those necessary to meet their data processing needs.

3.5.2 Management Control/Integration

Centralization's strongest point seems to be the potential that it offers for sharing and the tight management controls it can supply through standardization of data files, programming and documentation, and reporting. The following case studies showed this to be a significant force towards centralization of an organization's computer system.

Until 1975 law enforcement officials in Boston (case NN) were unable to do much about parking violations. Each of the nine district courts in the city handled these violations differently, which meant that some used manual systems to record violations while others used computer support. This made it impossible to relate violations in one district to those in another district. In order to accomodate sharing of information across the various district courts so that officials could begin to "crack down" on perpetual offenders, Boston implemented a central computer system. This system linked the separate courts to the police department and the Registry of Motor Vehicle's through a central computer in Boston City Hall.

Jones and Laughlin Steel Corporation (case OO) of Pittsburgh centralized their computers in particular to "bring centralized data base capability to the firm."

Burroughs Corporation (case PP) centralized the development and design of its internal systems in order to enforce standard reporting.

CONCLUSIONS

4.1 Summary of Conjecture and Results

We have examined over forty case studies of computer decentralization decisions and have tried to determine and catalogue the forces behind these decisions. A complete listing of the forces determined to be significant in these decisions is found in TABLE IV.

TABLE IV.

DECENTRALIZATION FORCES FOUND

Functional

Flexibility
Availability and Accessibility
Ability to Set Priorities
Ability to Regulate Response Time
Ability to Regulate Hardware and Software Upgrades
Avoidance of Overhead on Mainframe
Shorter Development Time Because Less Complexity
Privacy and Security Issues
Reliability

Economic

Low Entry Costs
Low Initial Investment
Fixed Cost of Own System
Lower Communication Costs
Smaller Investment Than Upgrading

Psychological

Bad Experiences With a Central System
Insures Greater User Acceptance
Fewer Political and Priority Conflicts
Philosophy of Organization

The conjecture is that there are significant forces in many organizations towards decentralization of the computer facility, that have been held in check until recently by economic and technological constraints. The economic constraint is clearly vanishing as hardware costs drop. The technological constraint is present but it may be overlooked in acquisition decisions, especially if these decisions are initiated at lower levels in the organization. The relaxation of these constraints seems to be releasing forces resulting in decentralization decisions at all levels in the organization. The significance of these forces may be judged by their ability to withstand trends in the computer industry. For example, we do not consider economies of scale a significant force towards centralization because the drop in hardware costs will continue and economies of scale are dependent on this trend in the computer industry. However, psychological forces leading towards decentralization decisions seem to be inherently independent of the computer industry and are therefore considered significant.

The results indicate that:

1. Hardware costs have dropped to the point that economies of scale arguments no longer influence decisions to the extent that they have in the past. Many organizations are obtaining dedicated computer systems and are even claiming substantial savings through their actions.

2. The major forces encouraging centralization of a computer system affect corporate management primarily and are industry dependent. These forces are (1) lingering faith in economies of scale and (2) the ability for sharing and management control in a central system. We conjecture that economies of scale arguments

are less significant as time passes. In addition as the technological problems of networking loosely coupled computers and distributing data bases are solved, the last force will become less significant.

3. The forces towards decentralization include many that involve function, i.e. better service of users' needs by the system. In addition there are psychological forces behind decentralization including increased user acceptance and ability to fit the system to the organization with minimal problems. The recent concern that "user-oriented" systems are developed seems to be a recognition of these psychological forces.

4. Decentralization decisions are made at low levels in the organization as well as at corporate levels. The drop in hardware costs enables operational managers to acquire and support a dedicated computer system.

5. Many decentralization decisions involve applications that would require upgrade of a mainframe if they were implemented on the central system.

4.2 Consequences

The results indicate that decentralization forces do exist in many organizations. The drop in hardware costs and the increasing sophistication of the minicomputer allows a manager to obtain a powerful, local computer for a relatively small investment. For these reasons, decentralization forces have become more visible.

The consequences of the existence of strong decentralization forces could include the disintegration of the organization's information system. Low entry costs allow decentralization decisions to be made by lower-level managers. While isolated instances of this decision would not be significant, a large number of these localized decisions could create chaos. First, incompatabilities among the computer systems of local units may prevent these these units from sharing data or programs. The current state of technology is the source of this problem. Networking of loosely coupled computers is not yet well understood. One hopes that technological advances within the next few years will alleviate the integration and sharing problems in decentralization. Second, a local system allows a department manager to "interpret" the data in his system in a number of ways. The computer system that the unit uses will provide some of this "intepretation" in the way it stores and manipulates data. Designers of application programs provide further "interpretation" of data through the algorithms they use in their programs. A lack of consistency throughout the organization in interpreting data may provide management control problems.

We do not feel that decentralization should be "outlawed" or even discouraged, because there are advantages to be enjoyed from decentralization. However corporate management should be aware of the current technological constraints. Compatability between machines can be assured if proper thought is given to equipment procurement.

4.3 Future Work

This thesis is an attempt to extend previous work done in the area of decentralization of an organizational computer system. The distinguishing feature of this thesis from previous work is that it explores decentralization decisions through numerous case studies, in an effort to show that there are forces towards decentralization that may in the future, cause these decisions to be made at lower and lower levels in the organization.

Section 4.2, which related the methods used in this research noted the limitations inherent in examining case studies obtained from computer community literature. The first limitation is that the forces that are revealed may or may not be the ones that actually were the cause of the decentralization decision. These cases are presented in the literature in a way that is highly dependent upon the perception of the manager relating the case and what that manager wishes to reveal about the decision. The second limitation is that certain categories of decisions are excluded from the literature. These cases may involve decisions made by lower level managers who wish to avoid publicity for political reasons, or who have no reason to publicly cite why, where and how they acquired a dedicated computer system. These cases are the most interesting and unfortunately the rarest in the literature.

We feel that future work is required in this area to extend and improve the work done here. This future work should employ an interview method to obtain case studies. Confidential conversations with managers of organizations unwilling to discuss their decentralization decisions publicly could yield more significant and viable results. In addition, this approach would allow more access to management decisions made at lower levels in the organization. Comprehensive exploration of acquisition patterns and the reasons for the acquisitions in only one organization would add to the understanding of decentralization decisions in organizations. Similarly, a better assessment of the future impact of these decisions on computer systems could be determined.

APPENDIX A

Code	Description of Case Study/Source	Section
A	Datascope Corporation, Source: "Firm's Figures Show Mini Use Justified," Computerworld, January 10, 1977	3.2.1
B	actuarial department of an unidentified insurance firm, Source: "Actuaries Say T/S Can't Compare to Dedicated Mini," Computerworld, February 2, 1976	3.2.2 3.2.4 3.3.3
C	unidentified engineering firm, Source: Burnett, Gerald, J., and Richard Nolan, "At Last Major Roles for Minicomputers," Harvard Business Review, May-June 1975	3.2.2 3.4.4
D	Lowe's Companies, Inc., Source: Acree, John, "Putting the Principle Into Practice," Data Systems, February, 1975	3.2.2
E	Ricardo Consulting Engineers, Source: "Mini Helps Control Engine Test Beds," Computerworld, May 23, 1977	3.2.2 3.2.4
F	Atlanta's First National Bank, Source: "Small Bank Division Sets Up Its Own Mini Computer," Computerworld, March 12, 1975	3.2.3
G	Deere and Company, Source: Vaughan, Frank, "Small Users' Needs Paramount Corporate DP Managers Warned," Computerworld, June 20, 1977	3.2.3
H	corporate division of unidentified service company, Source: Burnett, Gerald J., and Richard Nolan, "At Last Major Roles for Minicomputers," Harvard Business Review, May-June 1975	3.2.4 3.3.5
I	Office Canteens of Manhattan, Source: "Small System Helps Fast Food Firm Respond to Change," Computerworld, June 6, 1977	3.2.4
J	Chrysler Corporation, Source: "Distributed Mini Approach Protects Response Time," Computerworld, April 9, 1975	3.2.4
K	an unidentified commercial bank, Source: Confidential communication with a vendor	3.2.5 3.2.7 3.4.1

L	unidentified wholesale manufacturing firm, Source: Burnett, Gerald J., and Richard Nolan, "At Last Major Roles for Minicomputers," <u>Harvard Business Review</u>, May-June 1975	3.2.7
M	Retail Installment Loan Department of Wachovia Bank and Trust Company, Source: "Mini Dedicated to Preprocessing Increases Bank's Loan Capacity," <u>Computerworld</u>, January 31, 1977	3.2.6
N	Olinkraft, Inc. Mill Division, Source: "Mini Saves Time on Mainframe," <u>Computerworld</u>, July 30, 1975	3.2.6
O	unidentified railroad company, Source: Confidential communication with a vendor	3.2.6
P	Industrial Nucleonics, Inc., Source: Ward, Patrick, "User Finds Work Divided is Easily Conquered," <u>Computerworld</u>, January 8, 1975	3.2.6 3.4.1
Q	unidentified chemical plant division, Source: Confidential communication with a vendor	3.2.7
R	FBI Regulation, Sources: 1) French, Nancy, "States Blast NCIC Requirement for Dedicated Systems," <u>Computerworld</u>, July 30, 1975; 2) Lundell, E. Drake, Jr. "Cities Not Happy With FBI Data Bank Rules," <u>Computerworld</u>, January 12, 1972; 3) Smalheiser, Marvin "California DOJ Opposes Proposal for Dedicated Justice Systems," <u>Computerworld</u>, May 29, 1974	3.2.8 3.5.1
S	Central Congress for Privacy and Protection, Source: "Hiroshima Bomb Victims Fight Plan to Centralize Health Data," <u>Computerworld</u>, August 6, 1975	3.2.8
T	Arizona governor, Source: Ward, Patrick, "Centralization of Data Systems Continuing Despite Resistance," <u>Computerworld</u>, January 1, 1975	3.2.8
U	Georgia State Crime Lab, Source: "Crime Lab Decides Security the Motive As It Picks Mini to Watch Evidence," <u>Computerworld</u>, May 17, 1976	3.2.8
V	Lockwood-McDonald Hospital, Source: "Small In-House System Saves $12,000," <u>Computerworld</u>, June 25, 1975	3.2.8
X	Inter-Provincial Pipeline Company, Source: Speers, D. S., "Monitoring/Control By Distributed Computing" <u>Datamation</u>, July 1973	3.2.9 3.2.9

Y	ARPANET IMP System, Source: Schantz, R. E., "Protocols for Utilizing Redundant Processes in a Computer Network," Proceedings of the 5th Texas Conference on Computer Systems, October 1976	3.2.9
Z	Southern Bell Telephone and Telegraph, Source: Canning, Richard G., "Structures for Future Systems," EDP Analyzer, August 1974	3.2.9
AA	Boise City, Idaho, Source: DeGroff, William J., "Minicomputers: Boise's Approach to an Integrated Municipal Information System," Boise Center for Urban Research, Boise, Idaho, 1976	3.3 3.4.2
BB	large unidentified chemical plant, Source: Bothne, Ralph E., "Distributed Control Offers System Reliability and Low Initial Investment, Control Engineering, May 1977	3.3.2
CC	theoretical chemist at Berkeley, Source: Schaefer, Henry F., "Are Minicomputers Suitable for Large Scale Scientific Computation?," COMPCON, Fall 1975	3.3.3
DD	Lisner/Richelieu, Source: Surden, Esther, "Mini Saves Jewel Firm $120,000/Year," Computerworld, June 25, 1975	3.3.4
EE	unidentified corrugated container manufacturer, Source: Confidential communication with a vendor	3.3.4
FF	Citibank of New York, Sources 1) "Citibank Transaction Processing Environment: Management Guidelines for Automating Citibank's Financial Transaction Processing Base," release 2.0, March 1976; 2) Surden, Esther, "Debators Agree: Today's Revolution Focusing on User," Computerworld, June 13, 1977	3.4.1 3.4.4
GG	an unidentified major railroad, Source: Confidential communication with a vendor	3.4.2
HH	Data Tech Division of Penril Corporation, Source: "Service Bureau, Mini Split Manufacturer's Workload," Computerworld, June 13, 1977	3.4.3
II	European division of a large unidentified multi-national manufacturer, Source: Confidential communication with a vendor	3.4.4

JJ	W.R. Grace Corporation, Source: Deering, Allan B., "Centralization vs. Decentralization: The Grace Experience," presented at INFO 75, New York City, September 9, 1975	3.4.4
KK	State of Arizona, Source: "Arizona Consolidates From 16-6 cpu's 'to do something about excessive spending'," <u>Computerworld</u>, January 1, 1975	3.5.1
LL	Acme Markets, Inc., Source: Surden, Esther, "Firm Scraps Old System for Remote Batch Net," <u>Computerworld</u>, July 4, 1977	3.5.1
MM	Selwyn's study, Source: Selwyn, Lee L., "Economies of Scale in Computer Use: Initial Tests and Implications for the Computer Utility," MAC TR-68, M.I.T., 1970	3.5.1
NN	City of Boston, Source: "Boston Cracks Down on Chronic Parking Violators," <u>Computerworld</u>, January 8, 1975	3.5.2
OO	Jones and Laughlin Steel Corporation, Source: "The Centralization Alternative - Too Much Power - Too Hard to Handle," <u>Computerworld</u>, June 19, 1974	3.5.2
PP	Burroughs Corporation, Source: Rockart, John F. Leventer, Joav and Christine Bullen, "Centralization vs. Decentralization of Information Systems: A Preliminary Model for Decision Making," draft of a Center for Information Systems Research working paper, M.I.T. Sloan School of Management, 1976	3.5.2

REFERENCES

[1] Alexander, M. J., Information Systems Analysis, Science Research Associates, 1974, p.418

[2] Ibid, p. 98

[3] Withington, Frederic, The Real Computer: Its Influences, Uses and Effects, Addison Wesley, 1969, p.129

[4] Kriebel, Charles, "The Future MIS," Infosystems, June 1972

[5] Rockart, John F., Leventer, Joav and Christine Bullen, "Centralization vs. Decentralization of Information Systems: A Preliminary Model for Decision-Making," a draft of a working paper from the Center for Information Systems Research, M.I.T. Sloan School of Management, 1976

[6] Glaser, George, "The Centralization vs. Decentralization Issue: Arguments, Alternatives and Guidelines," Proceedings of the 1970 Fall Joint Computer Conference, Fall 1970

[7] Leavitt, Harold J., and Thomas L. Whisler, "Management in the 1980's," Harvard Business Review, 1958

[8] Rockart, John and Joav Leventer, "Centralization vs. Decentralization of Information Systems: An Annotated Bibliography," Center for Information Systems Research working paper, M.I.T. Sloan School of Management, 1976

[9] Cotton, Ira W., "Microeconomics and the Market for Computer Services," Computing Surveys, June 1975

[10] Knight, Kenneth E., "A Study of Technological Innovation-The Evolution of Digital Computers," Ph.d. dissertation, Carnegie Institute of Technology, November 1963

[11] Knight, Kenneth E., "Evolving Computer Performance," Datamation, January 1968

[12] Solomon, Martin B., "Economies of Scale and the IBM System/360," Communications of the ACM, June 1966

[13] Littrel, R. Fred., "Economies of Scale in the IBM 360 and 370," Datamation, March 1974

[14] Selwyn, Lee L., "Economies of Scale in Computer Use: Initial Tests and Implications for the Computer Utility," MAC TR-68, M.I.T., 1970

[15] Longbottom, R., "Software Reliability and Serviceability," British Civil Service Department, Central Computer Agency, p.14

[16] Bothne, Ralph E., "Distributed Control Offers System Reliability and Low Initial Investment," Control Engineering, May 1977

[17] Reynolds, Carl, "Issues in Centralization," Datamation, March 1977

[18] Datapro Research on Minicomputers, volumes 1 and 2, Datapro Research Corporation, 1976

[19] Awad, Elias, Business Data Processing, Prentice-Hall, Inc., 1971

[20] Rue, Joseph, "Power, Politics and DP," Datamation, December 1976

[21] Ward, Patrick, "Centralization of Data Systems Continuing Despite Resistance," Computerworld, May 17, 1976

[22] Wagner, Frank V., "Is Decentralization Inevitable," Datamation, November 1976

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