THE EFFECTS

OF

ADVANCES IN DATA PROCESSING AND COMMUNICATIONS

ON

THE PATTERN OF INFORMATION-HANDLING-BUSINESS ACTIVITY

by

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ABSTRACT

Title of the Thesis: THE EFFECTS OF ADVANCES IN DATA PROCESSING AND COMMUNICATIONS ON THE PATTERN OF INFORMATION-HANDLING BUSINESS ACTIVITY.

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SUBMITTED TO THE DEPARTMENT OF CITY AND REGIONAL PLANNING ON MAY 25, 1959 IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF CITY PLANNING.

The major objectives of the study were:

1. to determine whether the use of electronic data processing equipment and techniques by businesses would cause the centralization of information handling work,
2. to measure the extent to which centralization of information handling work may occur, and
3. to estimate the pattern and its consequences that may result from the general use of automatic data processing in conjunction with the use of communications to transport information to central units for processing.

The principal finding was that the use of automatic data processing techniques will stimulate the centralization of information handling work and that virtually every type of business will be affected. The impact is broad because every type of business performs some data processing (accounting, billing, etc.), and in order to utilize effectively highly automatic techniques, a large financial investment in equipment is necessary and which is feasible only when large amounts of information are processed.

Present trends and predictions of the future indicate that there will be a pooling of data processing work by firms for the purpose of taking advantage of highly automatic techniques. The use of low cost communications for transmitting information to central data processing units makes this arrangement feasible from an economic viewpoint.

Utilizing low cost communications to achieve centralized automatic data processing will stimulate the dispersal of activities that provide information handling services to places where their convenience to customers is maximized. Also, the locations of central processing units will be dispersed about depending upon where is the least cost location for communications service.

The planning implications of these developments are in terms of the increase in productivity and the redistribution of clerical workers. These factors alter the location requirements of firms and demonstrate the need for large area coordination for plan implementation through the use of the rate structure for communications services.

Thesis Supervisor:. . . . .

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INTRODUCTION AND OBJECTIVES

Scope of Study

This study is concerned with only a small segment of the entire field of automation. The segment to be investigated and discussed below is the automation of information handling and processing. The study includes an investigation of communications insofar as they are used for the transportation of information to be processed by automatic data processing equipment.

This study is concerned primarily with exploring this narrow segment of the field of automation in its own terms. The study does not specifically nor primarily extend to evaluate effects of the automation of information handling and processing as they apply to a particular firm or a particular type of industry. Rather it is concerned with investigating the automation sector per se to acquire a comprehensive understanding of the forces that are implicit in it that may act to influence the pattern of information-handling-business activity.

Since the availability and flow of up-to-date and accurate information is the life of all business and the function of some, it is expected that the automation of information handling will affect business greatly and that the planner will want to know how automation will affect those firms or those parts of firms that are engaged primarily in information handling.

Purpose of the Study

> "Now! Now!" cried the Queen. "Faster! Faster!" And they went so fast that at last they seemed to skim through the air, hardly touching the ground with their feet, till suddenly, just as Alice was getting quite exhausted, they stopped, and she found herself sitting on the ground, breathless and giddy.
>
> The Queen propped her up against a tree, and said kindly, "You may rest a little, now."
>
> Alice looked round her in great surprise. "Why, I do believe we've been under this tree the whole time! Everything's just as it was!"
>
> "Of course it is," said the Queen. "What would you have it?"
>
> "Well, in our country," said Alice, still panting a little, "you'd generally get to somewhere else -- if you ran very fast for a long time as we've been doing."
>
> "A slow sort of country." said the Queen. "Now, here, you see, it takes all the running you can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that."[1]

So today, it is necessary to produce at a very rapid pace merely to keep up. In order to get ahead, it is necessary to produce at an even faster rate.

The purpose of this study is to take time out from produ-

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[1]L. Carroll, Through the Looking-Glass, New York, MacMillan, 1932, pp. 41-42.

cing merely to keep up and to get ahead by looking into the future, to acquire an understanding and knowledge of the possible effect of advances in data processing and communications on the pattern of information handling business activity.

One might speculate about the value of prior knowledge in influencing future events. For example, could knowledge of the impact of the automobile on cities back in the first decade of this century have enabled cities to avoid completely or at least reduce the severity of the problems they face today?

It is clear that prior knowledge of an event is quite a distinct consideration from causing or preventing an event from happening. In order for prior knowledge to affect a future event, it must stimulate action directed towards influencing or guiding the forces that contribute to the occurrence of the predicted event.

This study is concerned primarily with acquiring prior knowledge of the effect of advances in communications and data processing on the distribution of information handling business activity. The study is based upon the assumption that understanding or knowledge is a prerequisite to intelligent and meaningful action.

Timeliness of the Study

The timeliness and importance of this study lie in the dramatic increase over the recent past in both clerical employment and the application of electronic data processing equipment[2] to clerical work[3] and in the field of business control.[4] According to E. L. Van Deusen,

> . . . the volume of paper work has grown much faster than either the U.S. economy or the hourly efficiency of those who do the paper work. Clerical workers have therefore suffered a relative loss of efficiency in terms of their ability to help others produce wealth. In order to keep

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[2]In this study, the terms "data processing equipment," "data processing unit," and "computers" are used synonymously. Computers have been variously defined as an electronic device that is capable of performing mathematical and logical operations entirely within itself and which receives information into the system and after operating on it delivers information out. A computer must not be thought of as merely the arithmetic unit with its logical capabilities, rather, a computer is a series of machines which operate together for the purpose of performing a particular task.

[3]Perhaps the most outstanding application of electronic data processing is to accounting, bookkeeping, billing, etc. See: M. Pyke, Automation: Its Purpose and Future, London, Hutchinson's Scientific and Technical Publications, 1956, and R. W. Fairbanks, "Electronics in the Modern Office," Harvard Business Review, XXX (Sept.-Oct. 1952) 83-98. Manufacturers of data processing equipment issue pamphlets illustrating in some detail specific applications. Almost no business is unaffected by the impact of this equipment.

[4]Lagging presently somewhat behind the application to clerical work is the application of electronics to control. This includes physical control over the actual equipment used in production as well as the control of inventory, sales, purchases, orders, labor, maintenance, depreciation, etc. For a discussion of the application of production and administrative control through electronics of an oil refinery, see: G. G. Gallagher and R. A. Robinson, "Trends in Process Automation," Instruments and Automation, 29 (February 1956) 294-298, and L. Ridenour, "The Role of the Computer," Scientific American, 186 (September 1952) 116-130. For additional information see: A. Glenn, "Push Button Controls," Barron's, 32 (March 31, 1952) 15-16; R. S. Rice, "Technology Is Ready for the Factory of the Future," Factory Management and Maintenance, 110-4 (April 1952) 85-109; "The Brain Builders," Time, 65 (March 28, 1955) 81-86; G. S. Brown and D. P. Campbell, "Control Systems," Scientific American, 187 (September 1952) 56-64; "Can Control Devices Solve Common Problems Facing Industry and Business?" Automatic Control, 2 (May 1955) 14-17; "Automation: Special Report,"

> up with all the paper, the clerical work force, in a little over 15 years [1940-1955] has almost doubled in size. There are now more clerical workers in the U.S. than there are farmers, and there are two-thirds as many clerical workers as factory workers. One dollar in every eight being spent on U.S. goods and services is now being paid to men and women who, in their daily work, produce nothing more intrinsically useful than marks on a piece of paper.[5]

And according to John Diebold,

> Although we have developed some extraordinary machines for handling information, between 1920 and 1950 there was a fifty three percent increase in the number of factory workers as against a one hundred fifty percent increase in the number of office workers.[6]

The rate at which more and more automatic data processing techniques are being used by business is indicated by the significant increase in the sales of electronic data processing equipment. In 1952, _Business Week_ magazine noted that ". . . since 1939 sales of tabulating and accounting machinery have tripled [and that] . . . they could well triple again in the next ten to fifteen years."[7] According to H. Solo,[8] in 1956, the U.S. automatic data processing capacity was just about

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Business Week, (October 1, 1955) 75-102; "The Computer Age," _Business Week_, (April 7, 1956) 52-68; M. G. Meldon, "What Computers Can Do For You," _Factory Management and Maintenance_, 114 (February 1956) 98-105.

[5]E. L. Van Deusen, "The Coming Victory Over Paper," _Fortune_, 52 (October 1955) 130-132.

[6]J. Diebold, _Automation; The Advent of the Automatic Factory_, New York, Van Nostrand, 1952, p. 91.

[7]_Business Week_, (August 2, 1952) 88-90.

[8]"Automation; News Behind the Noise," _Fortune_, 53 (April 1956) pp. 150-155.

doubling itself every two years. The U.S. Department of Commerce[9] notes that the sales of Electronic Computing and Associated Information Processing Equipment for 1955, 1956, and 1957 respectively were $46,984,000; $93,557,000; and $145,113,000. Remington Rand[10] estimates the national sales for digital computers only for 1954, 1955, 1956, 1957, and 1958 respectively at $10,000,000; $22,000,000; $70,000,000; $150,000,000; and $250,000,000. According to the Stanford Research Institute,[11] ". . . factory sales of data processing equipment rose from zero in 1940 to $25,000,000 in 1953 and are expected to reach $500,000,000 in 1960." And finally, W. Leontief[12] notes that the sales of recording and control instruments have risen and will rise far faster than U.S. expenditures for plant and equipment.

The present applications of automatic data processing techniques are to reduce labor costs. Most common are applications to duties that are now being performed manually. At that, there is a great deal of room for wider application. In 1955 IBM estimated that only about five percent of office work

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[9] Bulletin Series M 35 R, 05 and 07.

[10] Remington Rand Univac, Division of Sperry Rand Corporation is referred to here and throughout the entire study as Remington Rand.

[11] R. Bendiner, "The Age of the Thinking Robot, and What It Will Mean To Us," The Reporter, 12-7 (April 7, 1955) 12-18.

[12] "Machines and Men," Scientific American, 187 (September 1952) 150-160.

was mechanized and felt that at least 35 percent of office work could be mechanized if not more. While this may represent a considerable expansion in the use of automatic techniques, the most promising frontier is in the areas of work that have never been done before because of the time and expense involved. With the aid of electronic data processing equipment it would be economical to undertake some new work. One example of this is the use of automatic data processing in making market projections.[13] In this regard, C. K. Rieger, Vice President and General Sales Manager of G.E.'s major appliance division is quoted as saying, ". . . the use of computers in the area of sales analysis will prove to be one of the most powerful competitive tools ever developed."[14]

The ultimate use of automatic data processing equipment is in the control of processes, both administrative and production processes. In this regard Time magazine noted that ". . . businessmen envision the day when [data processing units] will be used not only for paperwork problems, but to operate factories and to run production lines where a process can be reduced to repetitive preset systems. Swiftly and obediently,

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[13] In this area of business research and economics, much work is being done on the preparation and use of models; see: M. L. Hurni, "Decision Making in the Age of Automation," Harvard Business Review, 33 (September-October 1955) 49-58; the Cowles Commission for Research in Economics; and the Regional Science Association.

[14] J. A. Higgins and J. S. Gilckauf, "Electronics Down to Earth," Harvard Business Review, 32 (March-April 1954) 97-104.

the big robot will start and stop production lines, supervise all the machines, correct faulty workmanship, inspect the finished product, package it, and ship it to the consumer."[15]

Contributing to the timeliness of this study is the increased use of communications by business for the purpose of transporting information to be used directly in data processing equipment. Both the telephone and telegraph companies have been leasing for some time communications lines and equipment for the purpose of transmitting information to be recorded directly upon punched cards and paper tape. Many firms today are actually utilizing communications for this purpose.[16]

It is clear that there is a definite trend on the part of business to take advantage of available developments in communications and data processing. It is clear also that the extent to which these techniques are being used at present is

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[15]"The Brain Builders," Time, 65 (March 28, 1955) 81-86.

[16]Sylvania Electric Products Company, Ford Motor Company, General Electric, Western Electric, American and several airlines companies, John Hancock Insurance Company, and United States Steel are a few contemporary examples. For additional information regarding the use of communications to provide information for processing at a central data processing unit, see: M. M. Koontz, "Supplementing Electronic Equipment With a Modern Communications System," Computers and Automation, 6-4 (April 1957) 12-17; R. W. Baridon, "The Communication of Data," A New Approach to Office Mechanization, New York, American Management Association, 1954, pp.53-62; L. C. Guest, "Administrative Automation At Sylvania: A Case Study," Administrative Automation Through IDP and EDP, Office Management Series, No. 144, New York, American Management Association, 1956, pp. 28-72; "Statement of Don G. Mitchell," Automation and Technological Change, Hearings Before the Subcommittee on Economic Stabilization of the Joint Committee on the Economic Report, 84th Congress, 1st Session, October 1955, Washington, GPO, 1955, pp. 169-196.

but a small fraction of the extent to which they will ultimately be used. From the planner's viewpoint, it is desirable to know now what effect these developments may have on the pattern of information-handling-business activity. With this knowledge he will be better prepared to make long range recommendations for orderly land use and economic development.

Objectives of the Study

The study seeks to verify the hypothesis that extensive use of automatic data processing equipment and automatic data processing techniques by business will cause centralization of information handling work[17] that formerly was performed at several remote locations. The basis for this hypothesis lies in the following:

1. The reported economies of scale that can be achieved by utilizing large, fast equipment to process large volumes of data vis a vis smaller equipment with lower capacity.

2. The apparent necessity of processing large volumes of data to make economical the use of special purpose equipment and programs that are used to perform specific jobs most effectively.

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[17] Several writers have advanced this view. For example, see: C. C. Hurd, "The Factory of the Future: Will Centralized Control be Possible?" *Keeping Pace With Automation,* Special Report, No. 7, New York, American Management Association, 1956, p. 101, wherein it is noted that the success of business will depend upon its ability to cope with the fluctuations of the market. Hurd suggests that centralized control is the only means by which business can respond quickly and effectively to fluctuations and that centralized control implies a single large data processor used to coordinate the various aspects of business.

3. The desirability and necessity of establishing feed back relationships for the purpose of integrating, optimizing, and controling the various aspects of business.

The specific objectives of the study are three-fold. First, it seeks to determine whether the use of electronic data processing techniques by business will cause centralization of information handling work. Second, it seeks to measure the extent to which centralization may occur. And third, it seeks to estimate the pattern and its consequences that may result from the general use of automatic data processing in conjunction with communications.

Methods and Procedures

To determine the centralization effect of the use of automatic data processing equipment, a relationship is sought between the unit cost of data processing and the volume of data processed in a given amount of time. This relationship is used to measure the economic advantages of centralization based upon the assumption that users of the equipment will try to minimize the unit cost of data processing. The unit cost-volume relationship is used to show that economically it is advantageous to centralize, and it is expected that the user will choose between locating the data processing center and the information using-and-generating activities together or establishing a channel of communication between them so that they act as a unit. It assumes that the savings in data processing costs achieved through centralization can be applied to the relocation of business activities or the establishing of communications channels.

In determining the resources available for centralization, changes in labor, material, transportation, and operating inputs are evaluated. However, some data relating to changes in labor, materials, and some operating inputs was not available. To weigh the importance of these inputs, it was assumed that present trends could be extrapolated -- that the same relative change in these inputs resulting from the automation of information handling would occur in the future. To determine the unit cost-volume function, only the inputs for equipment (a portion of the operating inputs) were used.

For interpreting the findings of the correlation of the unit cost-volume function with the changes in transportation inputs required for centralization, the above trend information and the less tangible advantages and disadvantages of centralizing were used as a background. By this means, many factors were brought together for the purpose of arriving at the conclusions to the above objectives.

Summary of Findings

The study shows that there are important advantages to centralizing data processing work at the site of a single large data processing unit. It is expected that central data processing units will be established to serve several local businesses. Each central unit could serve the data processing needs of over one hundred firms. Other central data processing units would be established to serve a large firm operating on a national or regional basis. The land use significance of centralization is that of relocating clerical jobs from several locations to a single site.

One of the most important factors influencing the location of a central data processing unit is the minimization of the cost of the communications used to supply the unit with information for processing. If a data processing unit was set up to serve only the business in the Boston CBD, the least cost location for communications might seem to be in the CBD itself. However, because the present rate structure for communications channels provides lower rates per airline mile for intercity communications than for intracity service, the least cost location would be in Cambridge, in the Boston and Maine railroad yards. If the zone method of charging is established, wherein the same total fee is extracted for communications service between any two points in the same zome, any site within the zone would be equally suitable for minimizing transportation costs. The communications companies are proposing that each state be made a single zone. In that case, theoretically, a data processing unit serving the Boston CBD would find any site in the State of Massachusetts equally suitable for minimizing communications costs. Clearly the rate structure will be an important means of controlling the pattern of information handling and processing activities.

Whatever method is used for determining communications costs, the least cost location for data processing units serving firms or branches in a number of cities throughout the United States probably would not be located in the heart of a CBD. Rather, because of the relative proportion of built up to undeveloped area, there is a high probability that the least cost location would be outside of a built up area. Hence, there does not seem to be any important specific advantage for the location of a data processing unit in a CBD unless the rate structure or some other locational factor makes a central location desirable. A data processing center could afford a central location if it was suitable from other points of view. Even at very expensive rents, the rent as a proportion of the total cost of operation would be less than one or two percent. On the other hand, the cost of communications could amount to considerably more than rent and hence, is an important locational factor.

The automation of information handling and processing and the use of communications to centralize this activity stimulate also an overall decentralization. While information handling and processing work may be centralized at a single data processing unit, it does not mean that the many units required to serve a single metropolitan area would be located in a single district. Rather there is high probability that they will be scattered about -- their specific location determined by the location of their clients.

There may be also a decentralization of the activities that the unit serves, expecially the data collecting and recording activities. With centralized data processing and the use of communications it will be possible to locate the activities that collect the information, such as bank tellers, at almost any location that has a demand for them and yet maintain an integrated operation.

The nature of the central automatic data processing unit is such as not to be much of a problem land use. The unit will have relatively few workers for its value and production and it will not require a great deal of floor space. Perhaps the only problem will be that of access and parking for its employees and visitors.

A secondary but very important consideration related to the main issue of the study is the considerable increase in clerical worker productivity resulting from the automation of information handling tasks. This will mean a reduction in the clerical labor force if the increase in productivity is not accompanied by economic expansion or an increase of information handling work.

Partially offsetting a reduction in the need for clerical labor, is the need for more skilled and highly trained personnel for the operation of the automatic data processing units. As a result of automation, the labor linkage of information handling activities will change from many clerical workers to fewer more highly trained personnel. This is an especially important factor for CBD's since, in Boston at least, almost 40% of the employment is clerical labor and since many firms locate in the CBD to tap the clerical labor force that is there.

Thus, the impact of the automation of information handling and processing will not create problem land uses. This is especially true, at least initially, of the central unit itself. The major problems it may cause relate primarily to those areas where information handling and processing are clustered at present, i.e., in the CBD. The problems of particular interest are those of increased productivity of clerical workers and the changing locational requirements of information handling and processing activities and activities linked closely thereto.

Section II

METHODOLOGY AND ASSUMPTIONS

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Outline of Procedure

The evaluation of the effect of the concomitant use of electronic data processing and communications in terms of the extent to which centralization of information handling work may occur, i.e., the relocation of clerical jobs, requires dealing with factors that can be handled mathematically as well as with factors that cannot reasonably be submitted to mathematical analysis. The basic approach used was first to subject some considerations to mathematical analysis and then evaluate the findings in the light of the other factors that could not as such be considered directly in the mathematical analysis.

Because of the reluctance of businesses to disclose the changes in their labor, material, and some operating inputs resulting from the automation of information handling, this data was not readily available. Because of the lack of this data, the study had to be conducted in two parts. The first part is a mathematical analysis of the factors for which data was available. This portion of the analysis considers the cost and capacity of automatic data processing equipment and the cost of communications facilities. The second part is a more general analysis, a trend analysis of the factors for which only a little data could be secured. The factors in this portion of the analysis are the changes in labor, material, and operating inputs resulting from automation of information handling, and the less tangible advantages and disadvantages of automating this activity.

The first part of the analysis consists of deriving a unit cost-volume relationship for the whole field of automatic data processing. This is achieved by analyzing several data processing units differing widely in their selling price and in the volume of data they can process in a given amount of time. The relationship is intended to be representative of the unit costs of data processing that would apply in the long run as users optimize data processing procedures and minimize costs.

Two methods are used to determine this relationship. Both methods involve the correlation of the monthly lease price of the data processing unit at which it can be rented from the manufacturer with its capacity to process data. In the first method, a specific problem was designed to utilize the three basic operations of a data processing unit, i.e., making an arithmetic addition, making a multiplication, and obtaining information from storage or memory. By correlating the lease price with the time required for each data processing unit to complete the problem, the unit cost for processing a range of volumes in a given amount of time was determined.

The second method makes use of the information published on the rated capacities of various data processing units to determine how much data each unit could process in a single month. By correlating the monthly lease price of the unit with the number of additions the unit could theoretically perform in a single month based upon the time necessary to perform a single addition, the unit cost (the cost per addition) was determined.

Once the unit cost-volume relationship was determined, it was correlated with the cost of communications to determine the extent to which communications could assist in centralizing information processing activities. The correlation is based upon the assumption that a portion of the savings that could be achieved by increasing volume, i.e., centralizing data processing work, could be applied to transporting information to the central unit for the purpose of increasing volume. The cost-distance relationship for communications was determined based upon the current rate structure. By this means the extent to which communications could be used to obtain economically information from remote places for processing at a central data processing unit was determined.

The second part of the analysis, the trend analysis, consists of examining some instances where automation of information processing has occurred to determine in general how the inputs for labor, materials, and operations changed subsequent to the installation of the automatic data processing equipment.

Since this information was not generally available, what information was obtained regarding the changes was used to secure a broad rather than a detailed understanding of the effect of automation on these inputs.

This information along with information regarding the less tangible advantages and disadvantages of automating information handling and processing was used to temper the findings of the mathematical analysis which could not take these considerations into account directly.

By this means, many of the aspects of the subject of automation of information handling and processing were considered and the forces acting to centralize information handling work at sites of large data processing units were determined.

Assumptions

In undertaking the study, several assumptions were made both with respect to the user of automatic data processing techniques and with respect to data processing equipment for the purpose of making cost comparisons. The basic assumption of the study, which is tested and verified later, is that the unit cost of processing data is lower when processed on high capacity than it is on low capacity equipment assuming full utilization of both machines. It is this phenomenon that provides the basis for assuming that users will seek to minimize data processing costs by using high capacity equipment and increase the volume of data processing performed.

Implicit in this are the assumptions that, in the long run, the user will expand the capacity of the data processing unit and will adapt as much information processing work to the automatic equipment as is desirable or possible. By so doing, the user can reduce the unit cost.[18]

It is assumed that a user who has automated almost all of the work he performs locally and who desires to increase volume will be faced with choosing among the following alternatives. First, he may increase volume and apply the anticipated saving to reduce the apparent distance between the data processing

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[18]Under the assumption that the primary motive of the user is to reduce the unit cost of data processing, it is expected that the user will increase the volume when the unit cost of data processing can be reduced thereby. In considering only the cost of the equipment, the initial costs of the installation, preparing and de-bugging of the programs (which are often sizable) are not considered directly. The amortization of this cost is a part of the operating expenses which influence the economics of increasing capacity. From a long range viewpoint, it is expected that users will increase their capacity and achieve economies of scale. However, when the increase in volume is small and does not raise the total volume to exceed the capacity of the equipment, no expenditure or only a small one is made for the installation of additional equipment. There is a point where the capacity of the data processing equipment would be exceeded by even a small increase in volume. If the capacity of the equipment is to be increased to handle this additional amount of data, the installation costs of new equipment would have to be incurred. Since it is impossible in many cases to increase the capacity of the equipment just enough to handle a small increase in volume, there is likely to be sufficient excess capacity in the new plant to increase the unit cost rather than to reduce it. However, as in the insurance industry, a firm experiencing growth, or seeing the opportunities to utilize the excess capacity in the future for other work now being performed manually, would suffer the initial increase in unit cost to secure savings in the future. Most firms today who purchase computers do so with this in mind.

unit and the information generating, using, or analyzing activities by physically relocating activities so that they are close together. Second, he may increase the volume at the central unit by setting up a communications system that may be used to transport information to the central unit for processing from remote places and if necessary, back again after processing. In this study, the use of communications is explored most thoroughly though the alternative of relocating activities is considered to be important in connection with activities that are closely linked to the data processing unit.

In regard to constructing a unit cost-volume relationship for the entire field of automatic data processing, several very broad assumptions had to be made. The basic assumption in this regard is that it is possible to construct such a relationship. While experts in the data processing field will admit that in general there is cost-volume relationship for the whole field of automatic data processing,[19] they say that it is very difficult to make completely valid comparisons between the unit costs of processing data on a group of different data processing units. They say, and it is true, that each data processing unit is so unique that it is difficult to find common aspects among any two without trying to find a basis

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[19]See, J. W. Forrester, "Computer Applications to Management Problems," Strengthening Management for the New Technology, General Management Series, No. 178, New York, American Management Association, 1955, p. 24.

for comparison for many more than two.[20] However, many of the differences among data processing units vary consistently with the size of the unit. This is particularly true of the flex-

[20]The following differences in computer set-ups make difficult unit cost comparisons between them: (1) Methods and costs of programming computers to do work differ. The basic difference is whether it is internally programmed through the memory or whether it is programmed externally by a wiring board; (2) The technique of programming, the number of program steps for a certain problem, etc. differ from computer to computer; (3) The best method of introducing the information into the computer differs for a number of computers according to the results desired and the type of problem; (4) The speed at which information can be introduced into the computer and the method of handling the information before the calculation is made differs; (5) The elapsed time for the calculator to gain access to information varies greatly according to the physical make-up of the computer; (6) The routing of the information inside the computer differs; (7) The basic forte of the computers differ, some are most suited to handling large amounts of data while others are best suited to handling small amounts of data while performing large numbers of calculations; (8) The number, function, and extent of the components that are set-up with the arithmetic unit differ widely; (9) The extent to which the computer uses memory also differs. Internally programmed computers utilize memory for every step of the program while externally programmed computers need use memory less often; (10) The internal number system used by computers varies and the whole logic that the computer uses differs from computer to computer; (11) It is practically impossible to set up, bases upon a specific task, a balanced arrangement for several computers so that each component, i.e., input, output, and arithmetic unit, is producing at its rated capacity. Each computer has its particular forte. Thus, when comparing them some components are producing at their rated capacity while others are either not producing at all or below their maximum capacity and the cost of these are included in the unit cost of processing because it is difficult to determine the cost of the excess capacity.

However, many of these differences work in favor of making an economic analysis as expressed in equasion [15]. Generally speaking, a large more flexible computer has greater excess capacity than does a smaller computer for any given problem. Hence, the parameters of equasion [15] derived by the methods discussed below would tend to be conservative statements of the economies of scale since the unit costs of the large computers are overstated.

ibility features and the amount of excess capacity remaining on large units when compared with smaller units on the basis used in method one and two.

While constructing a unit cost-volume relationship via the methods outlined above, every effort has been exerted to make sure that the cost of equipment used in the analysis did not include those portions of the data processing unit that were not called into use to perform the work and that the computation of the time necessary to do the work was based upon programs that would utilize the equipment at about the same level of efficiency. However, it is possible that this was not achieved exactly in every case because of difficulties in apportioning costs of some elements of the larger units. Hence, it was assumed that any error would cause the unit cost of processing on large equipment to be overstated.

In method two, the basic assumption was that the speed with which the data processing unit could perform a single addition is a fairly good indicator of how much work a unit could do. In a certain sense this is a reasonable assumption, but the larger equipment has more flexibility than would be indicated by merely examining the add speed. Since the cost of this built in flexibility is included in the cost of making an addition but which is not actually being used, the computed cost of performing an addition would be overstated. Hence, the derived unit cost-volume function will be conservative.

<u>The Basic Framework</u>

Utilizing an automatic data processing unit will require making some inputs for labor [b'], material [h'], transportation [t'], and operations [e']. The total cost of data processing [C_p'] would be the sum of the total inputs. This may be expressed mathematically as

$$C_p' = b' + h' + t' + e' \qquad [1]$$

If the volume of data processing is expressed in terms of the number of operations [V] performed by the data processing unit, the unit cost of data processing [C_p] is equal to the total cost of processing divided by the number of operations performed, viz.,

$$C_p = \frac{C_p'}{V} = \frac{b' + h' + t' + e'}{V} \qquad [2]$$

or

$$C_p = b + h + t + e \qquad [3]$$

where [b], [h], [t], and [e] respectively are the labor, material, transportation, and operating inputs per operation performed by the unit. Operations may be defined as digits input as in method one, arithmetic additions as in method two, or insurance policies, transactions, etc. Changes in inputs would result in a change in the unit cost of data processing. Changes could result from any of several factors, i.e., changes in the price of labor, reduction of material costs due to reorganization of the paper work, changes in procedures, achieving economies of scale, etc. This study is interested primarily in the changes of inputs as a result of increasing volume at a single data processing unit and achieving economies of scale; that is, the change in the unit cost of data processing [ΔC_p] as the volume of data processing [V] increases a small amount [ΔV] to a new total volume [$V+\Delta V$].

Any change in the unit cost [ΔC_p] would be the difference between the unit cost of performing [V] volume of operations minus the unit cost of performing [$V+\Delta V$] volumes of operations which could be expressed as

$$\Delta C_p = C_p(V) - C_p(V+\Delta V). \qquad [4]$$

This could be written more simply as the sum of the net changes in labor, material, transportation, and operating inputs, that is,

$$\Delta C_p = \Delta b + \Delta h + \Delta t + \Delta e \qquad [5]$$

where

$$\Delta b = b_{(V)} - b_{(V+\Delta V)}$$
$$\Delta h = h_{(V)} - h_{(V+\Delta V)}$$
$$\Delta t = t_{(V)} - t_{(V+\Delta V)}$$
$$\Delta e = e_{(V)} - e_{(V+\Delta V)}.$$

If the unit cost of data processing will decrease as a result of increasing volume, then some percentage [k], expressed as a decimal, of the anticipated saving can be used to increase volume. That is, some proportion of the anticipated saving can be applied to relocating work to the site of the data processing unit (or vice versa) or applied to securing communications facilities for transporting information to the

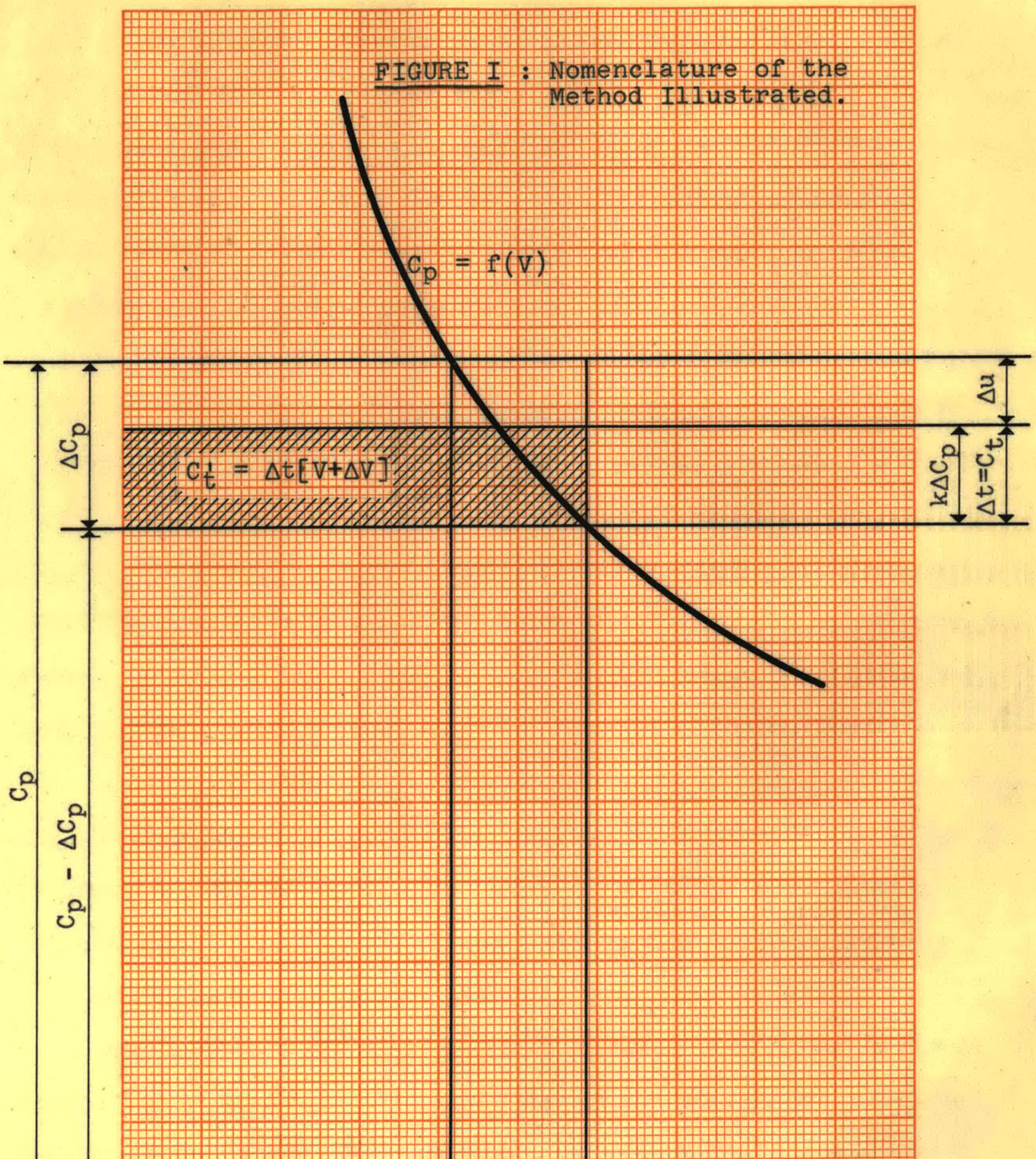

FIGURE I : Nomenclature of the Method Illustrated.

central unit for processing.

The additional resources available for transportation [Δt] representing an increase in transportation inputs would be

$$\Delta t = k \cdot \Delta C_p . \qquad [6]$$

When the value of [k] is unequal to unity, either more of less than the amount saved is being applied to transportation. If the difference between the amount saved and the amount applied to transportation is designated as [Δu], then

$$\Delta C_p = \Delta t + \Delta u \qquad [7]$$

where the value of [Δu] is either positive or negative depending upon whether more or less than the saving is used. When [Δu] is positive, there is a net reduction in processing costs which could be applied to lowering the cost to customers, increasing profit, etc. When [Δu] is negative and the value of [k] is greater than unity, it represents substitutions of non-data-processing inputs.

The total number of dollars available for purchasing communications facilities [C_t'], illustrated graphically in Figure I, would be the resources available per unit processed times the number of units [$V+\Delta V$] which may be written as

$$C_t' = \Delta t[V+\Delta V]. \qquad [8]$$

Consider now the unit cost of data processing as a function of volume. While the exact function is derived subsequently, the general relationship can be stated as "unit cost as a function of volume" and can be written as

$$C_p = f(V). \qquad [9]$$

Using the relationship set up in equation [4] and the equality established in equation [9], the change in unit cost of processing resulting from any increase in volume [ΔV] would be

$$\Delta C_p = f(V) - f(V+\Delta V). \qquad [10]$$

For very small values of [ΔV], a fundamental relationship in the Calculus, the derivative of a function, may be used to simplify equation [10]. The derivative of equation [9] is

$$F(V) = \frac{f(V+\Delta V) - f(V)}{\Delta V} . \qquad [11]$$

By multiplying equation [10] by $\frac{\Delta V}{\Delta V}$, its value would not be changed because this would be tantamount to multiplying it by unity. By doing this, equation [10] may be rewritten as

$$\Delta C_p = -F(V)\cdot\Delta V . \qquad [12]$$

Functions describing the additional resources available for transportation as volume increases may be derived by substituting in equation [6], [ΔC_p] as defined in equations [10] and [12]. The results of these substitutions are

$$\Delta t = k[f(V) - f(V+\Delta V)] \qquad [13a]$$

$$\Delta t = -k\cdot\Delta V\cdot F(V) \qquad [13b]$$

which when substituted in equation [8] yields

$$C_t' = k\cdot[V+\Delta V]\cdot[f(V) - f(V+\Delta V)] \qquad [14a]$$

$$C_t' = -k\cdot\Delta V\cdot F(V)\cdot[V+\Delta V]. \qquad [14b]$$

Thus, once [$f(V)$] is derived, equations [14a] and [14b] may be used to determine the centralization forces in the automation of information handling and they may be correlated with a function expressing the cost of communications to determine the extent to which communications may be used economically to centralize data processing.

Derivation of a Unit Cost-Volume Function

As has been stated above, the unit cost of data processing is a function of volume and the magnitude of labor, material, transportation, and operating inputs. Any unit cost-volume function should take into account all of these inputs. For this study, however, data pertaining to the inputs other than the cost of data processing equipment were not available and could not be used in the derivation of the unit cost-volume function. The costs of transporting data over communications channels was available. These data were not used in the derivation of the function, rather, they were correlated with the function after it was derived to determine the extent to which communications may be used to centralize information handling work.

A unit cost-volume function was derived by correlating only the cost of several data processing units with the amount of processing they could perform in a single work month. By this means it was possible to construct a function that described the unit cost of processing with respect to inputs for equipment and the volume of information processed.

After attempting to fit various mathematical functions to the data, the function that fitted the data best was selected.

The general form of the equation used is

$$C_p = f(V) = \frac{Q}{V^r} \qquad [15]$$

wherein [Q] is a positive constant controlling the unit cost at any particular volume and [r] is a positive exponent that establishes the rate of change of the unit cost with respect to volume.

It should be noted that the slope of equation [15] is always negative. Any mathematical function of this type with a negative slope for all positive values of [V] will show that the unit cost of data processing can be reduced by increasing volume *ad infinitum*; it shows that the unit cost will become very small as [V] becomes very large. Obviously, such a function could not be used to determine unit costs for extremely large values of [V]. However, the function can be used to evaluate unit cost within the range of values of [V] for which it was computed. It is expected that the function may be used also to evaluate unit costs for volumes somewhat larger than those used to construct it. This is assumed because the speed of computers can be increased without incurring undue additional expense until the speed of light becomes the limiting factor. It is estimated crudely that units could be produced capable of performing up to one thousand trillion operations per month -- based upon 21.7 seven hour days per month. The maximum number of operations per month that could be performed by the fastest computer analyzed in method one, the IBM 7090, would be in the neighborhood of about five hundred billion. While the derived unit cost-volume function might reasonably be used to describe costs on high capacity units yet to be developed, it is expected that ultimately there will be a reduction in the unit cost of processing on all equipment as new developments are achieved. It is expected, however, that economies of scale, described by the value of [r], will be available also; it will be the value of [Q] that will be reduced.

The first of two methods used to determine the values of the parameters [Q] and [r] utilized the technique of assigning a particular problem to several data processing units and estimating the time required by each unit to complete the problem. This information was used to determine the amount of processing each unit could perform in a month having 21.7 seven hour days. The problem selected was to determine the sum of the squares of 15,000,000 random numbers no one of which was larger than the number nine.

In order to estimate the time necessary for each data processing unit to complete the problem, it was necessary for a program for each unit to be prepared. The programs were prepared by specialists employed by Remington Rand and IBM to whom the writer is greatly indebted. On the basis of the prepared programs, the time necessary for each unit to complete the problem was estimated by summing up the time required to perform each portion of the program.

The time required to complete the entire problem was extrapolated to determine the number of digits each unit could process in a single month. The total number of digits was divided into the monthly lease price to determine the processing cost per digit input. A regression line was fitted to the unit cost-volume data by the method of least squares to determine the parameters [Q] and [r]. The data processing units compared by this method are stock models offered for sale or rent by either Remington Rand or IBM. A list of the data processing units with the results of the analysis may be found in Appendix I.

The second method used to determine the values of the parameters in equation [15] is less sophisticated than the first. In the second method, the amount of processing that each data processing unit could perform in a single month was determined by using the speed with which they could perform a single addition. If, for example, a unit could perform 1,000 additions per second, it was assumed that it could perform 5,467,400,000 additions per month. By dividing the monthly lease price by the number of additions each data processing unit could perform per month, the unit cost per addition was determined. The add speeds and the monthly lease prices of the equipment analyzed were obtained from, M. H. Weik, <u>A Second Survey of Domestic Electronic Digital Computing Systems</u>, Office of Technical Services Report, U.S. Department of Commerce, 1957.

The parameters [Q] and [r] were determined by fitting a regression line to the unit cost and volume data by the method of least squares. A list of the data processing units compared by this method is included in Appendix II.

Cost of Communications

According to the Tariff Regulations of the Federal Communications Commission and the Massachusetts Department of Public Utilities, the cost of communications [C_t'] is a function of the distance [D] in miles between the two points between which communication is provided. This is true generally of all types of service from a telephone call in a pay station to a private line installation. The generalized function describing the cost of the communication service may be written as

$$C_t' = aD + g \qquad [16]$$

where [a] is the charge per mile and [g] is the fixed monthly charge regardless of the distance involved. The value of [g] is determined by the type of service and the type and cost of the terminal equipment that is used.

On private line facilities and public communications services, the unit cost of transporting information would be equal to the monthly cost divided by the number of digits sent. The least cost would be when the number of digits sent is equal to the capacity of the facility since the cost of the facility is the same whether it is used or not. This basic difference between communications costs and the cost of other forms of transportation is an important factor in stimulating increased utilization of communications once they are installed and centralizing of information processing.

Synthesis

By correlating the mathematical relationships derived earlier pertaining to the cost of communications and the cost of information processing, it is possible to determine the extent to which communications will help to centralize information handling work. Equations [14a] and [14b] define the resources that can be made available for communications in terms of the volume of data processed. Equation [16] defines the amount of communications service that can be purchased with any given amount of resources. By equating each of the equations that define in terms of volume the resources available for purchasing communications with equation [16] and solving for distance over which communications can be obtained for a range of volumes of data processed, it is possible to evaluate the extent to which communications will assist the centralization of information handling. The result of equating equation [14a] and [16] is

$$D = \frac{k\cdot[V+\Delta V]\cdot[f(V) - f(V+\Delta V)] - g}{a} \qquad [17a]$$

and of equating equations [14b] and [16] is

$$D = \frac{-F(V)\cdot k\cdot \Delta V\cdot [V+\Delta V] - g}{a} . \qquad [17b]$$

Section III

FINDINGS AND EVALUATIONS

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Applications and Benefits of Automatic Data Processing

Since the early 1950's when the first computer was manufactured and put into use, the number of different types of work that are being performed on automatic data processing equipment as well as the number of installations have increased rapidly. The increased use of automatic data processing equipment has occurred primarily because of the many benefits it could offer. It is generally conceded that work can be performed faster using automatic methods, and many companies have suggested that peak loads can be handled more smoothly and inexpensively. Also, electronic equipment does its work with more accuracy than can be achieved by manual methods. Claims have been made also that the use of automatic methods frees skilled persons from routine jobs so their time and talents can be utilized more effectively. In addition, many firms boast that they have been able to reduce substantially the cost of collecting and preparing statistics and also that management now has more statistics than ever. In this regard, many users are programming computers to make analyses and elementary decisions based upon the statistics they prepare. By this means management can be freed from trivial tasks and can concentrate on important problems. Automatic techniques have enabled many firms to offer better service to customers which has many advantages that cannot per se be measured in dollars. This has been particularly true in the insurance and wholesale drug business where the quality of service is very important.

To date the most impressive expansion in the use of automatic techniques has been in the automation of manual tasks. This has been desirable both from the viewpoint of lowering labor costs and from the viewpoint of performing this work more rapidly and more accurately. Already automatic data processing has taken over a significant portion of the accounting, bookkeeping, payroll, and billing work in virtually every type of business.

In places where electronic data processing equipment has been installed, a noticeable amount of centralization of information handling work has begun to take place. For example, in the Boston City Hall a Remington Rand Univac was installed in the Auditing Department about a year ago. Since that time there has been an increased use of the Univac to perform some work that formerly was performed in other departments. According to the personnel who operate the Univac, new arrangements are continually being made for the performing of more work on the Univac that is presently being handled in other city departments. Instances of centralizing information handling work at a large data processing unit subsequent to its installation are common.

The advent of automatic data processing has enabled users to perform more information handling work than previously and has permitted the undertaking of work that heretofore was unfeasible economically. Many of these new applications have been devised for the purpose of achieving a higher degree of business control.

In the field of business control, automatic data processing techniques are being used to produce the following types of information for management: man-hour output, profitability of decisions, direct and overhead costs, budget analysis, best production levels, best labor force composition, cost-variance analysis, schedule compliance, equipment downtime, maintenance costs, trouble spots, contract project costs, absenteeism trends, employee satisfaction trends, area wage comparisons, accident analysis, and economic forecasts.[21] Automatic data processing techniques are being utilized to produce the following types of information for plant operation: production planning and scheduling, maintenance schedules and costs, inventory balances and requirements, invoicing and billing, manufacturing shop orders and instructions, stock selection tickets, employee work schedules, payrolls, shipping manifests and routes, cost records, accounting and related cash handling.[22]

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[21] M. G. Meldon, "What Computers Can Do For You," Factory Management and Maintenance, 114 (February 1956) 98-105.

[22] Ibid.

It has become apparent that in order to achieve business control through automatic data processing, a certain amount of centralization of information handling work is necessary. An examination of the list of items in the above paragraph will indicate that to produce this information correlations must be made between information generated by several separate divisions of a business. Centralization of information handling has been an effective and efficient means of organizing to produce this information and to achieve a high level of control.

Another factor inherent in automatic data processing that stimulates the centralization of information handling work is the relatively high cost of a highly automatic data processing unit. In order to secure a high level of automation, a significant amount of money must be invested, and in order to make the use of the system economical, large volumes of data must be processed. The centralization of information handling work has been an effective method per se in making available to the data processing unit large volumes of data.

Future Role of Automatic Data Processing

It is expected that more and more clerical work that is presently being performed manually will become automated. This statement is based upon an estimate made in 1955 by IBM that only five percent of clerical work was automated and that at least thirty-five percent of clerical work could ultimately be automated. As very high capacity automatic data processing units are developed, it is expected that much of the automated clerical work will be centralized so that high capacity equipment may be used and economies of scale may be secured.

By centralizing information handling work at the site of an automatic data processing unit, more exact control over many aspects of business can be achieved almost as a by-product thereof. The ultimate in control through automatic data processing can be achieved by integrating separate information handling tasks and establishing feedback relationships between them. It is expected that eventually automatic feedback relationships will be established between the control of the production equipment used in the manufacturing process and all aspects of management control through automatic data processing.

To a certain extent this has occurred already. In the petroleum industry especially, automatic data processing techniques are being used for controlling production based upon statistical forecasts of economic conditions. As techniques for achieving completely integrated business control are developed and perfected, it is expected that automatic information handling will become a vital part of business operations. As this occurs, it is likely that the automatic data processing center will become intimately linked functionally and perhaps spacially with the decision making role of management.

To achieve comprehensive and integrated control, centralization of information handling must occur to a certain extent.

Effective centralization may be achieved in either of two ways. First, the entire information processing unit could be completely centralized in a single location. Second, information processing could be decentralized spacially though each part would have to be intimately connected via communications so that they could function as a unit and the desired feedback relationships could be achieved. Within rather broad limits, as will be shown later, it is most economical from the viewpoint of minimizing inputs per unit for equipment to establish a single data processing center. In either case, communications play an important role in transporting information to the data processing unit or units and the minimization of communications costs will exert an influence on the ultimate distribution of units.

The Role of Communications

In this study, not all types of communications channels or circuits are considered as usable on a large scale for transmitting information to be used directly in automatic data processing equipment. Wireless communications have not been considered because, at least from the contemporary viewpoint, there seems to be a definite upper limit to the extent to which they can be used. Apparently there are only so many wireless communications channels that can be made available because of the finite range of broadcasting bands. Even if a system of zoning was adopted so that the same channels could be utilized without interference in a few different parts of the country, the entire number of wireless communications channels that could be available would not be great.

Wire communications seem to have the greatest capacity for expansion in terms of the number of channels available for use. Since it is expected that the number of communications channels that will be used ultimately will be very large, only communications over wires have been considered in determining the role of communications in the centralization of information handling work. The role of communications is primarily a function of three considerations. First, what types of communications service is or will become available? Second, what is the cost of these services? And third, what is the capacity of the communications facilities in terms of the volume of information they can handle?

With minor variations the telephone and the telegraph companies offer about the same types of services for transporting information which is to be used directly in data processing equipment. They offer both common carrier services and private line facilities.[23]

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[23]See: M. M. Koontz, "Supplementing Electronic Equipment With a Modern Communications System," Computers and Automation, 6-4 (April 1957) 12-17; R. W. Baridon, "The Communication of Data," A New Approach to Office Mechanization, New York, American Management Association, 1954, pp. 53-62; L. C. Guest, "Administrative Automation At Sylvania: A Case Study," Administrative Automation Through IDP and EDP, Office Management Series, No. 144, New York, American Management Association, 1956, pp. 28-72; "Statement of Don G. Mitchell," Automation and Technological Change, Hearings Before the Subcommittee on

Three types of common carrier service are offered. The first of these is the Teletypewriter Service which allows any subscriber to send information to the office of any other subscriber by entering the message into the channel either manually with a teletypewriter or automatically with a tape reader from a prepunched paper tape on which the message is recorded. The message may be received automatically either, or both, as a written message typed out on paper or as a coded message punched into paper tape.

The second common carrier service, commercial telegraph, is offered only by Western Union. Commercial telegraph service may be used not only for sending messages that are to be received as a telegram but it may be used for sending messages that are to be delivered as a strip of punched paper tape. A message recorded on paper tape can be introduced into automatic data processing units for processing.

The third common carrier service, offered only by the telephone companies, permits the use of any telephone for transmitting data that is to be processed automatically. This is achieved by installing a Dataphone along with the telephone. The Dataphone may be used to transmit information already recorded upon paper tape and to receive messages by recording them on paper tape. The cost of transmitting information by this means would be the same as the cost for making a telephone

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Economic Stabilization of the Joint Committee on the Economic Report, 84th Congress, 1st Session, October 1955, Washington, GPO, 1955, pp. 169-196.

call.

Private line facilities over either telegraph or telephone channels may be secured and utilized either the same way as the common carrier service would be used or they may be specially designed and installed with special switching equipment to suit the particular needs of the user.

At present it is not generally possible to introduce data from communications channels directly into data processing equipment without first recording the information on paper tape or punched cards. However, there are a few instances where this has been achieved. The data processing centers set up to track and control missiles, satellites, etc. as well as the data processing centers set up to handle automatically the making of airline reservations are two examples where information is introduced directly into the processing unit without first recording it on punched cards or paper tape. Since this technique eliminates paperwork and punching equipment, it is expected that it will be used more in the future.

The availability of such a wide range of communications service will contribute to the feasibility of centralizing information processing work. Since relatively economical communications service is available for transmitting almost any volume of information, small or large, communications will not inhibit the small business from taking advantage of large scale data processing on a service bureau basis. A business with low volumes of information to transmit could use either commercial telegraph or the Dataphone. Firms with large volumes of information to transmit could economically use private lines.

The cost of telegraph facilities to the user is the same regardless of whether it is obtained from the telegraph or the telephone company. The monthly charges levied for the use of private, 60 words per minute, Teletypewriter communications channels are as follows: $0.50 per quarter mile between points in the same building; $5.00 to $6.00 flat monthly charge, depending upon the particular city, between points in the same exchange, with multipoint connections at fifty percent of the base rate; $0.75 per quarter mile between any two points in the same city; $1.20 if used less than twelve hours per day, $1.50 if used more than twelve hours per day, between any two points in different cities within the same state; and $1.25 to $0.21 per mile, depending upon the time of day and the number of hours per day the facilities are used between any two points located in different states. To these rates, the following discounts apply for distances over 250 miles:

251 to 500 miles, 10% discount
501 to 1000 miles, 20% discount
1001 to 1500 miles, 30% discount
Over 1500 miles, 40% discount.

For facilities operating at 75 words per minute, add 10%; for facilities operating at 100 words per minute, add 25%. All distances used in computing the cost of communications are airline miles.

The cost of private telephone lines, whose capacity is about seventeen times that of a teletype communications channel, is the same as teletype channels for points within the same telephone exchange. Between any points in different exchanges the charge is $3.00 per airline mile measured to the nearest quarter mile with the same distance discounts applying.[24]

The rate structure is so arranged that the more the facilities are used, the lower is the unit cost of transmission, and the greater the distance between the two points, the lower is the cost of the facility per mile. Both of these considerations are such as to stimulate the applications of new uses of communications so that the facilities may be used more and the unit cost reduced. Since all distances used in computing the monthly charge are airline distances, the layout of the present communications lines does not enter directly into the cost to the user. Hence, the old established pattern will have little influence on the location of points between which communications are desired. This is a significant departure from the influence that transportation facilities in general have had on the location of business activity. However, when special installations must be made to establish communications between points, some of the cost of the installation must be borne by the client. Usually, if communications are desired

[24]All of the information cited pertaining to the costs of communications was obtained from the tariff regulations of the Federal Communications Commission and the Massachusetts Department of Public Utilities.

between any inhabited places, there is no problem of additional expense for installing lines. There is a nominal fee charged initially for each new installation which is comparable to the fee charged for the installation of a new telephone.

The rate structure is a powerful tool for influencing the distribution of information handling activities when communications are used. The per airline mile basis by which charges for communications are computed has the effect of reducing the importance of existing patterns and making many sites suitable for the location of a central data processing unit. However, it has been proposed that communications charges be computed on the basis of zones in which the cost of communications would be the same regardless of the distance between the two points. Eventually, it has been suggested, entire metropolitan areas may become single zones and ultimately, entire states. If this happens, the distance between the two points in the same zone will have no effect upon the cost of the communications. Thus, a central data processing unit serving the Boston CBD could be located anywhere in the metropolitan area or perhaps in the State of Massachusetts. Clearly, the rate structure can be an important influence on the overall concentration or dispersal of information handling work and other types of activities utilizing communications or linked closely to information handling work. Inasmuch as the rate structure is controlled by the State and Federal governments, its use for plan implementation becomes a question of large area coordination, metropolitan and-or state planning.

The third factor to be considered in determining the role of communications is the capacity of the available facilities. In terms of characters per minute that may be transmitted, the teletype channels can handle up to 600 while the telephone channel used with the Dataphone has a capacity of up to 10,000 characters per minute. Measured at full capacity, the telephone channel can be used to transmit information at about 25% the unit cost of transmission over a teletype channel. Of course, the use of the high capacity private telephone channel requires the availability of large volumes of data to be transmitted. However, the unit cost of transmission over a telephone channel would be equal to that of a teletype channel if only four times the volume was transmitted. This would leave room for expansion in use of over four hundred percent.

It is interesting to note that the larger data processing units are capable of accepting for processing over 200,000 digits per minute. Thus if all the information processed by the unit was imported over a 10,000 characters per minute communications channel, at least twenty such channels would be required. It is expected that in the future, very high capacity communications channels will be made available so that information may be transported at speeds equal to the rate at which it can be accepted by data processing equipment. It is expected that the unit cost of transmission over very high capacity lines will be very low and that this will make feasible the centralization of information handling work over larger geographical areas.

Analysis of the Centralization Force

The method used for analyzing the centralizing force is that of deriving a unit cost-volume function for the entire field of automatic data processing and then analyzing the function in terms of other factors that could not be considered in deriving the unit cost function. The unit cost function was derived by correlating statistically the unit cost of data processing on a number of different units with the volume of data that could be processed by each unit in a work month containing 21.7 days of seven hours each. The parameters that were derived using this data are [Q] and [r] in equation [15].

The most significant parameter, [r], which governs the rate of change of unit cost with respect to volume was found to be about 0.7 by both methods. By method one, where a standard problem was assigned to a number of data processing units, the value of the function was calculated to be

$$C_p = \frac{4366}{V^{.69}} \quad . \qquad [18]$$

By method two, where the capacity of the data processing units was measured by the speed with which the units could perform a single addition, the value of the function was computed to be

$$C_p = \frac{364.6}{V^{.64}} \quad . \qquad [19]$$

A list of the data processing units studied and the basic data

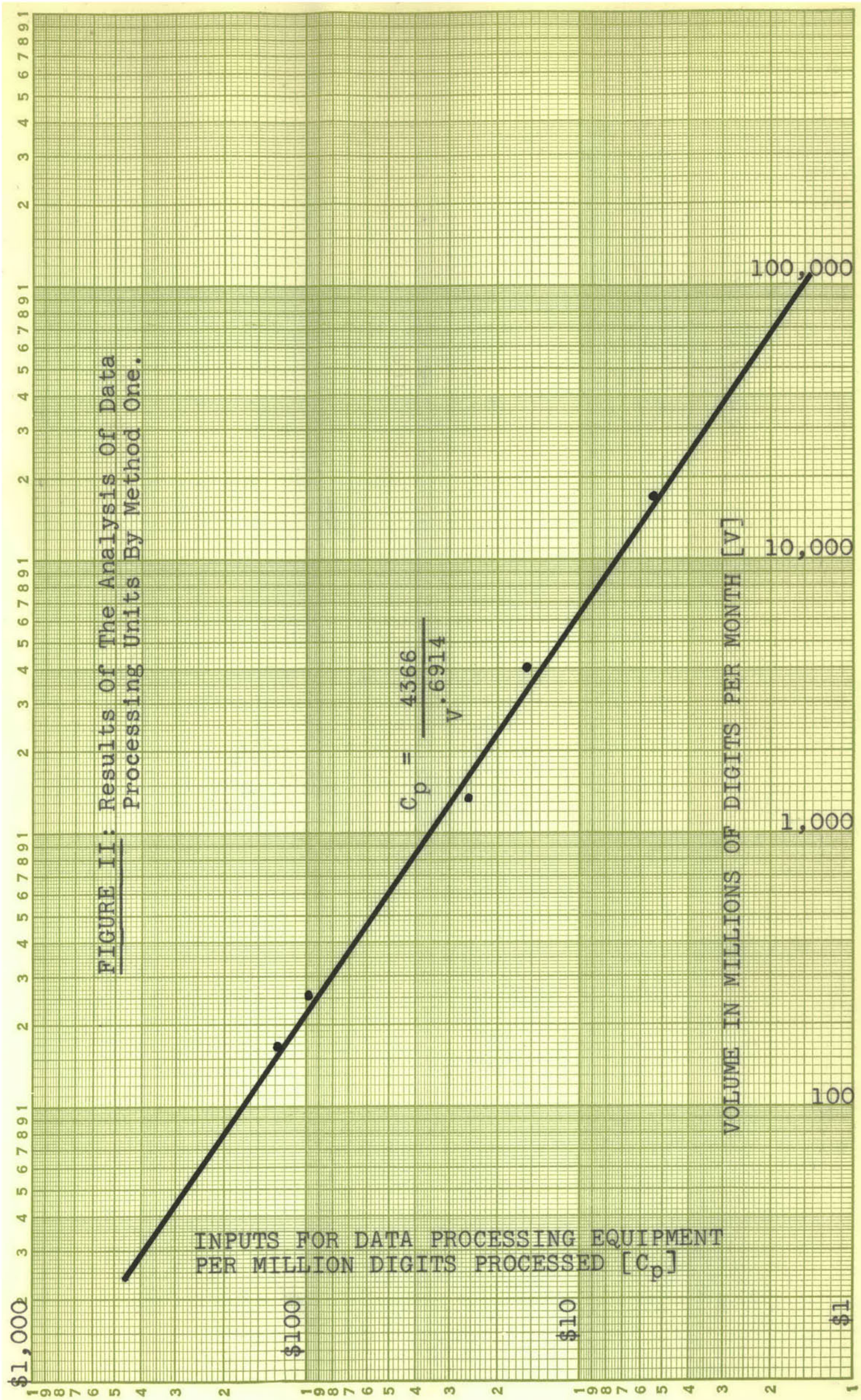

FIGURE II: Results Of The Analysis Of Data Processing Units By Method One.

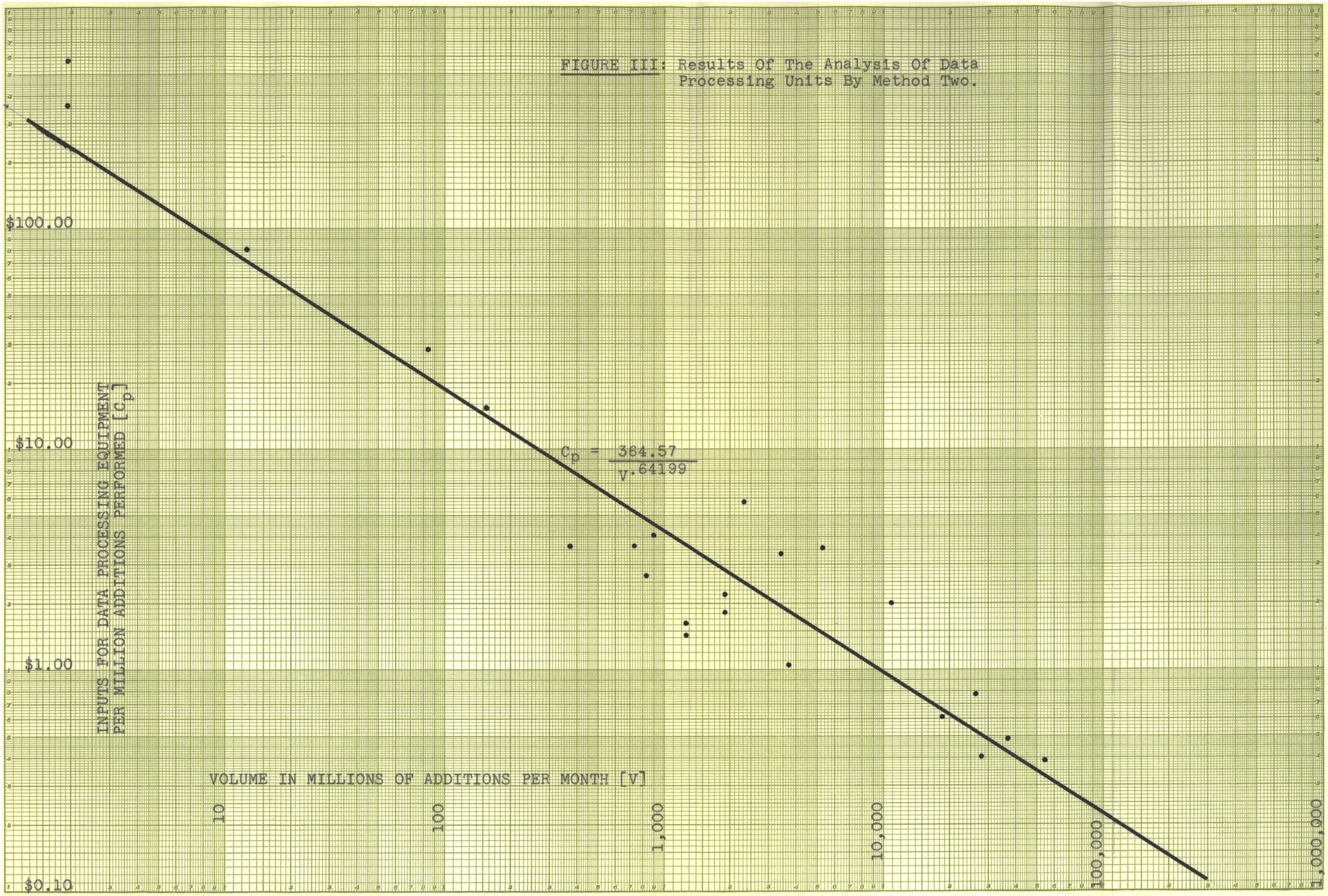
FIGURE III: Results Of The Analysis Of Data Processing Units By Method Two.
$C_p = \frac{364.57}{V^{.64199}}$
INPUTS FOR DATA PROCESSING EQUIPMENT PER MILLION ADDITIONS PERFORMED [C_p]
$100.00
$10.00
$1.00
$0.10
VOLUME IN MILLIONS OF ADDITIONS PER MONTH [V]
10
100
1,000
10,000
100,000
1,000,000

used to make these calculations may be found in Appendix I and II for method one and two respectively. Graphs illustrating the data and the regression lines may be found in Figures II and III.

It should be noted at the outset that there are limits to which these functions may be used. First, the functions are intended to give a general view of the unit costs of processing as higher capacity equipment is used, i.e., as information handling work is centralized. Hence, the functions are unusable by business to predict what their unit costs would be as they increase their volume. They would be unusable because several important costs have not been considered in their derivation which will influence the actual total and unit cost of processing, and because the bases used in methods one and two for comparing units would be different from the basis used by a business in making a similar analysis. Second, there is the problem of using the functions to describe unit costs as the volume becomes very large. A function that could be used for this purpose would have to have a damper built into it which would reflect the diseconomies of building a larger, faster data processing unit. These functions do not have such a damper and one could not be built into them at this time because it is not known when diseconomies will begin to occur. It is expected though that this point is not very close at hand and that data processing units of many times higher capacity than contrmporary units will be developed. However, neither of these limits of use affect adversely the intended use of the functions in this study.

In regard to the functions derived, it should be noted that the difference in the values of the parameter [Q] does not represent a discrepancy in the findings. Rather, the difference arises because of the differing bases of comparisons used in method one and two. In method one the comparison was based upon the number of digits input. In the second method, the basis for comparison was the number of computer operations, i.e., the number of additions. Thus, it would be expected that the value of [Q] computed by method one would be somewhat higher than by method two since there would be involved a number of computer operations per digit input to complete the problem. On the average, timewise, it took about twelve computer operations to perform the calculation per digit input. This can be seen by the relationship between the values of [Q] as computed by each method.

As can be seen by examining equations [18] and [19], the rate of change of cost with respect to volume as established by the value of the parameter [r] is about the same in each case. However, because of the overstatement of the unit costs of processing on large equipment noted earlier, it is expected that the actual value of [r] is somewhat higher than computed. An underestimation of the value of [r] means that the function understates the economies of scale.

It can be seen from Figure I that from a purely economic viewpoint fewer inputs are made for equipment per unit processed when the processing is performed on a single unit than when the work is performed on any combination of two or more units. As a practical example of this, Koontz compares the unit costs of processing on an IBM 650 with those of an IBM 705 -- which is forty times as fast and potentially able to perform forty times as much work as the 650 -- and notes that ". . . the cost per calculation on a loaded 705 would be less than ten percent of that on a loaded 650 in terms of rental alone."[25]

It can be seen from Figure II that it is possible to use two data processing units instead of a single unit and still process data at about the same unit cost. However, Koontz suggests seven points why spacial centralization is presently advantageous for efficient utilization of personnel and efficient operations, viz:

> 1. Personnel acquainted with the interaction of computer and commercial systems are too scarce and too expensive to "spread thin."
>
> 2. A large memory is not yet adequately adaptable to decentralization, which would remove it from the computing unit and the master file systems. A large magnetic memory is needed for paperwork elimination, rather than simplification, and elimination occurs when master files are integrated. Presently applied communications are not adequate, either in terms of facilities or personnel, to assure high-speed integration of decentralized memory components with the presently developed heart of the system, i.e., cards, tapes, and programs.
>
> 3. Integration of related master data simultaneously

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[25]Koontz, op. cit., p. 16.

reduces input error ratios and reduces the need for duplicating data from external sources.

4. The reduction of external input gained by centralized integration would reduce the load on the communications system, rendering it more effective for a given outlay.

5. Centralization of data improves computer payoff and builds necessary knowledge of techniques in the organization.

6. Larger capacity units handle greatly more complex logistical and research problems, which provide greater payoffs than straight commercial applications, to supplant today's generally unsophisticated analysis.

7. Complaints already have been heard that all of the fastest computers available cannot handle computer demand, either in terms of volume (this is on a national basis) or in terms of problem complexity.[26]

The economics of utilizing personnel, equipment and other resources may not be the only reason for centralizing information handling work. To a significant extent, achieving integrated and automatic business control requires centralization of data processing. This is because of the need to draw upon information generated by all aspects of business in order to make decisions about what the business should do next and in order to relate historical analysis and decision making to forecasting techniques. The very nature of a control mechanism that is to act swiftly and effectively is that of a single functioning unit either completely centralized or partially dispursed.

It is expected that the desire to achieve a high level of control will be satisfied by centralization of information

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[26] Ibid. pp. 15-16.

handling. It is expected also that even more resources may be made available for centralization than could be saved by automation per se in order to achieve a high level of automatic control. These resources would be those that were lost formerly through inefficiencies, i.e., spoilage, delays, inefficient operation, etc.

It is possible that additional resources could be applied to centralization. These would be the resources made available by automation. It is particularly common for users of electronic data processing equipment to experience rather sweeping changes in labor, material, and operating inputs. It is difficult to secure a complete understanding of the exact changes because often firms experiencing them are not quite aware of exactly what has changed and how much, and the firms that do know will not release this information.

Some examples of changes in inputs must suffice for the exact information. _Time_[27] magazine noted that an IBM 702, which is a relatively low capacity unit, was utilized to do a specific task. It completed in twelve hours what normally took 1800 man-hours to complete by hand methods. And in another instance, the 702 performed the work of 320 accountants in two hours. J. A. Higgins and J. S. Gilckauf, "Electronics Down To Earth,"[28] noted that by utilizing electronic equipment,

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[27] 65 (March 28, 1955) 81.

[28] _Harvard Business Review_, 32 (March-April 1954) 99.

". . . dollar savings have been achieved through the elimination of clerical labor by performing sequential operations automatically, by handling most exceptions to regular procedures automatically, and by making inroads into clerical work areas never before mechanized." Describing the findings of their studies they noted, ". . . our studies, which covered potential applications in a number of different industries, have in every case revealed clerical savings of very substantial proportions." However, reductions in material and operating inputs do not always follow the installation of electronic data processing equipment. Many users have been able to reduce considerably operating expenses by eliminating the need for many smaller pieces of equipment and furniture. Some users found they could perform the same amount of work in less floor space than formerly by eliminating desks, files, etc.

Thus, in summary, the forces operating to centralize information handling are the

1. Attempts to minimize inputs per unit processed for data processing equipment by utilizing high capacity equipment

2. Attempts to achieve a high degree of business control by integrating information handling

3. Attempts to maximize the efficiency of utilization of resources and achieve efficient operation utilizing automatic methods.

The resources required for centralizing information handling can be made available through the substitutions of inputs for equipment, inputs being lost through inefficiencies, and inputs released through automation of information handling work.

Demonstration and Analysis

A demonstration of how centralization of information handling activities may occur using the material developed above will enable the reader to understand more fully the impact of the use of automatic data processing with communications on the pattern of information-handling-business. For this demonstration, assume that there are one thousand units of production disbursed throughout the United States each of which is performing manually data processing involving five million digits per month. It is assumed also that each production unit is unable to move from its present location because of requirements that can be satisfied only at that location. While the assumed units of production are hypothetical, they might correspond to a group of banking institutions, wholesale or retail businesses, ticket offices, etc.

Assume that the long run unit cost-volume function for automatic data processing equipment is about the same as that computed by method one, i.e.,

$$C_p = \frac{4366}{V^{.7}} \qquad [20]$$

and that the unit equipment cost varies with volume about the same as shown by the regression line in Figure II.

Assume that two of the production units in the Boston area each pool their five million digits and set up an automatic

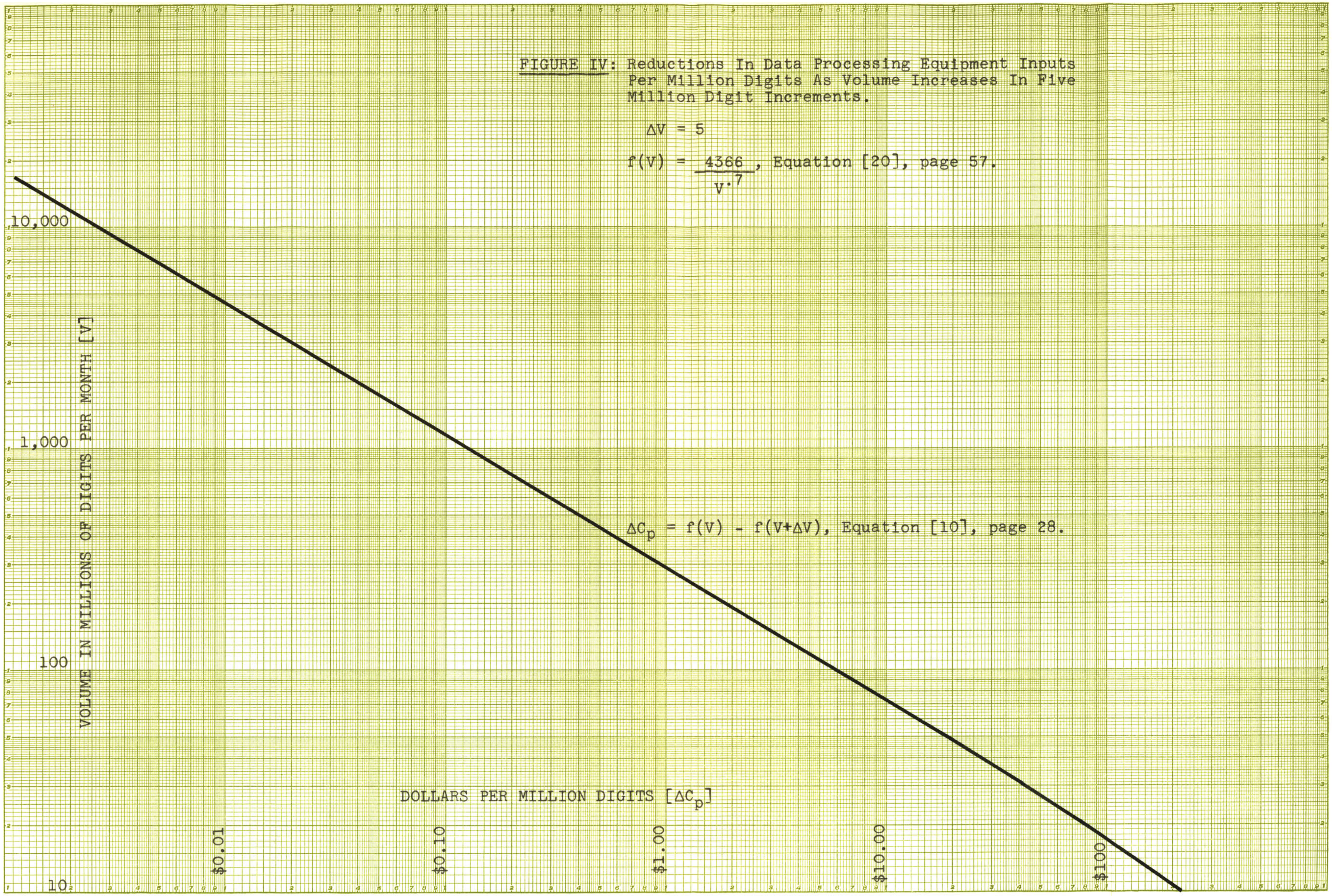
FIGURE IV: Reductions In Data Processing Equipment Inputs Per Million Digits As Volume Increases In Five Million Digit Increments.
ΔV = 5
f(V) = 4366 / V^.7, Equation [20], page 57.
ΔCp = f(V) - f(V+ΔV), Equation [10], page 28.
10,000
1,000
100
10
VOLUME IN MILLIONS OF DIGITS PER MONTH [V]
DOLLARS PER MILLION DIGITS [ΔCp]
$0.01
$0.10
$1.00
$10.00
$100

data processing unit for processing ten million digits per month. If the manual processing of five million digits is performed by clerks earning $1.57 per hour and the clerks are capable of processing one digit per two seconds at a desk calculator, the labor input per million digits would be $872 and twenty two clerks would be required. The labor inputs for manual processing would be about the same as equipment inputs for processing automatically ten million digits per month; see Figure II. It is expected that reductions in other inputs for operations -- i.e., rent, utilities, equipment, furniture, employee benefits, etc. -- will be sufficient to amortize the initial costs of establishing the data processing unit. It is estimated that the savings in rent in a single year would cover the installation and initial programming costs. This is based upon the assumption that each clerk occupies forty square feet of gross floor space renting at $3.00 per square foot per year, and that seventy five percent of the floor space used by clerical workers could be eliminated.

The data processing equipment inputs per million digits, which are a high percentage of the total input for processing, can be reduced in accordance with equation [20] by increasing volume; see Figure II. By increasing volume from ten to fifteen million digits per month, the input per million digits for equipment may be reduced by $215; see Figure IV. This can be computed by substituting equation [20] in equation [10].

This does not represent a reduction in the total cost of processing. Rather, it means merely that the inputs for equipment per million digits processed may be reduced by $215. In order to achieve this reduction, a portion [k] of the reduction of equipment inputs in each of the fifteen million-digit-units could be invested in communications facilities for transporting information to the data processing unit from one of the other units of production. Thus, in terms of equation [5], cited on page 25, assuming for the present that other inputs have not changed, some portion of the change in inputs per unit for equipment [Δe_1] may be substituted for transportation, i.e.,

$$k \cdot \Delta e_1 = \Delta t \quad . \qquad [21]$$

The cost of the communications facilities today for transporting five million digits per month would include the monthly charge for terminal equipment and the monthly lease price of a single teletype communications channel. The terminal equipment required to import the data would be an Automatic Transmitter and a Reperforator which together rent for $60.00 per month. Using present day rates for a 100 words per minute communications channel, the monthly charges would be:

$1.50 per mile when the distance is between 3 and 50 miles;
$0.90 per mile when the distance is between 50 and 250 miles;
$0.81 per mile when the distance is between 250 and 500 miles;
$0.72 per mile when the distance is between 500 and 1000 miles;
$0.63 per mile when the distance is between 1000 and 1500 miles;
and $0.54 per mile when the distance is over 1500 miles.[29]

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[29]See; Supra, p. 44.

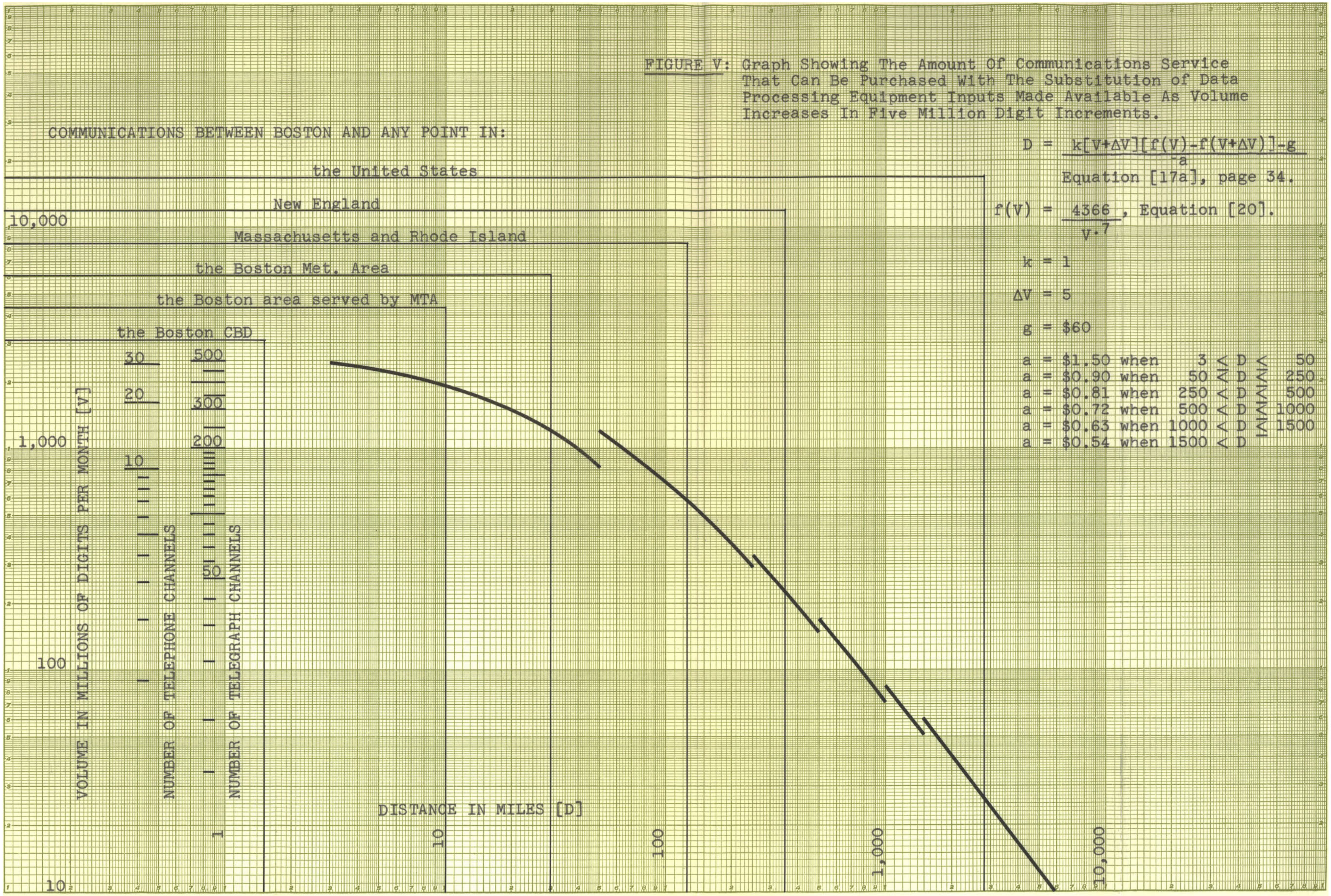

FIGURE V: Graph Showing The Amount Of Communications Service That Can Be Purchased With The Substitution of Data Processing Equipment Inputs Made Available As Volume Increases In Five Million Digit Increments.

By substituting these data into equation [17a] and solving for distance in terms of volume, the graph in Figure V may be constructed. Figure V indicates in terms of distance the amount of communications service that may be purchased with an amount equal to the reduction in inputs for equipment secured by increasing volume by five million digits.

As can be seen from Figure V, if all of the reduction in equipment inputs per unit processed resulting from an increase in volume from five to fifteen million units was applied to communications, service could be provided to a point located 5980 airline miles from the data processing center in Boston. If, however, a total of $1500 a month was invested in communications, communications service could be provided between Boston and almost any other point in the United States. The unit cost of transporting five million digits based upon the total volume of fifteen million digits would be $100 per million digits. Thus, if $100 of the $215 reduction in data processing equipment inputs per million digits was invested in communications, the net reduction in inputs for equipment would be $115. This saving along with reductions in other inputs due to automating the processing of five million digits would make it desirable to centralize this activity at a single data processing unit.

This line of reasoning could be applied each time the volume is to be increased. Figure V shows the amount of communications service that could be secured at any volume by substituting the reduction in data processing equipment inputs for transportation. By substituting data processing inputs each time volume is to be increased, it would be possible to secure communications to increase volume up to about two and one half billion digits per month. This would represent the relocation of this activity from 500 of the 1000 units of production and would affect 11,000 clerical workers. After volume is increased to two and one half billion digits per month, reductions possible through increasing volume fall off to the point where they are insufficient to purchase communications between points located three miles or more away, i.e., they do not amount to at least \$64.50 (\$60 for terminal equipment plus 3 miles at \$1.50 per mile).

Thus, the economies of acale that may be achieved by using high capacity automatic data processing equipment make feasible and desirable from an economic viewpoint the centralization of information processing. By centralizing the work of five hundred units of production amounting to two and one half billion digits per month, the inputs for equipment could be reduced from \$872 to \$19 per million digits (see Figure II) and the communications costs would amount to \$34 per million digits. The net reduction would be \$872 - (\$19 + \$34) = \$819.

It may be possible to centralize the processing being performed at the remaining five hundred units of production by investing reductions of other inputs in communications. For example, the labor inputs for processing manually one million digits is $872. If seventy five percent of this could be saved through automation, up to $654 per million digits could be made available for communications. This would be more than twice as much as is necessary for transporting five million digits per month from San Francisco to Boston. Thus, if reductions in other inputs are applied to communications, the processing being performed at the remaining units of production could be centralized at the data processing unit in Boston.

However, at this point it becomes a question of minimizing communications costs. Depending upon the distances involved, it might be more economical to set up another data processing unit and let each unit serve a particular portion of the country. The actual economics of this depend upon the total volume and the geographical distribution of the units of production generating the information for processing.

According to Figure II, the reduction in equipment inputs per million digits processed would be from $19 to $12 if the volume is increased from two and one half to five billion digits per month. In view of the low amount that can be saved, there is a strong probability that more could be gained through minimizing transportation costs (which are essentially a function of distance) by establishing two data processing units. Thus, it would seem that unless other advantages such as those of business control ensue from complete centralization, the actual amount of centralization that is economical would be a function of the costs of communications.

Nevertheless, the centralization of the work of five hundred units of production affecting directly 11,000 clerical workers is considerable any may have important planning implications.

Limits to Centralization

The limits to centralization are important to planners because they establish one of the boundaries to the area of consideration: the pattern of information-handling-business activities. Planners want to know how far centralization is possible and what forces will act to set limits to the centralization of information handling work.

Other than the availability of high capacity equipment, there are three concepts of a limit to centralization that should be discussed. The first of these is the cost of communications, the second is the cost of programming, and the third is the policies of the companies using automatic data processing.

The cost of communications relative to the cost of equipment when volume is small is also very low because the amount of information that is imported is not great. As the volume of information processed at a central data processing unit increases, the number of communications lines and the distance over which information is imported increases greatly because it is difficult to assemble at a data processing unit all of the information generating activities. For example, about five hundred teletype communications channels would be required to import for processing at a central data processing unit 2,500,000,000 digits per month as was suggested in the demonstration above. The cost of the communications service shown in Figure V would be about sixty percent greater than the cost of the equipment used for processing.

There is some point, depending upon the geographical distribution of the information generating activities, in the centralization of information handling work where the cost of communications becomes so large that the total cost of data processing including communications cost could be reduced by setting up more than one data processing center. This would involve a minimizing of communications costs since the cost of data processing equipment per unit processed can be reduced by centralization. Exactly where this point is depends upon the type and amount of communications service provided and the location and distribution of the places to which communications are provided. If the information generating activities are located close to the processing unit, the cost of communications would not be as much as if they were further away. Likewise, if they were scattered about more or less at random, it would cost more to provide communications service than if they were concentrated since in the latter case high capacity communication facilities could be used at a very low unit transmission cost.

Another way of establishing a limit to centralization

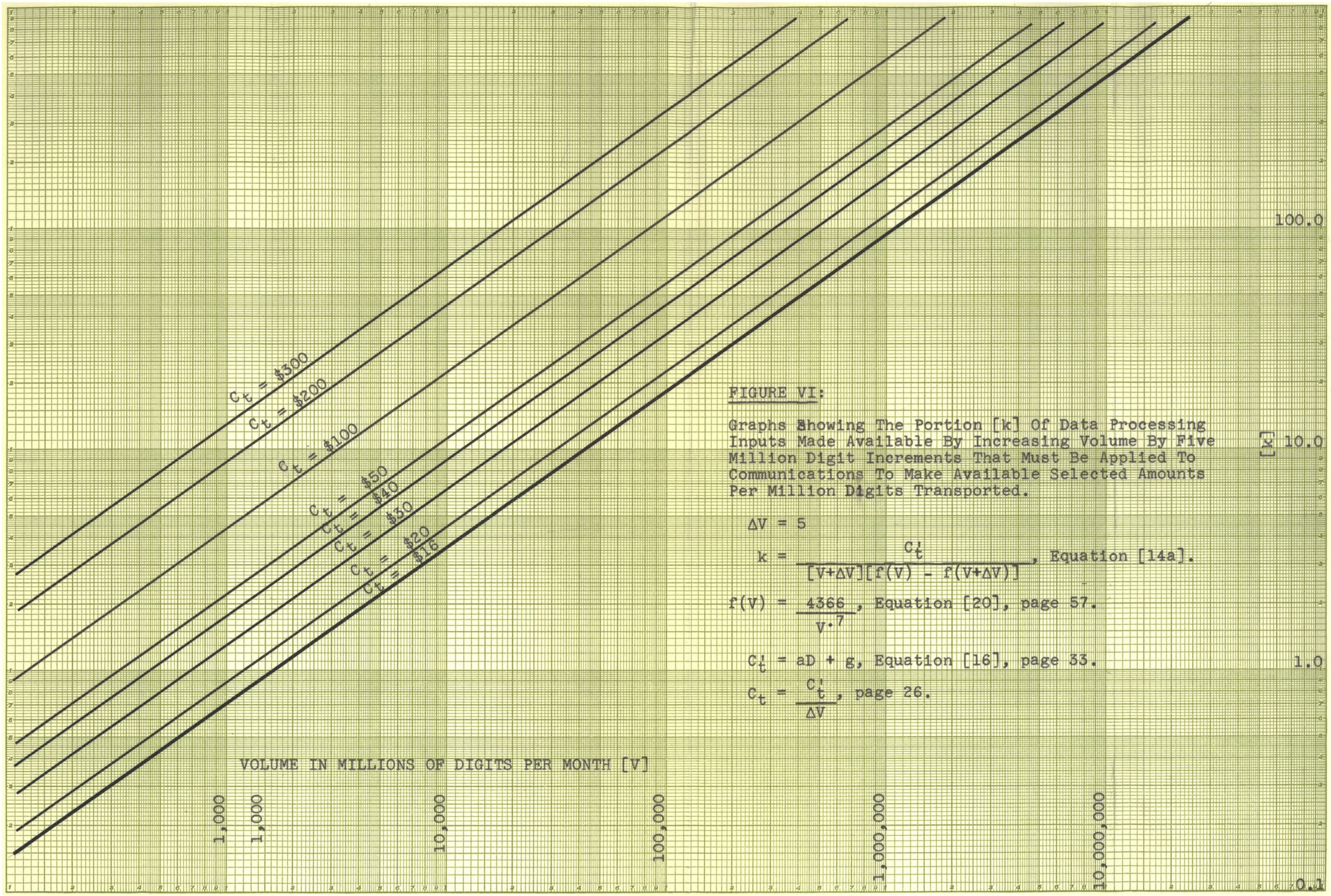

FIGURE VI:

Graphs Showing The Portion [k] Of Data Processing Inputs Made Available By Increasing Volume By Five Million Digit Increments That Must Be Applied To Communications To Make Available Selected Amounts Per Million Digits Transported.

$\Delta V = 5$

$$k = \frac{C'_t}{[V+\Delta V][f(V) - f(V+\Delta V)]}$$, Equation [14a].

$$f(V) = \frac{4366}{V^{.7}}$$, Equation [20], page 57.

$C'_t = aD + g$, Equation [16], page 33.

$$C_t = \frac{C'_t}{\Delta V}$$, page 26.

based upon the cost of communications is by examining the proportion [k] of the reduction in equipment inputs per unit processed resulting from an increase in volume that would have to be invested in communications in order to make available per month \$16.00 per million digits or \$80.00 per five million digits. Eighty dollars would be the minimum resource necessary to acquire terminal equipment and a telegraph channel over a short distance. Figure VI is a graphical presentation of the value of [k] plotted against volume for selected values of transportation inputs per million digits [C_t]. Equation [14a] was used to construct the graph and [f(V)] as noted in equation [20] was substituted therein.

Figure VI shows that a minimum of \$80.00 can be made available through increasing volume by five million digits up to a point where the total volume equals 1,600,000,000 digits per month without having to substitute inputs other than data processing equipment inputs. It may be that users will not tend to increase volume beyond this point especially when the total volume processed is imported since after this point transportation inputs rapidly become the major portion of the total cost of processing. However, if a large amount of information to be processed is generated locally, the total cost of communications may not become excessive until volume has increased far beyond this point. Also, it may be that users will always be willing to apply \$25, \$50, or even more per million digits in order to maintain economies and advantages of integrated data processing for achieving control.

The second limit to centralization is that of the cost and complexity of programming. The procedures of programming and testing programs preliminary to actually using them is sometimes very costly. The cost varies with the complexity of the programs. The feasibility of using automatic data processing techniques is based upon being able to amortize these costs over a large number of units processed.

The cost of programming is usually a determinent of whether the work will be performed automatically or not. It is in regard to programming very high capacity computers to perform several data processing tasks simultaneously that the cost of programming becomes important as a limit to centralization. This type of programming is in addition to the programming of the actual work. This programming is for the purpose of coordinating and keeping separate the elements of the various different tasks. This cost of programming for coordinating several tasks may become very large when many problems are being performed simultaneously. If a computer was able to perform one hundred different problems simultaneously, the cost of programming for coordination could be amortized if the individual programs remained the same for some times. However, if each one of the different programs was changed once every hundred days, statistically, it might be that the program for coordination might have to be changed daily. If this happens, the cost of programming, the cost of checking the programs as well as the costs of idle time for very expensive equipment would have to be incurred. In other words, the cost may be sufficiently high to make this type of operation unfeasible.

Besides the possibility of performing tasks sequentially rather than simultaneously, there is some suggestion that the complexity of programming will be greatly simplified and the expense reduced in the future. This combined with the possibility that frequent program changes on high capacity, fast equipment might be as economical as infrequent changes on lower capacity, slower equipment leaves to the future the answer to the limiting effect of programming on centralization.

However, programming does not seem to be a problem when large amounts of the same type of work are performed at a central location as would be the case with banking work. Since only a small number of related tasks need to be programmed, which normally would not be changed often, the programming problem would not be as significant as it would be when many different problems are being performed. This may be true also of a central data processing unit serving a single large firm.

Ultimately, programming costs will set the limit to centralization as well as the limit to the use of automatic data processing. On the surface, it seems that there is little that the computer cannot do as well or better than a human being. Norbert Wiener's chess playing machine, while elementary in concept, does approach having the facilities of the human mind. Not only that, but estimates of the future chess playing machines indicate that a machine could be built that would be difficult for even an expert to beat.

The programming problems involved in such a machine are many. The programming, if it could be done at all, would involve programming for every possible alternative that the equipment would have to choose among. In addition, the program would be of such extensive length that a human being could do the work faster in some instances. Also, certain portions of the machine, sometimes large portions, would not be called into use for long periods. As more flexibility and capacity is built into the computer, the program becomes more complex and expensive, the need for memory increases, and the average utilization of each section of memory decreases. Hence, there is some point where it is cheaper to use a man than to use a machine.

The third concept of the limit to centralization would be the policies of business on how they apportion responsibilities and duties. The contrast between the policies of the John Hancock and the Prudential Insurance companies indicates that there are limits to the degree of centralization of data processing based upon company policy. The Hancock company has centralized a significant portion of their data processing at their home office in Boston. On the other hand the Prudential company has followed the policy of setting up regional offices that handle substantially the same operations as does the central office of the Hancock company.

It may be that because the Prudential company is several times larger than the Hancock company in terms of volume, a completely centralized operation could not be set up using the relatively low capacity equipment available today and that there was relatively little to gain in centralizing a group of equipment that could function as effectively and economically on a regional basis. However, there is strong reason to believe that the Prudential office set up regional data processing units in their regional offices rather than in the home office because it is their policy to distribute responsibilities and duties regionally. In other words, it is their way of handling the insurance business regardless of whether they were using automatic data processing or not.

The policies of the Sylvania Electric Products Company exemplify a limitation to centralization of data processing even though they were about the first firm to centralize some of their information handling work. Sylvania has attempted to decentralize control. The manager of any of the fifty or so plants and installations, in effect has a separate business, and he runs it subject only to the broad framework of general policies and controls which must be retained by top management in order to assure coordinated action. Sylvania finds that by giving the manager of the local plant the responsibility for the success of the plant and the necessary authority to do the job, he acquires a sense of pride as if he personally owned every square inch of the plant and that pride is strikingly evident in everything he does.[30]

Another significant problem encountered in centralizing information handling work is the problem of standardization and cooperation. This is especially a problem when data processing is performed on a service bureau basis. Without a rather high degree of standardization, centralization may not be as economic as any other alternative. The problem of standardization is very difficult to solve when there is a pooling of work by several firms to permit the use of high capacity equipment. A solution is further complicated by the inherent reluctance of business to divulge anything of the inner workings of the business. The present problem underlying these difficulties is that businesses are not fully aware of the advantageous manner in which they may utilize present developments in automatic data processing and communications.

In summary, it seems that the cost of communications will be a very important factor in establishing the limit to which information handling work may be centralized. To determine at what level communications will limit centralization requires further investigations into the distribution of information generating activities on the land and the use of very high

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[30]See: "Statement by Don G. Mitchell," Automation and Technological Change, Hearings Before the Subcommittee on Economic Stabilization of the Joint Committee on the Economic Report, 84th Congress, 1st Session, October 1955, Washington, GPO, p. 184.

capacity communications facilities. The influence of programming on the limit to centralization cannot be determined at this time since it is not known what developments in programming and processing techniques which will affect the cost and complexity of programming will be achieved in the future. The entire question of the influence of business policy and its effect on centralization of information handling work also requires a great deal of further research since business policy could completely negate arrangements that would be feasible using developments in data processing and communications.

Section IV

IMPLICATIONS AND CONCLUSIONS

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Trends and Future Levels of Development

The concomitant use of automatic data processing and communications is expanding greatly in this country and ultimately throughout the world. There does not seem to be anything in view, except serious economic depression or saturation of the market, that will reduce the acceleration with which automatic information handling is being utilized.

Because of the relatively low level at which clerical work is presently mechanized, a rapid expansion of the present uses of automatic data processing is to be expected as more and more businesses automate routine clerical work. The economy and speed of automatic data processing will stimulate new applications to achieve more sensitive and accurate business control which heretofore could not economically be undertaken.

Expansion to include new applications will represent continuous long run substitutions of resources, which are being lost or wasted in present operations, for the purpose of achieving high level business control through the integration of information handling work presently being performed separately. Ultimate expansion will include a very high level of control through automatic data processing by establishing feedback relationships between all aspects of management and production, i.e., between sales forecast and the manufacturing process. Through centralization of information handling and processing work, integrated and comprehensive control through automatic data processing may be secured at its lowest cost.

Since the very life of business depends upon the availability and flow of up-to-date and accurate information, businesses will become increasingly dependent upon the data processing center and oriented thereto. The consequence of this linkage eventually may be the relocation of management to the data processing center or vice versa.

Communications service will make it feasible for both the large and the small user of automatic data processing to take advantage of large scale operations at low cost through centralizing information handling work. Low cost communications services are available today for the transportation of low volumes of information, i.e., using the teletype or the Data-phone. Low cost transmission of large volumes of information over single channels will be achieved also as developments in transmission and switching are made available. Thus, the use of inexpensive communications service for both small and large volumes of information will make feasible economically the centralization of information handling work. Most important is that the impact of the automation of information handling work extends from very large corporations down to small firms including perhaps the single proprietor.

Predicted developments in high capacity and low unit cost data processing equipment along with easier programming techniques and on-line facilities will make feasible and desirable the centralization of information handling work in order to secure the economies of scale and the most effective use of automation. The main problem is organizing to capitalize on centralized automatic data processing. However, eventually this will be overcome by devising suitable techniques and arrangements for standardization and the participation of several individual firms. It is expected also that the opportunity to secure competitive advantage by achieving higher degrees of business control through centralized data processing will reduce the reluctance of businesses to utilize these techniques.

Centralization of Information Handling Work

The forces tending to centralize information handling work at the sites of large data processing units are:

1. Greater productivity of capital investment in high capacity data processing equipment than in low capacity equipment.

2. Effective utilization of automatic data processing techniques requires a large investment in equipment which is warranted only when there are large volumes of data to be processed.

3. A high level of business control through automatic data processing is most effectively and inexpensively achieved through centralization of information handling work.

The case for centralization of information handling work is fairly well established. The question is what effect will this have on the general pattern of information-handling-business activity?

It is estimated that a single central data processing unit could handle the data processing needs of at least several hundred firms, and under certain conditions, many more than that. Technically, a central data processing unit could be set up to perform as many as one thousand trillion operations per month. This number would be sufficient to serve a million businesses each generating a billion calculations per month. From the viewpoint of volume, such a central unit could serve all the businesses in the Boston Metropolitan Area and perhaps more. However, because of the range of different work that would be generated by all the businesses in any metropolitan area, it does not appear that centralization will occur to the extent that there would be only one unit. On the contrary, it seems that there would be several units, perhaps several hundred, in a single area or region. Nevertheless, centralization of this amount of work is significant.

While the centralization forces tend to agglomerate some information handling work at single data processing units, the units that are actually set up would not tend to centralize in a single district of the city. There is no reason to believe that there would be an overall centralization of this activity. Instead this activity is made more mobile as a result of automation (reduction in linkages to large numbers of clerical workers) and because of low cost communications (reduction in importance of existing patterns of land use, access, and communications on the location of this activity). The location at which a unit would be established depends upon the location of the clients that it serves and where the air line-communication line distance between the unit and all of the clients is at a minimum.

The land planning significance of the centralizing forces lies in the implications that information handling work, and ultimately some related activities like information-analyzing and decision making activities, will be gathered together from a number of remote locations. This relocation of information handling activity has significance from the viewpoint of both the old and the new location of this activity. In terms of the new location, the land planner wants to know where this activity is likely to want to locate and how much of it will be located on one site. In terms of the old location the land planner wants to know what this means in terms of the reductions in business activity, employment, and the changed locational requirements of the remaining activities. In short, the land planner wants to know what may be the consequent distribution of business activity.

Distribution of Information-Handling-Business Activity

In considering what may be the consequent distribution or pattern of information-handling-business activity, three factors must be discussed: first, the operation of the centralizing force; second, the mobility provided by the use of communications; and third, the linkages established and changed because of automation.

The result of the operation of the centralization forces as outlined above is the relocation of some information handling work from several remote places where it is now performed to the site of a central data processing unit. This force will touch upon almost every firm in every type of business although its greatest impact will be upon those businesses that are heavy on the information handling work, namely, finance, insurance, wholesale trade, some services, and the central business offices of national organizations and firms. Most notable is the effect that this force is likely to have upon the CBD where clerical jobs are concentrated. The ultimate effect of the automation of information handling work and the use of communications to transport information may be an overall decentralization of this activity since the use of communications provides greater mobility and one locational objective will be the minimization of communications costs.

The use of low cost communications for transporting information to be processed by electronic equipment at a central data processing unit reduces the importance of existing patterns on the location of the central unit and gives the unit greater locational mobility. Conversely, communications will permit the providing of information handling services at almost any place where they are desired and yet take advantage of highly automatic data processing techniques. For example, consider the effect that a high degree of automation and centralization of records and data processing may have on banking. If all of the paper work of a financial transaction was automated so that the bank teller had only to record the transaction on a device at her desk and all the other functions were handled by a central data processing unit, it would not be entirely necessary to cluster tellers at the master record file in a single banking room or office. Instead, by using low cost communications, they could be disbursed to any number of points where the convenience to their customers and company profit could be maximized. Dispersal of the information gathering activities can be achieved only by centralizing records and data processing and by utilizing communications to link the many remote points to the central unit.

Communications allow not only the decentralization of information gathering activities to serve the needs of business and people which for other reasons are being decentralized, but also stimulate the centralization of information processing at large data processing units. While there is a strong force operating to centralize information handling at large processing units, it is expected that these units will have high mobility. The central units have high mobility since one of the major locational objectives is the minimizing of communications costs. In achieving this objective, the existing patterns will not be too important in influencing their location and the amount that communications costs would increase as a result of locating a significant distance away from the least cost location would not be too great.

Another factor that will contribute to the mobility of information handling activities in general is the change in the labor linkage caused by automation. In every instance where automatic data processing equipment has taken over information handling work, there has been a general up grading of positions. The general trend has been a reduction in semi-skilled clerical workers and a small increase in highly trained specialists to handle the automatic processing of information. This type of change in the labor requirements of business may make it more feasible for businesses to satisfy their labor requirements and take advantage of the amenities in less densely populated areas outside of the CBD.

It is expected that a change in the labor requirements and the mobility made possible through the use of communications will stimulate the decentralization of information gathering activities and ultimately the decentralization of data processing units.

The Sylvania Company is an excellent example of the mobility of a data processing unit. To determine where they should locate their data processing center, Sylvania used traditional location theory to determine the location at which the communications cost would be at a minimum. However, the final site selected was some forty miles away from the least cost location.

The site selected is at the periphery rather than at the center of the Syracuse metropolitan area to satisfy the need for accessability and service from Western Union and Remington Rand.

When the central data processing unit serves an entire region or the nation as a whole, as it does in the case of Sylvania, the possibility of the least cost location being outside of a built up area is great. When a single central unit serves a national organization, the least cost location would be to the west of the densely populated East coast. The least cost location will continue to move westward as population and business activity increase on the Pacific Coast.

A nationally oriented firm might find it more economical from the viewpoint of minimizing its communications costs to establish data processing centers on a regional basis rather than on a national basis. For example, it would seem logical for such a firm to set up a data processing unit to handle the entire Pacific Coast rather than transmit all information for processing across the large low density region between the Sierra Nevada and the Mississippi River. Integrated control could be achieved by transmitting only selected information that would be necessary for making top level decisions. The relative economics of this depend upon the total volume of information that is to be processed in any particular region and the balance between the cost of processing that amount and the cost of transporting it.

The Sylvania Company at present has most of its plants and branches located in the east with only a small percentage of their production located in the Pacific Region. Hence, with only a small need to process data in the Pacific Region, it is more economical to transport the information to the east than it would be to set up a data processing center there.

It does seem that a service bureau would not serve more than one metropolitan area because firms using it would minimize transportation costs. In a perfectly symmetrical metropolitan area, the least cost location might be in the CBD or at least near to it. Because of the high productivity of the use and the small portion of the total cost that rent would be, a central data processing unit might well be able to afford a choice central location if for other reasons it was desirable to locate there.

Communications costs are at least twenty percent higher in the CBD. If communications costs are significant, as they probably will be for high capacity units, their minimization is essential. The least cost location for a service bureau serving the Boston CBD would be in Cambridge because of the present rate structure. A service bureau serving the entire metropolitan area perhaps would be located in Brookline, Cambridge, or Watertown. A bureau serving the Boston-Providence area might be in Medfield.

Under the present rate structure, the cost of communications is a function of the air line distance between the two points for which the service is provided. There is a high probability that in the future the zone method for determining communications costs will be used wherein the cost of communications is the same between any two points located in the same zone. According to the communications companies, it would be advantageous to them to make the entire Boston Metropolitan Area and ultimately the entire State of Massachusetts a single zone in which the cost of communications would be the same. If this happens, any point in the zone would be equally suitable from the point of view of minimizing communications costs and greater decentralization can be expected.

Thus, it is clear that the most effective existing tool that may be used to influence the pattern of information handling work would be the rate structure for communications charges. Since the rate structure is controlled by the State and Federal governments, the effective use of this tool requires not merely regional thinking and regional planning, but mobilization for comprehensive regional coordination.

The Effect Upon the City

The effect upon the city arises out of the three ramifications of the use of automatic data processing and communications, i.e., the operation of the centralization force, the increase in mobility of information handling activities, and the altering of the labor requirements and linkages of businesses performing information handling activities.

The overall decentralization of information handling work as discussed above will have its greatest impact on those areas where this activity is concentrated, i.e., in the CBD. It is expected that due to the establishing of central data processing units at points where communications costs are at a minimum, the CBD may suffer a reduction in clerical employment as well as a loss of those jobs that would be created by automation. This would occur as existing businesses take advantage of central data processing.

In addition, the CBD may suffer the loss of employment due to increased productivity of workers achieved through automation. Also, there is the high possibility that some of the businesses that are located in the CBD to capture the clerical labor market there would find that automation has so changed their labor requirements that they may be satisfied as well or better in outlying locations. Some businesses may find also that they can operate better if there was more face to face interaction between some of their activities and the data processing unit. This is to be expected of the decision making role of management. This requirement may result in the relocation of these activities closer to the data processing center or vice versa if the center is controlled or owned by the particular business. Nevertheless, the impact of automatic data processing is likely to cause a change in the pattern of information-handling-business activities.

Off-setting these declines in employment are the various opportunities open to the businesses remaining in the CBD to undertake more data processing work than previously for the purpose of achieving higher degrees of business control. However, it is not known exactly what this additional work will require in terms of labor force. An additional factor that cannot be determined fully that may off-set declines in employment due to automation of information handling work is a possible expansion of business activity. Nevertheless, it seems reasonable to conclude that the CBD will suffer at least a small net loss in clerical employment.

As an example of what this could mean, consider the Boston CBD in which 210,000 persons were employed in 1957.[31] Of this number, 38%[32] to 48%[33] were clerical workers.[34] Under the realistic assumption that ultimately fifty percent of the clerical jobs could be eliminated through automation and twenty five percent of the persons laid off would be given jobs cre-

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[31] Boston City Planning Board.

[32] This is based upon a survey conducted by the U.S. Department of Labor, see: Bureau of Labor Statistics, Office Workers; Salaries, Hours of Work, and Supplementary Benefits, Bulletin No. 992, Washington, GPO, 1950.

[33] According to the estimates of the Boston City Planning Board.

[34] According to the definitions in the Bureau of Labor Statistics Survey, the following jobs were included: billing and bookkeeping machine operators, hand bookkeepers, calculation machine operators, file, general, order, payroll and typist clerks, keypunch operators, office boys, secretaries, stenographers, switchboard operators, transcribing machine operators, and typists. The source does not state that administrators or management personnel were included in the tally.

ated by automation, the net reduction in labor force would be from nine to twelve percent of the total CBD labor force or from twenty to twenty-five thousand persons. In addition, some of the jobs created by automation may be removed to a central data processing unit outside of the CBD. Since many of the other CBD activities, like professional offices, shopping, restaurants, entertainment establishments, etc., are dependent upon CBD workers for their business, the initial reduction of CBD employment may set off another round of decreases in employment in these activities. Ultimately, the new equilibrium point might be at a point where the total CBD employment is 25% or more lower than originally. The tertiary round of effects might include a decongestion of the highways leading downtown so that a higher percentage of CBD workers would be able to drive to work. This would involve a percentage reduction in transit passengers greater than the reduction in CBD employment. Included also would be a further altering of the function of the CBD in terms of information handling work as a high level node at which broker type activities are located. These activities would be the input and outlet for services that were performed at data processing centers outside of the CBD.

The running down of the primary, secondary, and tertiary effects that may ultimately occur would be an item for further research.

Effects on Non-Information Handling Activities

When a central data processing unit has been set up for a firm or corporation, in many instances the increases in the opportunities for coordination and control have made more feasible a greater decentralization of production units. The Sylvania company has professed this many times. Hence, to the extent that production-management linkages have impeded decentralization of production, the use of automatic data processing and communications can maintain this linkage when there is extensive physical separation. Thus, if the locational requirements of production -- market, resources, labor, transportation, taxes, building costs, worker environment, production techniques, etc. -- are conducive to decentralization, it is now feasible to decentralize greatly and yet maintain exact control. There is some question as to whether better control could be maintained if the data processing unit and the production unit were located in the same metropolitan area or the same city vis a vis separated by many hundreds of miles. The difference would be the cost of communications which would have to be weighed against the advantages of decentralization. The cost of communications, however far away the unit is located, is likely to be only a small fraction of total costs. (A private telegraph channel from the Pacific Coast to the Atlantic Coast would rent for about $1,000 per month which would be less than the total communications costs of even a medium small firm.)

Thus, the use of communications and automatic data processing may enable further dispersion and decentralization of units of production. The challenge to planners is that of devising techniques for dealing with rapid decentralization in terms of open space, community patterns, journey to work, homogenius verses hetrogenius areas, etc.

Land Use Characteristics of Central Data Processing Units

The most significant change in the character of land use of information handling activities is that of a significant increase in productivity per square foot of floor space. This has been a consistent trend in almost all forms of automation. This has been consistently true in information processing due to reductions in both work space and space for the storage of information. In the future, it is expected to be even more true because of the introduction of transistors and other small electronic components which will make smaller the data processing equipment.

A conservatively high estimate of the floor space required for a large, fast computer of the future along with communications equipment may be ten times the floor space required by the largest contemporary computers, i.e., 20,000 to 40,000 square feet. This would be equal to a one story building measuring from 140 to 200 feet square; about the size of a large super market. If most or all of the data preparation takes place at remote locations, the amount of floor space could be considerably reduced, perhaps even as much as 50 to 75 percent since the need for additional equipment would be reduced. The data processing unit certainly would generate less traffic than would a super market. At conservative standards for floor space per person, the employment at even a large unit probably would not exceed a few hundred with the average unit employing less than one hundred. Low employment could be expected especially if the data was prepared elsewhere and only processing was performed at the unit.

Alone, the unit is not a problem land use, in fact, it approaches somewhat the ideal described in R. C. Wood's, Suburbia, as a place of employment for PHD's where annually the product is picked up in a station wagon. Generally speaking, the problems that it might generate are trivial, i.e., access and parking for a few dozen employees and some visitors. Thus, central data processing units as such will not present many problems to planners.

There is the possibility of intimate linkages developing between other land uses and the data processing unit. The most obvious linkage is between management and the unit. The location of the management function and its ancillary activities plus any other activities that may develop linkages with the unit, could seriously alter the land use characteristics of the area around the data processing unit. Further research should be undertaken to determine the possible linkages that may develop so that these requirements may be satisfied in an orderly way.

Evaluation of the Study and Recommendations for Future Research

The study as outlined above gives a very general picture of how and why the concomitant use of automatic data processing techniques and communications may alter the pattern of information-handling-business activities, and the limits to which centralization of information handling work may occur. No doubt, the reader might have expected to find more specific information relating to the limits of centralization of information handling activity and particularly how automation would affect specific classifications of businesses as might be defined by an SIC number.

Due to the unavailability of key data, this approach could not be undertaken even though the practising planner might have found more direct use of that type of study. It is expected that future research designed to provide this information can be more easily undertaken by using material included here as a point of departure.

Specific advantageous future research, which could have been an alternative approach in this study, might proceed in two directions. First, on a broad and comprehensive level, research may be directed towards determining more precisely the most effective pattern of central data processing units in terms of size of service area, alternative arrangements of communications facilities for minimizing costs, and the cost of data processing as a function of volume. Hopefully, this research would lead to a contribution to the body of information that could enable planners to determine what would or should be the future form of metropolitan cities.

Second, on the level of the firm or a three digit SIC number, future research could be directed towards determining what would be the impact of automation on the pattern of that activity. The research could begin with some of the more important activities from an economic viewpoint that are primarily performing information handling work, i.e., banking, insurance, etc., and utilize the traditional economic theories of production and marginal products, etc. This technique would allow a more thorough evaluation and analysis of the changes in labor, material, and many of the operating inputs as they are affected by automation which could not be achieved in this study. By this means a series of cases could be compiled which would lead to a better understanding of the probable impact of these developments.

It is clear that automation in general, and information processing as it may be used to master-mind the utilization of other forms of automation in particular, will have an effect upon the pattern of business activities and that undertaking exploratory research at this time may pave the way to reducing the severity of future land use problems.

APPENDIX

APPENDIX I

Data Processing Units Compared in Method I by Means of Estimating the Time Required for Each Unit to Perform the Sum of the Squares of Fifteen Million Single Digit Numbers.[1]

Data Processing Units	Months Required To Form The Sum[2]	Total Equipment Costs For Forming The Sum[3]	Equipment Costs Per Million Digits Processed[4] C_p	Millions of Digits That Could Be Processed[5] in a Month[2] V
IBM 7090	.000877	$78.8	$5.25	17100
IBM 709	.0037	203	15.50	4050
IBM 704	.011	385	25.65	1360
Univac 1105	.058	1450	96.67	259
Univac 1103A	.0915	1830	122.00	164

Calculations; basic data:

$\Sigma(\log V) = 15.6021$

$\Sigma(\log C_p) = 7.4013$

$\Sigma[(\log V)^2] = 51.4805$

$\Sigma[(\log V)(\log C_p)] = 21.2014$

$$C_p = \frac{4366}{V^{.6914}}$$

[1] Estimates are based upon computer programs prepared by Remington Rand Univac and International Business Machines, Corp.

[2] A month was considered to have 21.7 days of seven hours each, i.e., 151.9 hours.

[3] This information was derived by multiplying the monthly lease price of the data processing unit by the number of months required to form the sum of fifteen million digits.

[4] This information was obtained by dividing the total equipment cost for forming the sum by fifteen.

[5] This information was obtained by dividing fifteen by the months required to form the sum of fifteen million digits.

APPENDIX II

Data Processing Units Compared in Method II.

Data Processing Units[1]	Add Time in Micro-seconds[2]	Monthly Lease Price	Millions of Additions That Could Be Performed[3] in a Month[4] V	Equipment Costs Per Million Additions[5] C_p
Alwac IIIE, 4096 Mem.	500	$1,775	1,250.	$1.42
Alwac IIIE, 8192 Mem.	500	2,050	1,250.	1.64
Burroughs E 101	50,000	1,000	12.5	80.00
Datamatic 1000	58	21,500	10,800.	2.00
Datatron	169	3,900	3,670.	1.06
Diana	186	11,250	3,340.	3.37
Elecom 120	330	3,500	1,890.	1.85
Elecom 125, 125 FP	330	4,185	1,890.	2.21
IBM CPC	760	2,200	820.	2.68
IBM 650 Ramac Tapes	700	3,700	890.	4.16
IBM 701	36	10,500	17,300.	.61
IBM 702	23	11,000	27,100.	.41
IBM 704	12	20,000	51,800.	.39
IBM 705	17	17,500	36,600.	.48
IBM 709	24	20,000	26,000.	.77
NCR CRC 102 A	7,400	2,400	84.	28.60
NCR 102 D	4,000	2,400	155.	15.50
Ordifiac	1,685	1,365	370.	3.70
Readix	850	2,725	735.	3.70
Univac I	282	13,390	2,290.	5.85
Univac II	120	18,540	5,180.	3.58
Univac 60	325,000	700	1.9	368.00
Univac 120	325,000	1,100	1.9	580.00

[1]Source for all data was Martin H. Weik, A Second Survey of Domestic Electronic Digital Computing Systems, Office of Technical Services Report, U.S. Department of Commerce, 1957.

[2]A microsecond is a millionth of a second.

[3]This information was derived by dividing the number of microseconds in 151.9 hours by the add time.

[4]A month was considered to have 21.7 days of seven hours each, i.e., 151.9 hours.

[5]This information was derived by dividing the monthly lease price by the number of additions performed in 151.9 hours.

(APPENDIX II, cont.)

Calculations; basic data:

$$C_p = \frac{364.57}{V^{.64199}}$$

$$\Sigma(\log V) = 70.337690$$

$$\Sigma(\log C_p) = 13.764979$$

$$\Sigma[(\log V)^2] = 250.333067$$

$$\Sigma[(\log V)(\log C_p)] = 19.478811$$

BIBLIOGRAPHY

BIBLIOGRAPHY

Communications

Baridon, R. W., "The Communication of Data", A New Approach to Office Mechanization: Integrated Data Processing Through Common Language Machines, New York, American Management Association, 1954, pp. 53-61.

Dirkes, Robert F., "Practical Aspects and New Horizons in Private Communications," Paper delivered at the Annual Convention of the Industrial Communications Association, San Francisco, May 21, 1958.

Earp, C. W., "Relationship Between Rate of Transmission of Information, Frequency Bandwidth and Signal-Noise Ratio," Elect. Commun., 25 (1948) 178-195.

Fidler, K. W., "Telecommunications at Shell-Mex House," British Communications and Electronics, 3-1 (January 1956) 10-13.

Goldman, Stanford, Information Theory, New York, Prentice-Hall, 1953, p. 371.

Jackson, "Information Theory," Nature, 167, 20-23, 1951.

King, Gilbert W., "Information," Scientific American, CLXXXVII (September 1952) 132-148.

Mayer, H. F., "Principles of Pulse Code Modulation," Advances In Electronics, L. Marton, (ed.) V. 3, New York, Academic Press, 1951, pp. 221-260.

Murphy, Vincent J., "Overhauling Wire Communications For Greater Savings," Streamlining Office Equipment and Service, Office Management Series, No. 135, New York, American Management Association, 1953, pp. 9-19.

Shannon, Claude E., "Communication in the Presence of Noise," Proc. I.R.E. 37, 10-21, 1949.

Tuller, W. G., "Theoretical Limitations on the Rate of Transmission of Information," Proc. I.R.E. 37, 468-478, 1949.

U.S. President's Communications Policy Board, "Telecommunications; A Program for Progress," A Report by the President's Communications Policy Board, Washington, 1951.

Automatic Data Processing

Bibliographies

Culbertson, James T., "Robots and Automata: A Short History," Computers and Automation, 6-4 (April 1957) 20-24.

Remington Rand Univac, Large Scale Digital Computers; An Annotated Bibliography.

U.S. Department of Labor, Automatic Technology and its Implications; A Selected Annotated Bibliography, Bulletin 1198, Washington, GPO, 1956.

General

American Management Association, Electronics in the Office: Problems and Prospects, Office Management Series No. 131, New York, American Management Association, 1952.

American Management Association, Establishing an Integrated Data-Processing System, Special Report No. 11, New York, American Management Association, 1956.

American Management Association, Keeping Pace With Automation: Practical Guides for the Company Executive, Special Report No. 7, New York, American Management Association, 1956.

American Management Association, Pioneering in Electronic Data Processing, Special Report No. 9, New York, American Management Association, 1956.

Carr, John W., and Perlis, Alan J., "A Comparison of Large Scale Calculators", Control Engineering, 3 (February 1956) 84-96.

de Latil, Pierre, Thinking by Machine; A Study of Cybernetics, Cambridge, Riverside, 1957.

Knight, Charles E., and Fawkner, Charles H., "The Impact of Automation on the Company Organization," Strengthening Management for the New Technology, General Management Series No. 178, New York, American Management Association, 1955, pp. 11-21.

Laubach, Peter B., and Thompson, Lawrence E., "Electronic Computers: A Progress Report," Harvard Business Review, 33 (March-April 1955) 120-128.

Leontief, Wassily, "Machines and Men," Scientific American, CLXXXVII (September 1952) 150-160.

"Office Robots," Fortune, XLV (January 1952) 82-87, 112-118.

U.S. Department of Labor, The Introduction of an Electronic Computer in a Large Insurance Company, Studies of Automatic Technology, 2, prepared by K. G. Van Auken, Jr., Bureau of Labor Statistics, Washington, GPO, 1955.

U.S. Joint Committee on the Economic Report, Automation and Technological Change, Report of the Subcommittee on Economic Stabilization to the Joint Committee on the Economic Report, 84th Congress, 1st Session, October 14-28, 1955, GPO, 1955.

Van Deusen, Edmund L., "The Coming Victory Over Paper," Fortune, 52 (October 1955) 130-132.

Central Data Processing

American Management Association, Administrative Automation Through IDP and RDP, Office Management Series, No. 144, New York, American Management Association, 1956.

Ammann, Charles E., "Airline Automation: A Major Step," Computers and Automation, 6-8 (August 1957).

Gallagher, Glen G., and Robinson, Robert A., "Trends in Process Automation," Instruments and Automation, 29 (February 1956) 294-298.

Hurd, Cuthbert C., "The Factory of the Future: Will Centralized Control Be Possible?" Keeping Pace With Automation, Special Report No. 7, New York, American Management Association, 1955, 97-101.

Koontz, Monroe M., "Supplementing Electronic Equipment with a Modern Communications System," Computers and Automation, 6-4 (April 1957) 12-17.

Steier, Henry P., "Airlines Plan Expanded Used of Reservisors," American Aviation, 19 (August 1, 1955) 27-28.

U.S. Department of Labor, Studies in Automatic Technology; A Case Study of an Automatic Airline Reservation System, Bureau of Labor Statistics Report No. 137, Washington, GPO, 1958.

U.S. Joint Committee on the Economic Report, "Statement By Don G. Mitchell, Chairman and President of Sylvania Electric Products, Inc.," Automation and Technological Change, Report of the Subcommittee on Economic Stabilization to the Joint Committee on the Economic Report, 84th Congress, 1st Session, October 14-28, 1955, GPO, 1955, pp. 169-196.

Applications

American Management Association, The Impact of Computers on Office Management: Experience in Computer Application, Office Management Series No. 136, New York, American Management Association, 1954.

"Automation," Time, 67 (March 19, 1956) 98-106.

"The Brain Builders," Time, 65 (March 1955) 81-86.

Canning, R. G., Production Control Through Electronic Data Processing: A Case Study, Management Sciences Research Project, Report No. 30, U.S. Department of Commerce, Office of Technical Services, 1954.

Colburn, Dorothy, "The Computer As An Accountant," Automatic Control, 1 (December 1954) 19-21.

Collins, Robert T., "Automation -- Advances in Automatic Production," Advanced Management, (May 1955) 26-30.

Diebold, John, Automation -- The Advent of the Automatic Factory, New York, Van Nostrand, 1952.

Fairbanks, R. W., "Electronics in the Modern Office," Harvard Business Review, XXX (September-October 1952) 83-98.

Forrester, Jay W., "Computer Applications to Management Problems," Strengthening Management For the New Technology, General Management Series, No. 178, New York, American Management Association, 1955.

"How a Computer Takes Over," Business Week, (July 24, 1954) 58-62.

Hurni, M. L., "Decision Making in the Age of Automation," *Harvard Business Review*, 33 (September-October 1955) 49-58.

Hurni, M. L., "Increasing the Opportunities for Automaticity," *Mechanical Engineering*, 76 (July 1954) 577-581.

Lucas, E. D., "Automatic Production Inventory Control," *Control Engineering*, 2 (September 1955) 68-73.

Massie, Joseph L., "Looking Around: Automation for Management," *Harvard Business Review*, 34 (March-April 1956) 139-152.

McPherson, James L.; Alexander, Samuel N.; Horton, H. Burke; and Glaser, E., "Information Processing in Social and Industrial Research," *Scientific Monthly*, 76 (February 1953) 100-108.

Meldon, Morley G., "What Computers Can Do For You," *Factory Management and Maintenance*, 114 (February 1956) 98-105.

Noe, Jerre D., "Data Processing Systems: How They Function," *Control Engineering*, 2 (October 1955) 70-77.

Osborn, Roddy F., "G. E. and Univac: Harnessing the High-Speed Computer," *Harvard Business Review*, 32 (July-August 1954) 99-107.

Pyke, Magnus, *Automation: Its Purpose and Future*, London, Hutchinson's Scientific and Technical Publications, 1956.

"Using a Computer to Run a Business," *Business Week*, (May 14, 1955) 68-75.

Woodbury, D. O., *Let Erma Do It*, New York, Harcourt-Brace, 1956.

Business Control

"Automation: A Factory Runs Itself," *Business Week*, (March 29, 1952) 146-150.

Ayers, Eugene, "An Automatic Chemical Plant," *Scientific American*, 187 (September 1952) 82-96.

Block, Alan, "Feedback Systems: A Basis for Self-Regulation," *Automatic Control*, 1 (July 1954) 16-22.

Brown, Gordon S., and Campbell, Donald P., "Control Systems," *Scientific American*, 187 (September 1952) 56-64.

Canning, R. G., "Cost Reduction Through Electronic Production Control," Mechanical Engineering, 75 (November 1953) 887-890.

Duncan, Robert A., "A Case for Electronics in Process Control," Automation, 3 (February 1956) 67-71.

Findlay, David A., "Electronic Controls for Machine Tools," Electronics, 29 (February 1956) 122-129.

Higgins, John A., and Gleckauf, Joseph S., "Electronics Down to Earth," Harvard Business Review, 32 (March-April 1954) 97-104.

Leaver, E. W., and Brown, J. J., "A Caveat on Computers," Automation, 3 (February 1956) 38-42.

Leaver, E. W., and Brown, J. J., "Machines Without Men," Fortune, XXXIV (November 1946) 165, 192-204.

Nagel, Ernest, "Automatic Control," Scientific American, CLXXXVII (September 1952) 44-47.

Ridenour, Louis, "The Role of the Computer," Scientific American, CLXXXVI (September 1952) 116-130.

Stocker, William M., Jr., and Emerson, Charles D., "Numerical Control: What It Means to Metalworking," American Machinist, 98 (October 25, 1954) 133-156.

Analysis

American Management Association, Electronics in Action, Special Report No. 22, New York, American Management Association, 1957.

Downs, Joseph V.; Keelan, Charles I.; and Bills, Marion A.; "Planning the Purchase of Office Machines," Streamlining Office Equipment and Services, Office Management Series No. 135, New York, American Management Association, 1953, 19-35.

Carroll, John M., "Electronic Computers for the Businessman," Electronics, 28 (June 1955) 122-131.

Chapin, Ned, "Can Computers Cut Your Costs?" Automation, 3 (March 1956) 45-51.

Clippinger, Richard F., "Economics of the Digital Computer," Harvard Business Review, 33 (January-February 1955) 77-88.

"Consumer Market Survey -- Report No. 1," Computers and Automation, 6-5 (May 1957) 8-17.

Evanson, C. E., "Evaluation and Planning for Automation," Automation, 3 (April 1955) 22-30.

Weik, Martin H., A Second Survey of Domestic Electronic Digital Computing Systems, Office of Technical Services Report, Washington, U.S. Department of Commerce, December 1957.