The Effects of Information Technology on Management and Organization.

Robert Sexton Adams
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in

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by

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ABSTRACT

Rapid and extensive progress is being made in the development of a new kind of technology - the processing of business information. This technology, commonly known as information technology, has moved into the area of management to affect jobs and organization. As a result, there is a growing concern and interest whether information technology will revolutionize the practice of management.

In the few short years since the inception of information technology into business organizations, numerous prognostications have been made proclaiming a revolutionary impact on management organization and processes. Consequently, this study undertakes an analysis and evaluation of the changes experienced by a selected company, which is a leader in its field, in order to judge these predictions. The hypothesis tested is that the effects of information technology on management have been an evolutionary process rather than the predicted revolutionary impact.

As a part of the analysis of information technology's effects on management, company operations employing various components of information technology, i.e., electronic-data-processing and management science techniques, were studied in order to gain a perspective of the corporate and departmental organization changes occurring since the introduction of
information technology. Managerial functions of decision making, planning, and controlling were subjected to the same type analysis as were the scope and nature of the managerial jobs concerned. These functions and jobs were evaluated at all levels of management within the organization.

The findings of the investigation reveal that information technology is not creating a structural revolution within the selected company, nor has its impact on middle management been as revolutionary as predicted. The organizational alterations which can be attributed to this phenomenon occurred at the departmental level and were of a minor nature. Although automatic decision making, generally of a routine nature, has penetrated the area of middle management, there has not been the widespread elimination of middle managers nor the relegation of them to positions of minor importance. Middle and supervisory management functions of decision making, planning, and controlling have been improved but not revolutionized.

Top management's functions and duties have been generally unaffected by information technology. Moreover, it is unlikely that upper management will be affected directly for many years since information technology can touch only the fringe of the problems faced by these managers. The major effect at this level has been an indirect one in that decision making, planning, and controlling have been improved by the speed, accuracy, and conciseness of information at lower organizational
levels. These improvements furnish a more precise base upon which top management decisions can be made. Centralization of decision making in top management has not occurred.

As a result of the evidence of this investigation, the conclusion is reached that the changes occurring within the company have been evolutionary rather than revolutionary. In most instances the findings of this study have been contradictory to the predictions found in the literature. The ability to compile large amounts of information quickly and to process it in various fashions can have only a minor impact on personnel involved and the organization in which it is used. Although many improvements have occurred because of information technology, they do not constitute a revolution in overthrowing managerial processes and practices at this company.
INTRODUCTION

In a little more than a decade, rapid and extensive progress has been made in the development of a new kind of technology - the processing of business information. The group of workers most affected by this new technology is business managers.

"Information technology," the name given to this new technology, embraces the various techniques and disciplines (operations research, simulation, electronic data processing) which can be and have been applied to the development of data in business. This technology has mushroomed in the past few years with most of the practical application confined to electronic data processing. The revolution in electronic data processing in many ways parallels the earlier days when factory mechanization was replacing manual operations and significant changes were occurring within the organization. Now, instead of a product being automatically processed, computers are processing managerial information. Thus, management itself is being affected.

The power plant of this advance in technology is the computer which has brought about changes in established methods of operation. It is becoming an indispensable tool in a wide variety of fields. The computer was initially used in scientific and technological fields where it solved
mathematical problems that required thousands of man-hours to solve manually. Clerical work was the next wide-spread application for the computer. In some instances, it is performing relatively simple office tasks, such as billing customers or figuring payrolls.

More recently, computers have moved into industry to control manufacturing processes and into the area of management to affect jobs, organizations, and philosophies.

As a result, there is a growing concern in management, particularly middle and supervisory management, over information technology. Many managers are now discovering that their jobs, functions, and organizations are slowly adjusting to this new technology.

Because of the growing interest in information technology's effects on management, numerous articles have been written proclaiming a revolutionary impact on management functions, job contents, and organization structures. An attempt is made in this study to delve behind these generalizations and to analyze in depth information technology's effects on the management of one company.

Purpose of the Study

This study was undertaken to test the hypothesis that the effect of information technology on management and organization has been an evolutionary process rather than the revolutionary impact as predicted by many writers.
The general thesis of this study is that many predictions of authorities on information technology are generalizations which will not apply with equal validity to every organization. Therefore, through research conducted at one company, this investigation is directed toward gaining a perspective of the effects of information technology upon management.

Scope and Nature of the Presentation

The evaluation of information technology's impact on management is a difficult and complex task. Edith Goodman stated that it:

... is as difficult as picking a single colored thread from a complex plaid. Interwoven like various colored threads through the fabric are such factors as a rapidly changing economy, management's attitude toward the computer, the purpose for which the computer is used, technology employed and many others.

As difficult as this task may appear, an attempt was made to determine what has happened to date in one company. An examination of the literature in this area revealed several industries that have made the most progress with information technology. From these industries, one company was selected on the basis of its willingness to cooperate in an investigation of this kind. Its experiences with information technology will be analyzed in depth. Personal consultations

with key management personnel provided the primary source of data, although some secondary resources were utilized. Conversations, however, with other businessmen and computer manufacturers supplied numerous insights into the problem.

This investigation is not an effort to get a comprehensive view, all experiences considered, but to see what is happening in one company selected for detailed study. To provide a general background, the investigation went into a wide variety of activities involving computers. However, it did not cover the specific and technical aspects of computer operation, nor the details of programming and coding.

The major emphasis is placed on certain management functions and organizational aspects which would seem to be affected by this technology. When possible, "before" and "after" analyses were made. In many instances, however, this type analysis was difficult to do since many of the changes evolved so gradually that management was unaware of the extent of the changes. An effort was made to examine the scope and job content of certain operating management jobs. Organizational structures were also examined to determine whether certain management positions have been eliminated or combined due to the influence of information technology.

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Background of the Company

The company under study, the Petro-Chem Refinery,\(^2\) is a large subsidiary of a major oil company which processes several million gallons of gasoline per day. In addition, it also develops a complete line of other petroleum and chemical products which are widely marketed.

Although the company requested that its identity be disguised, the five members of the examination committee are well aware of what company was investigated. Several of the members have personal and detailed knowledge of the company and its operations. Therefore, the results and findings of this study can be verified easily by the committee. This lends an air of authenticity that might otherwise be lacking in an investigation where the identity of the company must remain anonymous.

Assumptions

First, it is assumed that the company under study is a leader in the field of automation, including the automation of information processing. Therefore, if information technology is having a revolutionary impact on management functions and organization, it will be apparent in this company.

Second, it is assumed that the observations of the effect of information technology on management and organization in

\(^2\)The name of the company has been disguised.
this company can be used as an objective criterion by which to judge the predictions found in the literature.

Limitations

The primary limitation of a study of this type concerns the reliability of the observations and conclusions drawn from the study. It should be noted that much of the area dealt with falls into the realm of subjective judgment rather than objective fact. The word "observation" is used since major reliance was placed on unstructured interviews with management personnel. Their views concerning changes in their jobs, as well as organizational changes, were solicited and relied upon. Many of the departmental organization changes noted in this study, for example, could not be traced through existing organizational charts, but rather came from the memory of various department heads.

In addition, there is the limitation of how accurately members of management perceived and interpreted the changes affecting them and how objective they were in discussing such changes. The possibility exists that many of the people interviewed were not completely objective in discussing the effects and changes information technology may have had on their duties and functions. Their bias probably affected the results of this investigation. However, it is believed that sufficient interviews were conducted with various company
executives to cross-check the accuracy of individual interviews.

Definition of Terms

Information technology, as used in this study, involves three areas of activities: (1) the use of mathematical and statistical methods, with or without the aid of electronic computers; (2) the use of computers for mass data processing; and (3) the direct application of computers for routine planning and decision making and for more sophisticated decision making through simulation techniques. These areas are interdependent to some degree, and for that reason are called "information technology."³

Although different levels of management within a firm are often grouped together in the all-encompassing term, "management," for purposes of this study it is thought best to differentiate between the various levels. Top management, as used here, consists of those persons from the general manager through the level of product managers.⁴ Middle management includes those persons occupying intermediate and somewhat lower positions in the organization. This classification includes such management positions as division


⁴See the organization chart, p. 66.
and department heads. Supervisory management includes those departmental personnel below the department manager.

Plan of Presentation

Chapter I is involved with the task of presenting an introduction to information technology and its various components. Brief descriptions of data processing systems, management sciences, and computer simulation techniques are presented for orientation purposes.

Chapter II presents various applications of information technology at the Petro-Chem Refinery. Its integrated data processing system is described in detail, together with refinery simulation techniques, gasoline blending, and other techniques. These applications of information technology are described in detail so that an analysis and evaluation of their impact on management and organization will be more meaningful.

Organizational changes that have occurred, either directly or indirectly, due to information technology are presented in Chapter III. These changes are analyzed here in order that information technology's effects on management may be properly analyzed in the following chapter. These changes are compared with the prognostications of information technology's effects on organization.

The analysis of information technology's impact on management is analyzed in Chapter IV. The effects on top,
middle, and supervisory management are emphasized, especially any change in their traditional functions. Again, the evidence is contrasted with various predictions found in the literature concerning information technology's effects on management.

Finally, the summary of conclusions is set forth in Chapter V.
CHAPTER I

INFORMATION TECHNOLOGY AND ITS COMPONENTS

This chapter describes information technology's various components in order to furnish a background and an understanding for the techniques applied at the company under investigation. Brief descriptions of data processing systems, management sciences, and computer simulation techniques are presented as aids to decision making within the organization.

Decision Making in Business

Traditionally, the task of decision making in a business enterprise has been the prime responsibility of the executive. This job has become more difficult, with increased uncertainty as to the outcome of any decision, as the business environment has become more complex. Firms have grown in size of operations and in terms of products sold. Competition between companies has become much keener as the number and types of products sold have multiplied. This, in turn, has required marketing channels to be revamped, and, in many cases, the geographical scope of operations has been expanded.

The factors producing this complex business climate are many, but it is the end result - the increased complexity in decision making - that must be recognized.
An executive has an upper limit to the significant facts which he can retain and bring to bear on a problem at a given time. As business has increased in complexity, the factors which logically must be considered in each decision have multiplied many times. The obvious answer is to develop a means of collecting the relevant facts and to present them in a synthesized form so the executive may make the best possible decision. Data processing systems and management sciences, discussed in the following section, perform that type of service for decision makers.

Components of Information Technology

Information technology has already been defined as the processing of large amounts of information using a high-speed computer, use of quantitative techniques in decision making, and use of high order simulation techniques in the digital computer.\(^1\) Although the mathematical techniques are not new, their application to the computer has taken place in industry during the past few years.

This section will describe data processing systems and mathematical and statistical techniques as they apply to this investigation. No attempt will be made to develop these areas in detail. Only a general description will be made in order

\(^1\)Leavitt and Whisler, op. cit., XXXVI, 41.
to familiarize the reader with the terminology and techniques found in the chapters on company analysis.

Data Processing Systems

Data processing. Data processing is the office counterpart to production automation in the factory. In describing data processing, several significant points should be stressed. First, data must be screened by the processing system in order to develop pertinent information for managerial decision making. Thus, there is a significant difference between data and information. Second, the term "data reduction" stems from the processing of voluminous facts into meaningful form. In a sense, unwieldy amounts of data are "reduced" to manageable proportions in scientific computation and analysis. Third, business-data processing involves the flow of information for decisions within an organization. Data processing is involved regardless of the tools used in implementation, whether pencils and paper, hand calculators, or large-scale electronic digital computers.

Electronic computers. A computer is "a machine that manipulates symbols in accordance with given rules in a predetermined and self-directed manner. Speaking more technically, an automatic computer is a high-speed, automatic,

electronic, digital data-processing machine." The electronic computer offers tremendous potential as a management tool. Work (suited to its talent) can be done faster and more accurately with the computer than with any other equipment. Computers, programmed to carry out linear programming calculations, are now used to determine product mix for oil refineries. Also, a large commercial airline has used computers to simulate major parts of its flight and terminal operation and has used the simulation to decide how many reserve aircraft it needed - an investment decision of great magnitude. The potential applications of computer techniques to management problems, however, depend upon an individual company's attitude toward the computer, the technology involved, and the changing economy.

Electronic data processing system. Figure 1 represents in abstract fashion an electronic data processing system. This system is similar to a data processing system in general; that is, there are five basic elements, including input, output, operations, storage, and control.

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5Goodman, loc. cit.
Figure 1. An Electronic-Data-Processing System.


The larger circle represents the total system with connection to the environment via input and output media. The media could include punched cards, punched paper tape, magnetic tape, typewriters, or console instruments on the input side and the same elements for the output side, with the addition of high-speed printed output.

The operations element of the electronic data processing system involves arithmetic and logical manipulations. Storage facilities include magnetic cores, magnetic drums, magnetic disks, and auxiliary storage via the use of magnetic tape. The control element includes the program which covers, in minute detail, the steps to be taken in the processing
operation. Typical applications of electronic data processing include payroll, inventory, and accounts payable.6

Integrated data processing. Integrated data processing recognizes that business data flows through an organization in what is called an information system from its point of origin to the point of final use. An information system may be identified as a network of data processing operations which results in the creation of meaningful information such as the customer invoice, the employee paycheck, or the management report.

Integrated data processing, according to Garrott, is:

... a plan for mechanizing business paper work. One of its prime purposes is to reduce the danger of human failures by reducing the degree of direct human participation in the processing of vital business information. Another is to provide that information wherever it is needed, and in the form it is needed - more quickly.7

Integrated data processing, as used in this study, is the coordinated and uninterrupted flow of data from their point of origin to the point of providing management with essential information. The data typically are translated into a coded medium at their source. Mechanical and electrical equipment are employed whenever they will aid in organizing information handling into an uninterrupted whole.

6Johnson, op. cit., p. 192.

Many firms have succeeded only to a limited degree in developing integrated data processing.

The most sophisticated data processing systems are represented by "real-time," or "on-line," systems. In these cases, the computer is an integral part of an information-decision system, and it is used to provide information during the actual decision process. Whereas typical applications call for collection of data over some period of time to be processed as a batch, real-time, or on-line, processing requires up-to-the-minute processing and current information for decision making. So far, this approach has not been evident in industry.

Management Science

The term management science, as used here, covers a variety of mathematical and statistical techniques. No attempt will be made to cover the techniques exhaustively; each warrants book-length treatment to ensure some degree of understanding.

Operations research. Operations research, the first technique discussed under the general heading of management science, may be defined as:

... the application of scientific methods, techniques, and tools to problems involving the operations of a system so as to provide those in control of the system with optimum solutions to the problems. ... Its procedures can be broken into the following steps:

1. Formulating the problem
2. Constructing a mathematical model to represent the system under study
3. Deriving a solution from the model
4. Testing the model and the solution derived from it
5. Establishing controls over the solution
6. Putting the solution to work

The use of mathematical models is stressed in operations-research problems, and the definition implies treatment of larger-scale problems than was practicable with earlier techniques.

Problems in complex industrial settings often require the use of electronic computers. A computer allows solution of typical problems in a matter of minutes which would take thousands of individual steps requiring endless hours of clerical work without it. Not all mathematical analysis must be done via electronic computers. The problem in question must be analyzed in light of the most likely techniques and the most efficient processing of data required for solution. However, the importance of computers to management science will be increasingly evident as additional tools and techniques are explored.

**Linear programming.** Linear programming is one of the most useful of the operations-research techniques. It is both an approach to the formulation and statement of the problems for which it is suited and a set of mathematical

---

procedures for making the calculations leading to selection
of the best course of action. It has been defined as:

... a technique for specifying how to use
limited resources or capacities of a business to
obtain a particular objective, such as least cost,
highest margin, or least time, when those resources
have limited uses. It is a technique that systema-
tizes (for certain conditions) the process of se-
lecting the most desirable course of action from
a number of available courses of action; thereby
giving management information for making a more
effective decision about the resources under its
control.9

Linear programming has been applied with good results in the
determination of:

1. The most profitable manufacturing program
2. The best inventory strategy
3. The effects of changes in purchasing and selling
price
4. Whether to make or buy certain components
5. The best location of plants
6. The lowest-cost manufacturing schedule
7. The best location of warehouses and distribution
outlets
8. The most profitable product mix10

9Robert O. Ferguson and Lauren F. Fargent, Linear

10Johnson, op. cit., p. 221.
This is only a partial list of applications, but it does point out the type of problem for which linear programming is most useful.

Statistics and probability. Many classes of problems involving uncertainty require somewhat different techniques of analysis. For this reason, statistics and probability are appropriate tools in this area. Statistical inference is a firmly established analytical technique of management. Modern statistical techniques provide a useful tool for the decision making process primarily in the area of estimation and hypothesis testing.

Many managerial decisions involve assumptions concerning the probability of future events. Therefore, an understanding of probability theory and its application in decision making is important. The probability of certain outcomes must be related to the importance of those outcomes in order to provide meaningful information. The probabilities which must be attached to particular events may be obtained from past experience, or it may require judgment on the part of the decision maker.

Queuing theory. Queuing theory or waiting-line theory applies to those decisions which arise when service must be provided to meet some demand which is neither controllable nor precisely predictable by management. Some of the basic characteristics which may vary from problem to problem include:
1. The size of the group being serviced, i.e., whether it is finite or infinite
2. The elements requiring service, whether they are "patient" or not
3. The distribution of holding or servicing times
4. The characteristics of arrival, i.e., their time pattern
5. The number of servicing units

Applications of queuing theory for determining the appropriate number of toll booths, bank tellers, and maintenance men are not unusual.

**Game theory.** Game theory involves analysis of the choice of strategies in competitive situations. It had a major impact on the development of linear programming, as well as starting a new way of thinking about competitive decisions. Since game theory to date is still primarily a field of pure theory, applications are few and limited in scope.

**Simulation**

Simulation, as a problem-solving tool, has been used for a number of years. It has enabled management to experiment with and test certain types of policies, procedures, and organizational changes in much the same way an engineer tests

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12 Churchman, Ackoff, and Arnoff, *op. cit.*, p. 519.
new designs. With the use of computers and probability methods, simulation can also be applied to complex operating plans or management controlling systems in addition to day-to-day operating problems.

Simulation means "to obtain the essence of, without reality." It is used to imitate the behavior of a system for the purpose of studying the response to specific changes. Where the problem is entirely physical in nature, such as in testing a new product, the object itself can be used. However, in studying business systems, an exact analogue of the problem may not be possible because of the dangers involved. Thus, various devices such as pilot lines, scale models, and mathematical models are used.

These mathematical models, in the form of equations, describe the elements and properties of the system under study. It should be noted that a model need not duplicate actual conditions to be useful. A model should be designed to predict actual behavior resulting from changes in the system design (i.e., policies, procedures, or organizational changes). Thus, insights into the response characteristics

13 Johnson, op. cit., p. 227.

of the system are obtained by examining the results shown in the computer output.

Several illustrations of how such techniques are used in actual operation are given in the next chapter. One is the use of a linear programming model in gasoline blending problems, and another is the use of complicated techniques in simulating operating processes in an oil refinery. Also, an economic model used to simulate investment decisions will be discussed.
CHAPTER II

APPLICATIONS OF INFORMATION TECHNOLOGY

AT PETRO-CHEM REFINERY

This chapter develops the applications of information technology at the Petro-Chem Refinery. The seven-project "EDPM Master Plan" (electronic data processing machines) will be described in detail since this integrated information system has had the largest influence on management organization. Business simulation techniques are also developed fully since they, too, play an important role in refinery operations.

Developments in Information Technology

Technological change has long been accepted as an intricate part of the refining phase of the petroleum industry. The Petro-Chem Refinery in particular has been an advocate of continual modernization in order to be a leader in its field. For example, the first full-scale fluid catalytic cracking unit ever built was installed in this refinery in 1942. This development, perhaps the most important in the oil industry, was but one of a series of changes taking place almost constantly.
Punched Card Equipment

This refinery readily accepted a mechanized data processing system in the late 1930's when it acquired an installation of IBM punched-card equipment. This installation was located in, and operated by, the Accounting Division and was devoted entirely to accounting operations. Acquisition of new equipment continued over the years, particularly the period immediately following World War II, as more and more of the accounting work was mechanized. By the early 1950's, the refinery had one of the largest punched-card installations in the South. Throughout this period it concentrated on the mechanization of accounting work as a means of cost reduction. As a result, accounting division personnel was reduced from 263 employees in 1946 to 174 employees during this period. As of August, 1964, there were 72 people involved with accounting activities in the Accounting Department. As a result of plant-wide interest, data processing activities were gradually expanded to other departments. By mid-1953, a considerable amount of non-accounting work was being done on IBM equipment.¹

Limitations of the Equipment

There developed in the mid-1950's a feeling among the systems people in the Accounting Division that the limit in

¹Statement made during an interview with the Data Processing Manager, August 17, 1964.
cost reductions and improved systems had been reached in punched card equipment. The personnel directly involved with the data processing activity were concerned with the approach that had been taken in developing the data processing system. Through a process of evolution, a system of small pieces had been developed. Mechanization had taken place on a departmental basis rather than on an integrated functional basis. A study of the problem clearly indicated that maximum benefit from mechanization could come only from development of an integrated functional system crossing departmental lines. This study led to the development of a basic framework for an integrated data processing system. This report also pointed out that the conventional punched card equipment lacked the speed and flexibility to implement this integrated system.²

Appointment of a Feasibility Committee

During this time, International Business Machines Corporation was releasing reports concerning their new 650 electronic data processing machine. A three-man committee was appointed to look into the feasibility of this machine for data processing usage at the refinery. This feasibility study convinced top management that the refinery should have computers. Orders were placed for two IBM 650's and one IBM 705, which were delivered in 1955 and 1956.

²Ibid.
The committee began to work on the development of data processing systems suited to the use of this equipment after the orders were placed. A new approach was needed in order to utilize fully computer capabilities since the punched card equipment had been pushed to its maximum. The study group decided that the computers could provide the speed and flexibility to develop the integrated functional system crossing departmental lines. The "EDFM Master Plan" that resulted from this decision can be seen in Figure 2 on the following page.

Organization of EDP

Originally, the committee which conducted the feasibility study was part of the Accounting Division reporting directly to the Chief Accountant. This organization existed until after the decision was reached to develop an integrated system. During the period of conversion to the computer, the size of this group was gradually enlarged by personnel trained in computer programming. This group was then recognized as a separate department.

While this organization for data processing was developing, a group had been set up to handle the technical computations on the IBM 650 and 705. As time went by, it became evident

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3This section was developed through personal interviews with the Heads of the Business Systems and Data Processing Departments during the week of August 17-21, 1964.
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Figure 2

that all computing should be centralized in one department and the programming for business and technical computation done by one group. Consequently, a Methods Development and Programming Department was formed for this purpose and was established as part of the Business Services Division. Data processing continued to operate as a separate section reporting to the Accounting Division. It continued to have responsibility for operation of the computer and the maintenance of all operational programs.

As the EDPM Master Plan became more complex and as other phases of information technology developed, the placement of data processing in the Accounting Division was questioned. This uneasy placement of data processing in this division led
to a divisional reorganization. Accounting is now a department in the Business Services Division. A Computing and General Services Department, on the same organizational level as accounting, was established. It consists of three sections: Business Systems, Operations Research, and Data Processing.

The "EDPM Master Plan"

Five of the projects, M, P, A, F, and E, as shown in Figure 2, went into effect in 1956. By the end of 1958, Projects S and O were also operational. Originally, these projects were programmed on the IBM 705. In 1958, however, a conversion was made to the IBM 7074—a machine of much greater sophistication. It is in operation two shifts a day running the following seven projects:

Project P: Payroll and Personnel. The Petro-Chem Refinery had two major goals in this project: (1) to reduce the tremendous duplication of personnel records at the refinery level, and (2) to assist supervision in assigning people to their jobs.

The refinery, in 1956, had approximately 5,000 hourly paid employees of which about 2,000 were assigned to the Process Division and about 3,000 were assigned to the Mechanical Division. The Process Division was responsible for the operation of the processing units, and the Mechanical Division
was responsible for the construction of new facilities and repair and maintenance of the existing process units.⁴

Manpower allocation, in the past, for the employees of both divisions was carried out by the foremen, who made out time sheets at the end of each day giving the name and number of hours worked for each employee assigned to him. These time sheets were sent to the payroll section, and this information was placed on punched cards for input into the payroll system.

When time control in the Process Division was converted to the new project, the computer was given a list of all people assigned to each unit for each shift. The computer now prepares its own new list each day. Every day each foreman receives a printed form indicating the people expected to work at each job for the following day. If all assigned employees work full time, the foreman signs the sheet and returns it at the end of the day. Corrections pertaining to assignments and hours worked can be noted on the time sheet by the foreman. The returned sheets then become input to the computer; only the changes are considered.

⁴Since 1956, a reorganization at the plant level has occurred. Process operations are now divided into two groups: petro-chemical operations and chemical operations. The Mechanical Division and the petro-chemical operation are placed under a Petroleum Products Manager, and the chemical operations are under the Chemical Products Group. See p. 66 for organizational chart. However, the principles of manpower allocation are the same as they were before the reorganization.
The time sheets also provide the basis for preparing the next day's list of assignments, the labor cost distribution, and a corrected payroll tape for the bi-weekly pay period.

Employees in the Mechanical Division, unlike the ones in the Process Division who must keep their stations manned constantly, are not scheduled to specific jobs on a regular basis. Any assignment system for them must be quite flexible - a very complicated task.⁵

In the past, the Planning Office would reassign men who had completed their jobs. This was a daily task involving several hundred men. Since many of these jobs were scheduled to end on Friday, the following Monday there might be as many as 500-600 people awaiting new assignments. The Planning Office would then make these assignments, matching skills with job requirements.

In 1956 management realized that this unsatisfactory arrangement could not continue. Thus, the planning function was reorganized by shifting from craft supervision to multi-craft supervision or supervision by area.⁶ This system was

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⁵This section of the study involving manpower scheduling in the Mechanical Division was developed through an interview with the head of this division and with a planner. These interviews were conducted on August 18 and 25, 1964.

⁶Pressure for craft supervision was applied by both union and management alike up to this time. In other words, electricians would supervise electricians; carpenters would supervise carpenters, etc. Multicraft or area supervision required the foremen to supervise many different craft skills - a greatly improved arrangement.
designed to achieve mechanical flexibility. The planning work of the Mechanical Division was divided into five parts, three operating divisions for the refinery, one for construction, and one for the machine shop. Each division was further divided into zones and then into areas.

**Manpower allocation** is now done in two steps. First, there is a weekly meeting of the division planning supervisor and the five zone planning supervisors. At this meeting the manpower allocation to the five divisions for the next week is determined. Next, each zone supervisor makes a daily allocation of the available personnel to the areas where the work is to be done. This requires the zone planning supervisor to have a thorough knowledge of the jobs to be done and the skills required to do them.

The area supervisor receives a daily work schedule sheet from the computer showing the men assigned to him, broken down by skills. This computer run schedules maintenance people not only to their job assignments for that day, but also for the following day, so that the supervisor can plan ahead to some extent. The foremen, upon receiving these sheets, examine them, make any corrections necessary, sign them, and send them back to the payroll section. These corrections have been running at a rate of about 17 per cent of the original total entries. Corrections are then typed on a semi-automatic typewriter which prepares a new tape. The information from the work schedule sheets then becomes
input for the payroll. Allocation of labor cost for each skill is obtained by furnishing the computer total hours worked per skill. Each job is then charged for its skill requirements.

The zone planning supervisor also receives a copy of the work schedule sheet for each area supervisor, and also reports on jobs completed and work requests from area supervisors. From these he can match men released from completed jobs to the work requests from the area supervisors. The changes in assignments resulting from these are sent to the computer and serve as a basis for preparing the next day's work schedule sheets.

In order to reduce labor cost, the Mechanical Division has cut its labor force sharply in the past several years. There are now approximately 1,500 wage earners and about 200 supervisors. The work force for the entire refinery numbers less than 4,000.

Many types of construction and maintenance work are now done by contract rather than by the Mechanical Division's work force. For example, cooling tower repairs are done by contract as are major steel revisions to a process unit, repairs to a vessel and to piping. Maintenance painting by contract has just begun. Understandably, work done by contract is a touchy subject for the union at this time.

The personnel inventory and recruitment program is still another part of Project P. The personnel inventory production
provides a basic record for each employee for the accumulation of all personnel history from which personnel statistics, seniority lists, educational attainments, and other information can be produced.

The Petroleum Products Manager said that this part of the project is extremely useful to management. With all pertinent employee information on a master tape, it is relatively easy to obtain educational achievements for each employee, for example. This information is then used in selecting personnel for various training programs in order to prepare them for changing technology.

The professional recruitment part of the project covers the interviews with thousands of prospective employees each year and provides a complete file of relevant information about them. The number of people contacted by each interviewer in each job classification is also provided along with job offers made and the number hired. Periodic follow-ups on those interviewed are also made if the company is interested in contacting them. Management can determine, through periodic reports, the effectiveness of interviewers and the recruitment program to determine if any changes are needed.

The major goal of Project P in reducing the duplication of personnel records has been accomplished with great success. In general, the reduction in clerical work has greatly aided supervisors and management personnel by permitting them to do a better job of supervision. Planning personnel, in particular, can do a better job of forecasting construction and
maintenance projects and scheduling the necessary manpower to meet them. With this decrease in clerical burden, one planner commented that he now receives five or ten times more pertinent information that helps him meet his responsibilities.

Project M: Materials and Stores. The refinery storehouse contains some 25,000 items of maintenance and operating supplies and is maintained by the Stores Department of the Mechanical Division. In addition to controlling this inventory, the IBM 7074 is utilized for reordering, follow-up, checking, and paying invoices on these 25,000 stock items.

Inventory is controlled by furnishing the computer daily all material receipts and all stock issues for each stock item. By adding to the starting inventory all quantities received and subtracting all quantities withdrawn from stock, the computer maintains a current inventory of each item. Then by establishing in memory a reorder point for each item, the machine can be made to signal when the inventory of each item reaches reordering status. Reorder point is, of course, a function of lead quantity and safety stock.

Maintenance of stock balances, up-dating of issues and receipts, and ordering decisions were formerly handled by

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7The material for the description of this project was obtained from interviews with the Head of the Stores Department and with the Assistant Head of Purchasing and Traffic and his Senior Buyer on August 19, 1964.
Stores Department personnel using manually kept Kardex files. About 1,500 transactions per day were involved in the updating procedure and approximately 60 to 65 requisitions were forwarded daily to the Purchasing Department for ordering. This hand-posting of stock records has now been replaced by key punching of data such as quantity received and quantities withdrawn. The computer performs additions and subtractions and, by comparing the resulting inventory with a pre-established reorder point, indicates when to reorder.

In order to program the quantity to order in the computer, an ordering quantity for each item has to be inserted in the basic data. In effect, this system consists of a "fixed ordering quantity, variable ordering frequency." Conceivably, there may be situations where a "fixed ordering frequency, variable ordering quantity" would be preferable. Either one can be readily programmed.

By using the fixed ordering quantity, the Purchasing Department achieves the advantage of always ordering in full package rather than broken package quantities; most practical quantity brackets; and, in some cases, in pallet loads rather than quantities not conforming with pallet size, by establishing the desirable quantity as the "fixed" quantity. Once this quantity is established in the basic data, the computer will always (but subject to adjustment) order the same quantity or multiples of that quantity.
This system effectively controls the inventory of 25,000 stock items and automatically reorders 95 times out of 100. The remaining 5 per cent represents emergency situations that will inevitably arise due to failure on the part of a supplier to deliver on time or due to unexpected demands on stock when consumption of an item temporarily exceeds the average rate of consumption. In these instances, the machine signals the emergency, and the situation is handled manually either by expediting an open order or by placing an emergency order to supplement stock until the next delivery against an open order is made.

In January and July of each year, a machine scanning is made and order points and economic order quantities are set using mathematical formulae where applicable. About 7,000 of the 25,000 items in storehouse inventories are machine adjusted on this basis.

The end result of the inventory control phase of the operation is the "reorder point." When this point is reached, a purchase order can be written since the master tape contains all constant information needed in ordering. The program is written so that all items to be ordered from the same supplier within the same main class of material will be combined on one purchase order. Another feature of this program is the "can-order point." If an item is approaching the ordering point and another item in the same class of material must be ordered
from the same supplier, the "can-order" item will also be ordered.

**Purchase orders** are printed automatically after first establishing in the master record tape all the data to be incorporated in the order. Information to be included on the purchase order includes the supplier's name and address, the order number, a complete ordering specification, order quantity, and a requested delivery date. In starting the run, the machine operator inserts the current date, and to this the computer automatically adds lead time to establish a delivery date. Lead time had already been introduced into the data for inventory control purposes.

Such additional data as price, f.o.b. terms, and cash terms are optional. If automation is not to be carried beyond the order writing stage, and if there is no objection to releasing purchase orders without showing price and terms, these factors need not be included in the basic data. On the other hand, if price and terms must appear on the order, or if automation is to be carried through a subsequent invoice checking phase, it is necessary to introduce price and terms at this point.

Buyers may have some concern about automatic writing of purchase orders for items for which they are not prepared to designate a specific source of supply, or which can not always be tagged with a specific price. Provision is made for this situation by coding such items for "no supplier" or "supplier
to be determined" in which case the 7074 prints out an order omitting the vendor's name. This paper is then used as a requisition; price inquiries may be issued or the proper supplier is determined by other means. Thereafter the item can be returned to the system for automatic print out of an order to the supplier then designated, or the purchase order may be written manually and introduced to the system for handling through the subsequent phases.

Routine tracing of open purchase orders is a part of the program. This tracing procedure is accomplished by pre-establishing in the program a pattern of practical follow-up intervals and the text of several tracer letters appropriate to the different situations which may arise. Having both an order date and a due date for each open order, and guided by the follow-up intervals, the program works forward from the order date in tracing for an acknowledgment and a shipping promise, and backward from the due date in asking "Will you deliver on the date requested?" Receipt of material or receipt of an invoice automatically stops follow-up. All shipping promises received from suppliers are key-punched into the system. The computer then compares the promised date with the due date already incorporated into memory in the order writing phase of the operation. If the two dates agree, within pre-established limits, the machine accepts the promise. If the supplier proposes to deliver either too late or too
early, the machine prints out a notice to the Purchasing Department which then takes action.

Under the principle of "management by exception," the Purchasing Department acts only on the problem cases which are called to its attention. No time or effort is wasted on the items which will be delivered on time.

In the case of long lead time items, where the delivery promise is three months or more, the computer is programmed to trace the supplies by form letter, 30 to 60 days ahead of the due date for reaffirmation of the promise. If the order is not received within three to seven days of the expected delivery date, a notice is printed out to initiate Purchasing Department action.

Checking, verifying, and paying of supplier's invoices, formerly done by the Purchasing and Accounting Departments, are the next steps in the program and are now accomplished by the computer. In addition to basic purchase order data, the open order master tape record provides spaces for bringing in receipt and invoice data. Orders remain on the tape in "open status" until the material and the invoice have been received and all the built-in checks of the system have been satisfied.

The computer compares the quantities received and quantities invoiced with the quantity ordered. It accepts the invoice if these quantities agree and rejects it if they do not agree.
The computer then compares invoice prices, f.o.b. terms, cash discount, and pay terms with prices and terms previously recorded from the purchase order.

If an invoice is rejected at any stage of the checking operation, the machine produces a print-out identifying the source of the error. This print-out is then hand matched with the invoice by the Accounting Department. If the error is arithmetical, the correct amount due is verified manually and the transaction is then returned to the system for automatic writing of the check. In some cases checks in the correct amounts may be written manually.

If the invoice has been rejected for unit price or terms, the print-out from the machine is matched with a copy of the invoice retained in the Purchasing Department which handles the necessary adjustments manually by communication with the vendor.

Here again the principle of "management by exception" is noticeable in that the system processes automatically the correct invoices and reverts to manual handling only when an invoice does not agree with the data which has been placed in memory.

Management is pleased with the application of Project M. It is an excellent system that contributes to the better management of the company. The system has always been subjected to modifications, refinements, and expansions in order to make it more efficient. While there have been substantial
manpower savings from the Materials and Stores Project, the people directly involved believe that noteworthy strides have been made in the realm of the application of the theory of good purchasing and materials management.

The Assistant Purchasing Agent, as well as the Head of the Stores Department, believes that the principal advantage of the computer operation is to free them from much routine clerical work, leaving more time to devote to actual supervision. The buyers, in particular, have gained a freedom from clerical work which enables them to concentrate on their buying function. The computer gives them time to determine the source of supply, to establish prices, and lead times. Also, through the computer, better analysis of vendors' performance can be made so that lead times are met as promised. This performance analysis also serves to establish more realistic lead times resulting in better planned purchases. A reorganization of the department took place because of the influence of Project M on purchasing. This will be discussed in the next chapter.

The Head of the Stores Department is "extremely pleased with the applications of this project." Not only is the function of inventory control easier and the entire system of record keeping more accurate, but important information for decision making is easily obtainable by several levels of management. For instance, he pointed out that information, heretofore difficult to compile, is being obtained that will
help in value analysis, appraisal of vendor performance (as previously mentioned), reports to management, and studies of stock obsolescence.

A special program, determining stock obsolescence, is run twice a year printing out a list of all items that have been inactive for two years or longer. The majority of these items are "insurance" stock, which are so critical to operations that they must be carried in stock in case of breakdown. Inactive items not in such a category will be quickly discovered and eliminated from stock.

An additional program used in this connection is a computer run that prints out a complete list of all materials used on a particular operating unit. When a unit becomes obsolete and is retired from service, this list is sent to the Mechanical Facilities Department where it is examined for items usable in other operating units. These items are then re-classified and the remaining items on the list are eliminated. When a unit is to be taken from service for a major overhaul, this program serves as a planning device. Overhauls are critical operations that may take five or six weeks for major units such as catalytic crackers and involve thousands of dollars in labor and material costs. Careful planning is required in closing this unit down, repairing it, and returning it to service as quickly as possible.

Storehouse operations dealing with these overhauls have been improved greatly because of the computer program. This
program stores complete information on all materials that are required by these overhauls, including balance on hand and on order and recent usage history for use by the engineers in planning material requirements. As each unit is shut down for a turn-around, a record is kept of material ordered, used, and returned. The next time the unit is closed down for a turn-around this record will be available. This record permits closer estimate of material requirements and results in reduction of overstocking of unused material.

**Project A: Fixed Assets.** This project involves maximum mechanization of fixed asset reports and records which were formerly done manually. Until July, 1956, when this project became operational, the company accounting records were maintained on approximately 30,000 manually posted cards. These records have now been converted to master tapes and are up-dated on the 7074. This tape serves as one of the subsidiary ledgers underlying the general ledger which is maintained as a part of Project F.

**Project F: Financial and Cost.** This project covers the general accounting and financial and cost report preparation. It involves the accumulation of a general ledger history tape and the preparation of general and subsidiary ledger entries, including the voucher register. Each of the other projects provides basic accounting data to this project

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8Statement made by the Data Processing Manager, August 17, 1964.
for processing. Output consists of a variety of reports including labor and material cost distribution reports, material issues by classes and accounts, and cost reports by processing units.9

Project E: Secondary Reports. This project provides for collecting and organizing data for the preparation of reports that can not be conveniently produced directly in the other projects. It provides for the collection and organization of this information and the subsequent preparation of these reports. Since its conception in July, 1956, many additional reports have been added. Not only has this project eliminated the manual effort formerly involved in such report preparation, it also provides faster, more accurate information to all levels of management.10

Project S: Sales and Shipping.11 Through the use of the IBM 7074, customer data and shipping data are processed for maximum mechanization of the sales and shipping function. Two departments of the Petroleum Operations Division, the Packaging and Shipping Department and the Oil Movement Department, work closely on this project. The 7074 also produces shipping papers, package inventory reports, customer

9Ibid.  
10Ibid.  
11The description of this project was obtained through interviews with the Office Supervisor of the Packaging and Shipping Department and the Head of the Oil Movement Department on August 19, 1964.
invoices, sales statistical reports, and the necessary accounting entries to reflect the sales to customers.

The Packaging and Shipping Department compares the bills of lading, memorandum invoices, and shipping papers, prepared by the computer, with what is actually shipped. If there are no deviations in these reports, then these papers flow out of the department.

The system prepares for this department a daily inventory of packaged products. This inventory reflects, as of 7:00 a.m. daily, the number of different types of packages by the various products and package styles. It produces the orders of goods to be shipped and the date that they are to be shipped. In addition, an Export Status Report is prepared which serves as a basis for determining material to be loaded for shipments abroad. This report furnishes advanced information to freight forwarders on what stocks are going to be loaded on various vessels.

The system also furnishes information on the production scheduled for lubricating and gasoline blending operations and grease manufacture. Production and inventory of these products can be adjusted to meet the shipping schedules.

Since this department is concerned basically with packaging and shipping and not with storage, the optimum inventory of warehouse items is of great interest to it. The system provides better operation of warehousing activities by providing the basic reorder points of products stocked in
inventory. The program here is very similar to that used by the Stores Department. It determines, based on prior shipping experience, the most economical number of packages of various styles that should be carried. This program has resulted in some reduction of inventory items and also provides optimization of floor space.

The Oil Movement Department controls the movement and storage of crude oil, process charge stocks, and most of the petroleum products. Oil Movement blends all the major fuel products such as motor and aviation gasoline, jet propulsion fuel, tractor fuel, diesel fuels, heating oil and asphalts and residual fuel. It receives all crude oil, stores it, and pumps it to the pipe stills that are in operation. The department handles the bulk loading of finished products. Shipments are made by pipeline, truck, railroad, and vessel.

The scheduling of the manufacture of various grades of oil was a major part of Project S in 1958. Monte Carlo techniques were used to determine optimum scheduling. This program proved so unsuccessful that it was finally abandoned. However, a revision is currently underway which will utilize an IBM 1050, a tremendous improvement over the original 705.

Project 0: Operations Analysis. This project is designed to maximize mechanical preparation of operating data, product and crude oil inventories, and laboratory data.

12Blending operations of gasoline and other fuels will be described in a later section in this chapter.
Operating the processing units in a refinery has always been a formidable job and may involve over 150 measured variables regarding input and output. Some of these variables are recorded by instruments which provide an instantaneous visual and written record of what is occurring within the unit. For other variables measurements may be recorded every few hours or samples may be drawn off and analyzed to obtain the desired information.

Simple gauges and meters to very complex mass spectrometers have been developed to provide the necessary information. To serve its purpose this mass of information must be accumulated in a single place. This accumulation and processing was done manually up until 1954 when an effort was made to utilize IBM 604s and 607s. In 1958 complete conversion to punched cards was made, thereby permitting more complete reports and increasing the speed of processing these reports.

These reports on the major units in the refinery were first processed on the IBM 705 and are now done on the 7074. One such report, which concerns the Oil Movement Department, is a daily inventory summary. The refinery has approximately 1,200 tanks of various sizes, and the quantity in them must be known in order for daily planning for the use of the oil. Formerly it took two or three men all day to take the tank measurements and to develop a report. Improved measuring devices now allow the inventory to be taken quickly. After
this information is converted into punched cards, it is then processed by the 7074 which prepares the inventory summary report by about 8:30 each morning.

The Head of the Oil Movement Department is extremely pleased with this section of the project because of its speed. Control of operating performance is more quickly accomplished. For instance, if there has been a great increase in the catalytic cracking unit inventory, he can immediately take steps to control it or negotiate with the parent organization to take the surplus. In the past adverse inventory changes such as this could upset planning efforts for days. Now oil inventories can be quickly corrected and the planning for their use greatly improved.

Although one of the primary uses of these operating unit reports is to allow the Oil Movement Department to improve operations of units, they serve several other purposes also. One of the most important of these is to furnish actual operating data into the refinery simulation program which is discussed later (see page 46). Another is to check for errors in measuring instruments, one of the things that foremen must check carefully.

Finally, the results of this phase of Project O are also made available to the Petroleum Technical Department and the Construction Department where they are used in improving operations and in determining the design of future units.
The seven major systems which have been described are essentially an integrated system. Each has an output which enters directly into daily refining operation. In addition to this direct output, there are accounting entries of one type or another fed into a financial project for the preparation of the profit and loss statement and balance sheet. These seven projects also provide a variety of statistical data. Thus, all of the refinery's report requirements are satisfied from a single system.

This integrated system represents one very successful application of the various phases of information technology at Petro-Chem Refinery. In the following sections of the chapter other applications of information technology, such as refinery simulation, gasoline blending, and economic simulation models for long-range planning, will be described. Although these techniques do not always tie in closely with the seven projects, they do furnish important data to several parts of the programs and perhaps, more importantly, furnish top and middle management personnel with valuable information to improve profitability of operations.

Business Simulation

One of the most interesting recent facets of the use of mathematics and statistics in business has been the development of mathematical models to simulate some area of business operation. Although models to simulate a real-life situation
are not new, their use, until recently, has been seriously hampered by the lack of devices capable of handling the computation problems involved. With the advent of the computer, the situation changed.

The various techniques of operations research in conjunction with the computer have been used with varying degrees of complexity by various companies. In order to illustrate how such techniques are used in actual operation several illustrations are given. One is the use of a linear programming model in gasoline blending problems; another is the use of complicated techniques in simulating operating processes in an oil refinery; additionally, an economic model used in investment planning will be discussed; finally, two technical applications will be described.

Gasoline blending.13 The Petro-Chem Refinery produces approximately five million gallons of motor gasoline per day. This is produced in several grades, each differing from the other with respect to one or more of from four to sixteen specifications that describe their characteristics. These gasolines may be made up of from two to twelve components, each of which is describable in terms of the same four to sixteen characteristics as the gasoline.

13Unless otherwise indicated, the material describing this operation came from a discussion with the Head of the Oil Movement Department, who is responsible for blending operations, on August 19, 1964.
There are various ways in which the components can be mixed to achieve the specifications required. Finding a feasible way to blend the components to meet specifications can be difficult - the most profitable way even more difficult. The blending problem is further complicated by the many changes occurring over time that affect either the input components or the finished product. An example of this can be seen in the gradual increase in octane requirements as cars with larger, higher compression ratio engines have appeared. The weather also influences the desired specification since different climates often require seasonal shifts in the mix of gasoline (Texaco is one oil company which capitalizes on this through its advertisements stressing customer service). The amount of inventories on hand of the desired components may also affect the quality and mix of the gasoline.

Manual means have been used to handle this complex problem in the past. This required the use of several simplifying assumptions and approximations. The relationships involved in the problem are linear, however, so that the problem is susceptible to a more nearly optimum solution by the use of linear programming. For a problem with as many variables as involved in gasoline blending, this method of solution required such extensive computation that it could not be used on a routine basis.
While manual means were being used to blend the various grades of gasoline, these blends were not made on a cost basis as much as they were to keep the pool of inventories balanced. When an inventory of one component began to build up, more of it was used. Perhaps the only effort to economize was to minimize the use of tetraethyl lead, a high price component. Before the use of linear programming, blenders could never be certain that they were developing the optimum (least cost) blend.

Computers are now aiding the refinery in handling the planning for gasoline blending by dividing the problem into three stages. First, a long-term optimum blend is calculated monthly, taking into account projections of usage for the various components. This monthly plan gives the desired lead levels and sets the severity of reforming operations. Finally, daily blending calculations are made for each blend taking into account the "target" compositions set by the IBM 1620. The daily target blend is set to minimize the difference between what can be blended and the target as established by the monthly plan. This operation actually amounts to an "on-line" operation (see page 7 for a description of "on-line" data processing).

There are several advantages to this program. One of the most important has been a reduction in "product quality giveaway." This occurs when the finished gasoline exceeds the minimum specifications on some requirements. Giveaway
has been reduced in two ways: (1) precise calculations of the blending factors have replaced the approximations that were necessary under the manual system, and (2) consideration of all specifications has replaced the former system which considered only the most important factors.

Among other advantages are better inventory control and increased ability to meet emergency situations. In one instance an unscheduled shutdown of a hydroforming unit created what would have originally been a severe problem in revising plans due to decreased octane normally created in this operation. The computer program handled this emergency situation by permitting a quick and complete adjustment of plans to meet the situation.

**Allocation of lube oil manufacture.** Another use of linear programming has been in allocating the production of high-grade lubricating oil requirements among the refineries of the parent company. There are two refineries, which differ as to capacities, processes, and costs, involved in the production of these grades of lube oil. The problem is to allocate the production between these refineries in order to maximize profit.

In the past, representatives of the two refineries would meet at the parent company every six months to determine the allocation. Each representative would present a suggested plan. These plans were then compared and a final plan decided upon. The optimum allocation could never be reached,
however, because of the complexities and interrelationships involved.

The applied mathematics section at the Petro-Chem Refinery developed an optimizing simulation model of these various production processes to be used in preparing a suggested plan for the next allocation meeting. At the next meeting in 1957 the major parts of this program were accepted. This plan proved to be considerably more profitable than the previous ones.

Refinery simulation. The manufacturing process in an oil industry is very complex and gasoline blending is only the last stage of this process for one product. Conversion of crude oil into salable products involves three basically different manufacturing processes - distillation, fractionation, and blending. In the first process the application of heat divides crude oil into its variety of components without changing the chemical composition of these components. In fractionation some of the components resulting from distillation are subjected to heat, pressure, and sometimes a catalyst, to produce other components which have a different chemical structure. Finally, the resulting components are blended and put back together again in a variety of ways to obtain some 300 different end products.

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14Simulation techniques were discussed with the Section Head of Operations Research and with the Section Head of Economics and Budgets, August 19 and 25, 1964.
The actual process is a great deal more complicated than the above indicates. In a gasoline blending problem, for example, there may be a large number of ways in which a given stock of components can be mixed to achieve the specifications required. The characteristics of these components can be changed by making changes in one or more of the preceding operating processes. This increases the complexity of the problem. For example, one of the characteristics of the components is the octane number rating. To achieve the specified octane rating, blending operations may have to be adjusted by adding higher octane components or adding tetraethyl lead. This is the problem with a fixed stock of components. By careful planning the octane number of some of the components coming out of the conversion process can be increased by increasing the "severity" of reforming.

Any change in reforming severity, while it increases octane rating, thus decreasing lead requirements, also increases the cost of operating the reformer. In addition it decreases the volume of components produced per unit of input and may change volatility, which is another of the important specifications in the finished product.

These effects may be traced back through other conversion processes, such as thermal and catalytic cracking, as well as the distillation processes. At each point changes in certain operating variables, such as heat, pressure, rate of flow, catalyst level, etc., produce changes in the resulting product.
When these effects are traced all the way back to the point of crude input, it is found that a given refinery may have access to as many as 200 different kinds of crude, each having unique qualities that affect the quantity or quality of the output of the various refinery processes.

The manual approach to the kinds of problems involved in this is first to work out a feasible plan - that is, one that meets all the specifications of the end product while staying within quantity, equipment, and other limitations. Attempts are then made to improve upon this plan. However, the factors involved are so interrelated that a change in one factor influences another factor, which in turn changes a third, such that a whole chain of repercussions is set up that may extend throughout the process. These repercussions must be traced all the way through to make sure that they do not cover a failure to meet end product specifications. When the time-consuming job is done manually, it does not permit an examination of very many potentially profitable changes.

Simulation models for use of the computer are now used by the refinery in meeting this kind of problem. The model contains the decision rules used by the planners and schedulers, the logical rules governing input data, and mathematical equations describing time, quantity, equipment, and other limitations. If a case under study involves changes over time, process variability can be introduced randomly by the use of
distributions based on past experience. This program can then be used to test a proposed plan by running the plan through the computer and examining the results for validity. Suggested changes in the plan can be inserted and tested by having the computer trace through to the end all repercussions resulting from any change. A great number of cases can be examined since the computer can perform this operation in a very small fraction of the time required for manual operation. Thus, the probability of achieving a better final plan is increased greatly.

Unless an optimizing technique such as linear programming is used, such a procedure does not result in an "optimum" solution in any real sense. Planners can never be absolutely certain that some better plan does not exist unless they examine all possible cases, a procedure which is highly impractical in view of the large number of possible cases. However, when personnel thoroughly familiar with the problem being considered suggest changes, a plan very close to the optimum may be found. In addition, the computer program can include all variables at little cost in time, whereas the manual method had to exclude certain variables considered relatively less important than others. This program reduces the possibility that the final product will fail to meet inspection tests because of an omitted factor.

The basic operating data for input in this program consists of the characteristics of the crude oils to be processed,
the operating and equipment limitations that must be observed, and the end product specifications. The program develops in less than an hour a completely balanced feasible operating plan that meets these specifications and falls within the limitations. It also prints out detailed predictions of intermediate and final yields from each of the processing units involved, manufacturing costs, and a profit and loss statement.

The following section should develop an appreciation of this highly complex and technical program. Catalytic cracking, although only one part of this program involves one of the most important of the long series of processes involved in a refinery.

**Catalytic cracking.** Catalytic cracking operations are optimized by calculating a series of special cases. Each case involves use of a combination of values for several controllable variables - catalyst addition rate, temperature, carbon burning rate, etc. - which determine the amount and dollar value of final products flowing out of the unit. The purpose of the optimization calculations is to maximize the dollar value of output products.

The procedure depends upon the ability to calculate the dollar value of the product for any set of values of the controllable variables. Methods for calculating the response have long been used by oil companies, but because the calculations are so complex and require so much time, about two
or three days on a desk calculator, it was not feasible before electronic computers to compute enough cases to permit optimization of this process. The refinery, because of the high speed of the computer, was able to develop a trial-and-error technique which could be used to optimize cracking operations.

The computer procedure incorporates the same set of calculations to compute response as was used when responses were manually calculated on a desk calculator. Optimization is achieved by calculating as many as 30 or more cases until no increase in response can be obtained by further changes in the controllable variables. Each case can be calculated in less than three minutes. This trial-and-error technique depends upon a rule which, at each step, determines a way in which the values of the controllable variables may be changed so as to cause an increase in response. The rules used by the refinery to guide the computation are based on the mathematical technique of linear programming.

Linear programming, which requires that all mathematical relations used be linear equations, can not be used alone to optimize catalytic cracker operations since the response is not a linear function of the controllable variables. If, however, only a very small range of variables is considered, the response can be fairly accurately approximated by a linear equation. The catalyst holdup rate and total feed rate can also be considered. When these linear equations are found,
the response within a small range of the variables can be maximized.

An advantage of linear programming is that many equations can be considered. This means that this technique is able to take into account many alternative courses of action and thus to find the optimum operation.

**Economic model.** The Long Range Economic and Budget Section of the Technical and Coordination Division has the responsibility for coordinating the development of a capital budget and analyzing proposed project investments. The alternative investment routine rates projects by yield and time required to produce the yield and relates them to the capital available.

The development of the capital budget begins early in the year by collecting ideas for new projects, for improving efficiency of existing investments, and recommendations for expansion or deletion of products. Various review levels are established in the organization. The first review takes place early in the Spring when the Head of the Economic and Budget Group meets with his assistants and advisors to discuss the proposals submitted by the various operations analysis groups within the divisions. At this meeting judgments are made to eliminate proposals or to analyze further attractive projects.

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15 This section of the paper was specifically developed during an interview with the Section Head of Economics and Budgets, August 26, 1964.
Approximately one month later another review is held by the entire division where the proposed budget is presented to the Head of the Technical and Coordination Division for his approval. Again, projects are deleted or developed.

Next, a meeting with the General Manager and representatives from the parent organization is held. If the projects reviewed here are sufficiently attractive, then formal presentation is made one month later to the parent organization. Eventually, final approval is received from the parent company on the attractive proposals. Attractiveness is judged by several profitability indexes including payout and discounted cash flow.

The development of the capital budget requires months of careful planning and analysis of proposed investments. In the past, analysis has been made on a manual basis. Now, an economic simulation model is used to determine the rate of return on all proposals.

The economic model is a cash-flow type of program where a list of cash flows (i.e., expenditures or investments to be made and savings which will be derived from the investments) are submitted as inputs to the computer. By using this model, determination of the relative attractiveness of each proposal is made. In addition to establishing the yield, it also furnishes the book return of each investment which is the return on investment in the first year of the project.
The week before a budget review, the Economic and Budget Group is normally involved with preparation of cases (i.e., proposals and alternatives) which requires several computer runs per day. This analysis can be done in approximately 15 seconds per case on the IBM 7074. Normally, ten to twelve cases are analyzed a day, which is a great improvement over the manual method. Thus, with the information available on the computer, a faster, more complete analysis of proposed investments can be made.

This program is also used in crude oil evaluation where a simulation model of a hypothetical refinery is set up. This model is used in determining what prices can be paid for given crude oils to yield an adequate return on investment. A hypothetical refinery is used in this program in order to take into consideration competition from other refineries in the market for crude oil. The principal advantage for this particular program is, again, the greater speed with which it can be run. The evaluation of a crude oil takes about ten minutes of 7074 computer time, compared with approximately two months required for one man to do this manually.

In addition to evaluation of proposed budget items and evaluation of crude oil, this program is used with a variety of problems. These range from fairly simple (compared to the power of the program) cases to one case involving plans for a large refinery running more than ten types of crude oils through the complete sequence of process units. The major
advantages of this program are increased speed, decreased costs, and greater reliability.

**Engineering design.** The high speed calculating ability of the computer is used by the engineering departments at Petro-Chem Refinery to relieve the burden of routine calculations. More importantly, however, is the use of simulation models to test proposed designs. The design characteristics of the operating units may be changed to determine the effects of different operating variables on outputs and costs.

The basic advantage of such a technique is that it permits the study of a great many more variables before determination of a particular design is made. Practically no experimentation of this kind can be carried out on full-scale operating units, and the time and cost involved limits even pilot plant experimentation. Thus, the use of a computer simulation model permits a considerable expansion in the amount of this kind of experimentation.

The solution of design problems, as well as others, can be found easier and quicker due to the establishment of a library of programs. The library is part of an information retrieval program whereby certain engineering problems and project evaluations are established on tape for the use of various departments. For instance, if an engineer is working a tower distillation problem, he can obtain the answer in a few minutes running time on the computer. He then can spend
his time analyzing the results of this calculation rather than tediously working the problem by hand.

Summary

In analyzing the results of the applications of information technology it is significant to note that many routine decisions which were formerly made by management personnel are now made through the use of the computer. Examples of these automatic decisions may be found in the operations of the Stores Department, Purchasing Department, and certainly in the gasoline blending operation of the Oil Movement Department.

These operating problems are important because they involve areas where small variations have a great effect on profitability. For example, the importance of the gasoline blending decisions can be seen from the fact that the Petro-Chem Refinery produces an average of five million gallons of motor gasoline per day. Decisions that result in cost variations of fractions of a cent per gallon can have substantial effects on profits. The blending operations are now routine in that target mixes are established in a program which does not involve day-to-day decisions as in the past.

Improved Decisions

In other situations where decisions are not so routine, information technology has aided management to make better
decisions. They are better in the sense that they are more nearly optimum in terms of specified criteria. These criteria may be the same for computer operations as they were before, usually being defined basically in terms of minimum cost. But the speed of computer computations permits management to consider all of the relevant factors, rather than only a few as before. It also allows the use of either specific optimizing techniques, such as linear programming, or enough trials in a trial-and-error method to assure more nearly optimum results.

A greater degree of flexibility has been established because the high speed available permits changing decisions in view of changing conditions. Analysis of managerial action indicates that middle management spends 80 per cent of their time simply handling information. The integrated information system (the EDPM Master Plan) permits large amounts of data to be processed rapidly, thus making it possible to disseminate information quickly and accurately through the organization. Middle management is thus relieved of much of the burden of routine paper work in addition to the creation of a flexible managerial organization.

Acceptance of Information Technology

Computers, integrated data systems, operations research techniques, and applied mathematics are, perhaps, not familiar

terms in the vocabulary of every manager, but they are by no means strange terms at the Petro-Chem Refinery. Management has long recognized the importance of information technology to the operations of the refinery. In looking ahead to the challenges that face them with respect to technological advances, management agrees with Drucker that:

In dealing with their new tasks, the managers of the 1960's will, to a large extent, have to employ the same tools that they are using today. But managers will also find, increasingly, that they are expected to know, understand, and handle new concepts and tools of management. Increasingly, they will find that they are expected to use systematic methods of analysis and decision-making, supplemented by new tools of communications, computations, and presentation.\(^\text{17}\)

The next chapter will involve an extensive analysis of some direct and indirect organizational changes that have developed from the introduction of information technology to refinery operations. Some of these changes are directly attributable to information technology. Others, more subtle, can be seen where information technology played only a small part in their development.

\(^{17}\)Peter F. Drucker, "The Next Decade in Management," *Dun's Review and Modern Industry*, LXXIV, No. 6 (December, 1959), 44.
CHAPTER III

THE IMPACT ON ORGANIZATIONAL STRUCTURE

This chapter examines the impact of information technology on the organizational structure of the Petro-Chem Refinery. The first section presents quotations which are representative of the type predictions found in the management literature. These predictions, and others, were tested at the refinery to evaluate their validity with the purpose of gaining a proper perspective of the effects of information technology on the organization of this company. The results of the observations concerning organizational changes due to information technology are presented in the latter part of this chapter.

The Predictions

In the past few years there has been a growing interest about the effects of information technology on management and organization. Numerous articles have appeared predicting that this new technology will have a revolutionary effect on management functions and organizational structures. On the other hand, another philosophy is that the computer and the various mathematical techniques are only tools to aid management. The following quotations may be considered representative
of the type prognostications which have been made concerning information technology:

A radical reorganization of middle management levels should occur, with certain classes of middle management jobs moving downward in status and compensation (because they will require less autonomy and skill), while other classes move upward into the top management group.¹

There seems little doubt that the computer will have a substantial effect on management. It will "automate" many routine (and even some not-so-routine) decisions; it will sharply cut back on the number and status of middle managers; . . .²

With the replacement of much routine and detail activity by computerized applications and the increased speed and accuracy of information flows, we will not need as many people in management positions. . . In the future the span of control will widen and the number of levels will decrease.³

The redesigning and re-engineering of the flow of business data is going to have an important effect with respect to corporate organization. Traditional departmental lines, as we have known them for the past decades, will be greatly expanded. Merging of departments, brought about by the logical realignment of work effort rather than an existence surrounded by traditional limits, will mean new concepts in corporate structure. Now the corporation can look forward on a long range basis to an organization based truly on functional lines. Activities will be grouped


according to their interdependent relationship, premised on functional objectives. These writers are concerned with the effects on organizational structure, particularly on the middle management level. Still other sophisticated writers on information technology are involved in a controversy over centralization versus decentralization of control. It is argued by some that information technology creates a growing trend toward recentralization of managerial control or decision making. Shultz and Whisler say:

Our argument is that use of the high-speed computer and associated techniques, "information technology," will be a force for centralization of decision-making, along with an extended staff at the top levels and fewer jobs, with more highly programmed content, at lower levels in the management hierarchy.5

It is their view that management will be able to do what it always has wished to do - control from a central point with computers performing routine decision-making and top management confining itself to broad policy thinking and establishment of objectives. Ida Russakoff Hoos, in a two-year study of 19 organizations in the San Francisco Bay area that had introduced electronic data processing, supported this view. She concluded:

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Analysis of the experience of San Francisco Bay area firms reveals that EDP stimulates two distinct types of recentralization. One type relates to the integration of specific functions and affects primarily the internal organization of the company. The other involves regrouping of entire units of the operation and causes sweeping changes of external structure as well.  

Supporters of decentralization, on the other hand, believe that it is more accurate to say that computers give business the means to support decentralized local management with better facts for local decision making and control as developed by central computer accumulation of information.  

Burlingame supports this argument:  

Counter to many arguments, the anticipated advances in information technology, in my opinion, can strengthen decentralization in those businesses that have adopted it and will encourage more management to experiment and to operate in accordance with the decentralization philosophy.  

It is important to avoid dangerous generalization, and look in depth at the questions and issues involved. Therefore, these arguments, as well as the preceding predictions are considered in the following section with the view of examining the observed changes at the refinery since the inception of  


7 See Peter W. Melitz, "Impact of Electronic Data Processing on Managers," Advanced Management, XXVI, No. 4 (April, 1961), 4-5.  

information technology. However, no attempt is made to answer each prediction specifically.

Organizational Impacts

This section examines the observable changes or influences on the organization of the Petro-Chem Refinery which have accompanied the growing-pains of information technology. It is important to note that it will not always be possible to establish direct cause and effect relationships, nor will it be possible to establish that information technology played the only role in any change. Many of the changes observed may have been an indirect result of information technology. The changes result directly from management decisions based on more thorough, more timely, more meaningful information.

Corporate Changes

There have been numerous organizational adjustments on the corporate level since World War II. With few exceptions, it is difficult to attribute any of these changes to increased sophistication of information processing. Rather, they seem to be the natural evolutionary adjustments of a refinery keenly aware of changing conditions and technology.

Organizational structures. In comparing the organizational structures of 1946 and 1964, as denoted by Figures 3 and 4, it can be seen that a certain "flattening" has taken place. That is, the organization has evolved into one where
divisions, departments, and functions have been rearranged for more efficient operation. Many of the changes seen in these charts should not be regarded as unique to the Petro-Chem Refinery; undoubtedly similar transfigurations have occurred to a greater or lesser degree in many companies.

The organization chart of 1946 was chosen to illustrate the evolution of the refinery from then until the present time for two primary reasons. First, the company structure of 1946 depicts the organization as it was at the beginning of its movement toward automation. Most of its automatic processes, control techniques, and data processing has occurred since that date. Second, the structure experienced few major realignments until recently. Therefore, any organizational change is more vividly portrayed in a comparison of the two charts.

Reorganizations. One of the top level organizational realignments occurred in 1962 when the Process Division was separated into two groups: petro-chemical operations and chemical operations. The former, together with the entire Mechanical Division, was placed under the supervision of a Petroleum Products Manager, while the latter was placed under the supervision of a Chemical Products Manager. These alterations took place in order to improve control over these areas, and to recognize the contributions of the chemical products group to the profitability of the refinery.

This same reorganization produced another significant change in the establishment of a manager over the service
Petro-Chem Refinery Organization, 1946

Figure 3. Organization Chart
divisions of the company. Perhaps the most distinctive is the Business Services Division which consists of two departments, Accounting and Computing. This organizational change can be attributed to the recognition of the importance of information to the refinery and will be described in the following section.

**Departmental Changes**

**Computing and General Services Department**. When computers first began to appear in the refinery, they were placed under the responsibility of the company's chief financial officer. The decision, although practically automatic, was considered sound. The computer was perceived as an ultra-high speed development of the conventional tabulating machine. Its principal advantage was thought of as more rapid processing of the same data that had been prepared in the past.

There was another reason for locating computers in the Accounting Division, and that was the Chief Accountant's leading role in the feasibility study preceding the installation. This study was, generally speaking, chiefly concerned with drawing a comparison between the expenditures for the new equipment and the clerical cost reductions that it could be expected to produce. In addition, this study indicated that maximum benefit from mechanization could come only from development of an integrated data processing system. This kind of analysis was a proper function of the financial
officer, and most of the cost elements and savings were within his own field of responsibility.

But the initial placement of the computer within this division was questioned. With the development of the EDPM Master Plan, the range of computer applications far exceeded the limits of the accounting system. The growth of this management information system extended the organizational impact of electronic data processing from the machine room to other departments.

The establishment of a separate Computer Department was one of the first organizational changes noted at the refinery. As the responsibility for computer-based services rose in importance within the financial officer's organization, it was felt that a new arrangement was required. As a result of this feeling, the new department was formed.

However, the establishment of the Computer Department was only the first step. Later, the entire Accounting Division was reorganized into a Business Services Division, which included two departments: Accounting and Computing. The Computing and General Services Department consisted of three sections: Business Systems, Operations Research, and Data Processing.

To the extent that changes have occurred in other departments it is, generally speaking, because of the fact that the Computer Department has taken over some of the clerical functions formerly done in the affected operating department.
Also, the development of the integrated information system allows an increased degree of coordination and communication between these autonomous units. Consequently, there are signs of pressures which are building in such a way as to challenge the efficacy of existing organizational structures. Departments which communicate with one another through projects of the EDPM Master Plan are particularly susceptible to structural changes.

The changes observed in the Stores and Purchasing Departments resulted primarily from the establishment and operation of Project M, the system common to both departments.

**Stores Department.** The Stores Department is one of five departments in the Mechanical Division. Its primary function, as its name implies, is that of acquiring equipment, tools, and supplies and making these items available in the right quantity, quality, and characteristics for use within the refinery.

The inventory control function, described in detail in Chapter II, and material handling facilities are highly mechanized. Automation was first introduced in this department in the late 1940's when automatic material handling equipment was installed. Improvements in facilities and equipment have continued until the present. This warehouse activity is probably as highly mechanized and efficient as found in any company.

The organization of the Stores Department has gone through several transitions since the middle 1950's. The
functions of this department, inventory control and material handling, are each so highly automated that any structural alteration can not be attributed solely to one. Rather, the change denoted in Figures 5 and 6 came about through a gradual materialization of automated processes, including data processing, materials handling, and facilities.

The departmental organization in 1956, before the inception of Project M, is indicated by Figure 5. Shown here is a tall, hierarchical structure consisting of a department head, two assistants, two section foremen, and eight first-line supervisors. The personnel of the department numbered approximately 150.

In 1959, after the retirement of the Assistant Department Head in charge of the material handling section, the two assistant positions were combined. It was believed that the duties and responsibilities of both jobs could be carried by one man. Three years later the two section foremen's positions were eliminated leaving the Assistant Department Head in direct charge of the first-line supervisors. The present organization is indicated in Figure 6. The department employs less than half the personnel it did in 1956, yet it handles twice the volume of work.

The Manager of the Stores Department anticipates an additional organization realignment after his retirement. In three years he will reach retirement age and he expects that he will not be replaced. Rather, the Assistant Head
Stores Department Prior to Organization Change

Head

Assistant Head Material Control

Section Foreman

Foreman Foreman

Assistant Head Material Handling

Section Foreman

Foreman Foreman

Foreman Foreman

Figure 5. Organization Chart of the Stores Department
Stores Department After Organization Change

Figure 6. Organization Chart of Stores Department
will be given full authority and responsibility to run the department.

The reason for this future change is that the operations of the department have been streamlined, through automatic data processing and material handling, to the extent that supervision of the department is much easier. Also, there is a policy of delegating operating authority downward to the lowest possible level of management. In this situation, the Stores Manager anticipates that it will be delegated to his assistant.

The inventory control system of Project M has accomplished a tremendous reduction in the manual effort necessary for the maintenance of stock balances, up-dating for issues and receipts, and ordering decisions. Manpower savings are not considered to be the most important aspect of this project, however. Improved performance, cost savings from the reduction of inventories, and improved management reports are considered more important.

Project M contributed a great deal to the gradual evolution of the Stores Department's organization, although the organization was also affected by the automation of work processes.

Purchasing and Traffic Department. Shortly after the new Computing and General Services Department assumed the follow-up and invoice-checking clerical operations through Project M, a reorganization resulted in the Purchasing
Department. These two clerical sections were reduced in importance and personnel while the buyers' section was re-organized to provide an assistant for each buyer. The purpose of this change was to free the buyers from routine clerical work so that they could give more attention to their major buying work.

It must be noted that this realignment, especially the addition of assistant buyers, developed for at least two reasons: (1) the establishment of the computer material run, and (2) the major plant expansion program which was in effect at that time.

The Head of the Purchasing Department requested additional personnel early in 1956 so that the department would be prepared for the change from manual operations to the EDPM system. The assistant buyers were added for this reason and functioned as an EDPM development group. Their major responsibility was to assist data-processing personnel in the "de-bugging" of the inventory control and material phases of Project M. After the retirement of the department head, these men were transferred since their work was completed and since they were now considered surplus personnel.

The organization or authority-relationship structure is depicted in Figure 7 as it appeared at that time.

Late in 1960, the Supervisory Buyer in charge of purchasing process equipment, tank and pressure vessels was transferred. The remaining Supervisory Buyer accepted the
Figure 7. Organization Chart of the Purchasing Department
responsibility of handling both positions and has functioned in that capacity until the present time. The primary reason for this position merger was that since actual purchasing of commodities had already been delegated downward, the supervisory task was easier and there was no longer a need for two separate positions. Therefore, the two were combined.

The Traffic Department's primary function is the coordination of the movement of products out of the refinery by truck, rail, and air. Minimizing transportation rates in order to improve profitability is one of its major objectives. The department's organization consisted, at this time, of a manager, an assistant, and two section supervisors in charge of operations and rates.

The department existed independently from the Purchasing Department until late in 1961, when the two were consolidated. The coalescence of these departments occurred when the Traffic Manager was transferred to the parent organization. Management believed that there was no longer any necessity of separating the two, and, therefore, placed the Head of Purchasing in charge of both departments. Other than the elimination of the position of Traffic Manager, there were no further supervisory changes at this time. The merged organization can be seen in Figure 8.

Although the EDFM program has been of great assistance to the purchasing section of the department, it has not benefited the traffic section to any extent. Approximately
two years ago, a program was prepared as a part of Project M which would have assumed some of the clerical functions of scheduling and coordinating the shipments of products from the refinery to the point of destination. It proved unsuccessful and was discontinued. The encoding of computer data and the resulting output required for fast, efficient operations were too slow to be of any real assistance.

The information generated through Project M has freed the managers and buyers in the purchasing section of many routine and repetitive activities. This in turn enables them to devote more time to their major functions. They can now concentrate on such aspects as vendor analysis, lead times, and investigation of vendor's commodity prices.

During the period of time in which the project has been in operation, the number of personnel in this department has decreased from approximately 35 to 23. These figures do not include the elimination of the assistant buyers.

The organization changes described in this section occurred from the inception of Project M in 1956 to the present time. It is difficult to designate any major change brought about specifically by the EDPM system other than the elimination of some clerical personnel. Certainly the program contributed to the manner in which work activities were re-organized and regrouped as job structures were affected.

There were two occasions when work activities were re-organized in such a manner that a supervisory position was
Figure 8. Organization Chart of Purchasing and Traffic Department
eliminated or combined with another. The first occasion occurred when the decision was made to combine the supervisory buyers' positions. The second, perhaps more significant than the first, was the redeployment of the Purchasing and Traffic Departments under one manager. It is entirely possible that these two organizational changes would never have occurred if the supervisory burden had not been lightened through the programming of routine information analysis and decision making into the information system.

**Oil Movement Department.** Project O, Operations Analysis, of the EDPM Master Plan is of major importance to the Oil Movement Department. This project is designed to maximize the mechanical preparation of operating data, product and crude oil inventories, and laboratory data. According to the Department Head, this information actually runs the department.

The operations and responsibilities of this department were described in Chapter II and will not be repeated here. The complexity of operations, it will be recalled, was greatly diminished through the extensive utilization of the computer.

The department is in the charge of a manager presently reporting directly to the Assistant Head of the Petroleum Operations Division. There are two sections, each normally under the supervision of an assistant department head. One
is the coordination section; the other is the operations section. There are approximately 109 personnel in the department.

This structure of superior-subordinate relationship developed prior to the inauguration of the Operations Analysis Project in 1958. Figure 9, on the following page, indicates the departmental structure as of that date. Although major organizational adjustments have already occurred in other departments, similar changes are just beginning to appear in this department.

A reformation of authority and responsibility on the assistant department head level is expected to occur. The Department Head normally has two assistants reporting to him. The position of Assistant Department Head of the Coordination Section, which has the responsibility for inventory control, order filling, and scheduling the blending and shipping operations, has been vacant for several months. The duties of this position have been assumed by the Department Head on an intermittent basis.

According to the Department Head, the functions of the coordination section have been computerized to the extent that there is no longer a need for a supervisor. Consequently, he believes that within one year the department will officially operate with only one Assistant Department Head who will assume the duties of both the coordination and operations sections.
Figure 9. Organization Chart of Oil Movement Department
The merger of these positions will occur for two reasons: (1) the number of personnel is being reduced steadily due to automation on the docks and in the refinery; and (2) information on operations is much easier to obtain, and this makes it easier for one man to supervise both sections of the department.

The number of personnel in the department has been slowly decreasing from approximately 160 men eight years ago to the 109 men at the current time. The coordination section has had the greatest reduction as automation improved operations on the docks and as the computer simplified clerical work. Of course, gasoline blending is done on the IBM 1620. Progressive mechanization in the operations section, including data processing, storage measurements, and shipping activities, has reduced personnel in this section.

The speed in which operation analysis and inventory summary reports are now prepared and transmitted to management permits a greater degree of flexibility in planning the operations of the department. The availability of these reports permits a quick alteration of plans to meet unexpected situations. For example, a sudden increase in crude oil inventory can be quickly detected, usually in a matter of a few hours, and a pre-established plan put into operation for a satisfactory disposal of the surplus. In the past, an adverse inventory fluctuation may have gone unnoticed for days, seriously upsetting normal operations.
System and procedure personnel of the Computer Department are currently working closely with the Oil Movement Department to develop a program for use on IBM 1050 Data Transmitter Sets. This program is a sophistication of several aspects of the Operations Analysis Program (Project O) and will supply management with heretofore unavailable day-to-day manufacturing information.

An IBM 1050 is presently being installed in each of the main control rooms of the Oil Movement Department, and one will be centrally located in the main office. Tank gauge measurements and pumping orders will be typed on the machines in the control rooms and transmitted to the main office where this information will be automatically punched on a card. Each day a compilation of this data will be made and a report prepared for the department. This report will be available early each morning and will furnish a break-down of the past-day's production for each grade of oil.

The speed in which this report is prepared will permit the department increased flexibility in planning and scheduling the manufacture of oil components. This flexibility, mentioned previously, has been lacking in the past. Normally, there is a two-week lag between the production run and the production report. By the time discrepancies in production were discovered, it was often too late to make the necessary corrections. The reduction in reporting time allowed by this future program will permit better control of operations.
It is becoming easier for the Department Head to manage this department as a result of the steadily improving information system. He believes that eventually the remaining Assistant Department Head's position will be eliminated with the result that the section foremen will report directly to him. The future organization is shown in Figure 10.

Other changes. The previous sections of this chapter have been concerned with a detailed analysis of departmental organization adjustments. These changes were generally contributed to some form of information technology, either specific projects of the EDPM Master Plan, or computer control techniques as used in the Oil Movement Department. There have been, however, mergers of departments and management positions and reorganization of work activities which can be attributed to information technology only to a small degree.

One such departmental change occurred in the Petroleum Operations Division in 1963 when the Distillation and Cracking Departments were combined. Each of these departments was formerly organized with a department head and two assistant department heads. After the reorganization, the merged department was placed under the supervision of a manager and two assistants. Three management positions were eliminated.

There were several factors involved in this transformation. First, the availability of balanced feasible operating plans due to refinery simulation techniques reduced the complexity
Oil Movement Department Anticipated Organization Change

Figure 10. Organization Chart of Oil Movement Department
of operations. Second, engineering improvements in the manufacturing processes of distillation and fractionation also reduced the necessity of maintaining two separate departments. Finally, the factors mentioned above played a part in shifting the delegation of authority downward to the section foremen actually in charge of operating the pipe stills.

An additional departmental organization change, very similar to the one described above, occurred within the Technical and Coordination Divisions. At one time there was a Petroleum Technical Services Department and a Process Engineering Department where the functions of the two were clearly defined. This arrangement was altered by the creation of a Specialty Technical Department and a Fuel Technical Department where the functions of both the previous departments were broken down according to products. Soon afterwards this arrangement was abandoned and the two departments combined into the Petroleum Technical Department, which can be seen on the corporate organization chart of page 66.

Information technology may have played a small role in the evolution of the one existing department. A more likely explanation, however, is that this transformation occurred because of shifting work emphasis and gradual technological change.
Influence on Organizational Principles

The preceding sections of this chapter have dealt with the significant relationship between organization and information flow and with the organizational structure changes which have occurred within the refinery. Accompanying these changes were modifications of certain organizational principles. This section is concerned with these changes.

The Principle of Decentralization

The Petro-Chem Refinery has long operated under a policy of decentralization of control within its internal organization, and, to a lesser degree, with its relationship to the parent organization. A certain amount of control is exercised by the parent company over the refinery in that the activities of all affiliates are coordinated in the best interests of the entire company.

As pointed out in the beginning of this chapter, there exists a controversy over whether or not information technology will cause a recentralization of control in top management or a push toward further decentralization of authority and control to lower levels. In reality, there exists two dimensions to the principle of decentralization as it applies to the refinery. The first dimension to be examined is internal; the second dimension concerns the external relationship between the refinery and its parent organization.
The first dimension. The philosophy or principle of internal decentralization of control has been affected by information technology in some degree. At first glance information technology would seem to encourage greater centralization because the relevant data would be more accessible to top management. However, the same data can also be more quickly available for self-control to managers in decentralized operations. There is some evidence of a small movement toward pushing authority and decision making downward in certain operating departments. Access to improved and faster control information allows certain operating decisions to be made at lower levels within these departments. Foremen in the Oil Movement Department, for example, are making decisions concerning disposal of oil inventories to an increasing degree. Burlingame argues that decentralization can be strengthened by information technology. He comments: "Counter to many arguments, the anticipated advances in information technology, in my opinion, can strengthen decentralization in those businesses that have adopted it."10

The second dimension. This dimension of the principle of decentralization concerns the relationship between the refinery and the parent organization. The parent company has long

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10Burlingame, op. cit., p. 124.
maintained a philosophy of decentralization among its affiliates. Each develops its own operating and long range plans, but the parent organization coordinates the activities of all affiliates in the best interests of the entire company. There are some indications that this philosophy may be altered because of improved information technology.

The allocation of the flow of petroleum products among its affiliates has always been directed by the parent organization. This complex allocation problem has been handled through simulation techniques. In order that company-wide activities be coordinated, the need for uniform reporting practices is apparent. As each affiliate's information system and operating practices become more standardized, there is a growing feeling that decentralization may diminish as a concept and as an operating reality. 11

In sum, the Petro-Chem Refinery operates under centralized policy control and a certain amount of decentralized operating authority in its relationship to the parent organization. Information technology may influence the concept of decentralization as now practiced between the parent organization and the refinery. 12


12 Ibid.
The Role of Information Technologists

The specialists engaged in information technology occupy an important place on the management team at the refinery. They are officially organized into the company in a staff or advisory capacity. There is an apparent fundamental separation of interests and abilities between those people who carry out day-to-day operations and those who are engaged in computer and systems analysis, which can be seen in the corporate organization chart on page 66. However, the organization chart does not disclose the interactions between departmental personnel.

Role playing. McGregor has noted that each manager plays a variety of roles. A manager of an operating department can function in the roles of both line and staff, depending upon whether he is giving commands to his subordinates or acting as an advisor to his superior.

The information technologist, too, plays many roles. At times he does research for and gives advice to top management. At other times he is devising means to help operating management free itself of much routine paper work so that it can devote itself to the significant aspects of managing. And sometimes, he may be engaged in making major changes in the

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information system that in turn strongly affect other managers. In initiating these changes, he may be acting more in a directory fashion than in an advisory one. 14

Line and staff principle. The traditional organization principle of line and staff has been affected somewhat by the activities of the information technologists. This concept may be affected even more in the future.

In speaking of the effects of automation, of which information technology is a part, Buckingham makes this comment: "The widely used 'Line and Staff' principle grew out of the needs of mass production techniques. This principle may have to be re-examined in the light of automation." 15 When this principle is re-examined, the form of organization may be changed. Buckingham concludes:

Automation also requires technicians to be flexible and cooperative rather than rigid and competitive. Since the traditional line and staff principle permits empire building based on the objectives of special groups rather than over-all objectives of the enterprise, experimentation with new forms of organization will be required. 16

The specialists at the refinery attempt to establish a professional-client relationship with the various groups within the organization. The general feeling of management is that

14 Ibid., p. 108.


16 Ibid., p. 58.
the important consideration is the establishment of a high degree of coordination and unity of purpose among the two groups, not whether the specialists operate in a line or staff capacity.

The Span of Management

The principle of span of management, or span of control, has long been a basic concept in organizational theory. It is referred to here as the number of subordinates a manager can effectively supervise.

The span of management is analyzed from two levels. The first considers observed changes in the span of supervision at the middle management level. The second level of analysis is concerned with supervisory levels of management. Each is considered in turn.

Middle management level. At the departmental or middle management level, there has been no observable movement toward either an increased or decreased span of management as a result of information technology. In observing the departments directly concerned with some phase of the integrated

17Through observance of the refinery's organization charts (pp. 65 and 66) it can be seen that there has been a general decrease in the span of management during the last 18 years. However, this study is concerned with the changes in the span of management since the inception of information technology in 1956. Since that time there has not been any basic change in the span at the top level of management due to information technology. Therefore, only middle and lower levels were analyzed since they are supposed to be the ones most affected by information technology.
data processing system, it was noted that in some instances the head of the department now supervised an increased number of subordinates. For example, the Head of the Purchasing and Traffic Department now supervises two assistants rather than one. On the other hand, the Managers of the Stores and Oil Movement Departments now have fewer supervisors reporting directly to them.

Supervisory management level. There is a small movement toward a decreasing span of supervision at this organizational level. For the past ten years there has been a steady decrease in the number of workers within the refinery. A part of this decrease resulted from increased mechanization or automation and a part from the automation of information. These findings concur with the results of a survey of highly automated companies. This survey reported that 82 per cent of the companies surveyed said that work teams had been reduced in size, and 75 per cent said that the span of supervision had been reduced as a result of automation. 18

However, there exists a small amount of conflicting evidence concerning a decreased span of supervision as a result of information technology. For example, the Supervisory Buyer of the Purchasing Department clearly supervises the activities of an increased number of buyers. This is also true

in the case of the Assistant Head of Stores who has an increased number of section foremen reporting to him.

Although there has been an interaction of many internal forces that affected the number of employees, there is a movement toward a decreased span of management at the supervisory level. However, there is not a clear-cut pattern concerning this span at the middle management level. It might be noted that the latter conclusion is in conflict with various predictions that information technology causes an increased span of management.  

This chapter has been concerned with organizational changes on the corporate and department level. Its primary emphasis has been placed on structural adjustments and combination of management positions. Since no part of the organization has actually vegetated over the past few years, there have been other changes. Subtle shifts and adjustments have appeared in managerial decision making, functions, and job content. These changes will be examined in the next chapter.

Summary and Evaluation

**Difficulty of Distinguishing the Effects of Information Technology**

An attempt was made in this chapter to single out one factor of a complex problem and to attribute to it the organizational

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changes that have occurred in the past few years. Obviously, the effects of information technology on the organization can not always be separated from the natural evolution of an organization over time. Factors such as improved competitive conditions, expanding markets, shifts in work emphasis, and technological improvements all play a part in organizational adjustments.

The significance of an observed change can perhaps be assessed in terms of the organizational level that is affected and the portion of the total job that is affected at each level. In terms of the over-all corporate level, there have been few changes that could be directly attributed to information technology. When changes did occur, it was simply the post-war organization adjusting to the complexities of modern technology and operations. This conclusion is supported by the findings of E. S. McCollister, Division Vice-President, Business Planning and Marketing, Electronic Data Processing, Radio Corporation of America; he concludes: "Rarely does the computer create a structural revolution when it is introduced in the organization. The changes which it favors evolve naturally." 20

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Corporate Organizational Developments

It is significant to note that there has been one top-level organization realignment that can be attributed to the recognition of the importance of information to the organization. This is, of course, in reference to the establishment of the Business Services Division composed of the Accounting and Computer Departments. These departments are charged with the responsibility of supplying other units with fast, factual operating data so that these units can meet their objectives efficiently. The Computer Department, in particular, is responsible for the development and maintenance of the refinery's integrated information system.

Departmental Organizational Developments

Departmental organizational changes have been numerous. The emergence of the Computer Department was the first to be observed. The kind of information generated through the EDPM Master Plan and developed by this department contributed to adjustments in client departments. A great number of managers and employees in operating departments have been freed of many routine and repetitive activities. This in turn enabled them to devote more time to creative or more important aspects of their work.

Changes such as just described were noted in the Stores Department, the Purchasing and Traffic Department and the Oil Movement Department. Operating information developed through
the EDPM Master Plan frequently inspired management decisions which affected the departmental structure. Two departments were combined, management positions merged and some also eliminated, new procedures adopted, and shifts in authority and responsibility all occurred in these departments due to the speed and availability of this operating information.

Other departmental changes were noted which occurred primarily because of improved engineering skills and technological change. Information technology may have played a small role in their development. An example of this type change is the combination of the Distillation and Cracking Departments. Simulation of operating plans in the manufacturing processes of distillation and fractionation enabled these processes to be greatly improved. However, other contributory factors to this merger, such as engineering improvements to the operating units and shifts in departmental functions, were more important.

Organizational Principles

The organizational principles of the refinery have been affected somewhat by information technology. However, contrary to many prognostications concerning increased centralization, a small movement toward increased decentralization of control was observed. This finding is in line with the

See pp. 61-62.
evidence of other studies of information technology's effect on the principle of decentralization. But, the philosophy of decentralization under which the parent organization has always operated in connection with its affiliates, may experience greater change than the refinery's internal philosophy.

Turning now to the span of management, a long-established concept in organizational theory, two observations can be made. First, there seems to be no movement toward either an increased or decreased span at the middle management level. Second, confirming evidence found in other surveys and studies, there has been some decrease in the span of management at supervisory levels within the organization. These findings emphasize the danger involved in wide-spread generalizations, as evidenced by the predictions found in the first section of this chapter, which often are too all-encompassing in their sweeping statements. In particular, the prediction that the span of management would widen did not consider that various levels of management could be affected differently by information technology.

No Structural Revolution

Information technology has not created a structural revolution at the Petro-Chem Refinery. This is contradictory

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to the predictions that radical reorganizations would result from the introduction of information technology into an enterprise.\textsuperscript{23} The changes which have occurred, both in structure and principles, have been minor ones and have evolved slowly. However, this is not to imply that the advent of information technology may not ultimately have far-reaching effects on the corporate organizational structure. To date, largely because of the routineness of most applications, this impact has not been felt.\textsuperscript{24}

There has been a small movement toward the merging of departments within the refinery. Improvements in the integrated information system have played a part in this movement. As the relationship and coordination needed between departments sharing a common EDPM project become more apparent, barriers between these departments may be eventually broken down. At some point this trend may lead to a reorganization of the Stores and Purchasing and Traffic Departments into a single department. If this does occur, it will not be a radical reorganization of certain middle management levels, but a natural evolution of the refinery adjusting to changing conditions and technology.

\textsuperscript{23}See the prediction on page 60.

\textsuperscript{24}This is true in other organizations. See D. Ronald Daniel, "Measure Your EDP Progress: A 5000-Mile Checkup for Computer Installations," \textit{Management Review}, L, No. 3 (March, 1961), 76.
In final evaluation of the various premises and predictions concerning the effect of information technology on organizational structure, the evidence of this study supports the view that although the changes accompanying information technology are extraordinary, they are not revolutionary. The predictions singled out in the introduction of this chapter have been proven to be too general, too sweeping to be completely valid at this time. These predictions, although containing elements of truth, can not be considered as accurate descriptions of what has occurred at the refinery to-date because of information technology.
CHAPTER IV

THE IMPACT ON MANAGEMENT

The preceding chapters indicate that information technology may cause changes in business operations to which management must adapt. Information processing techniques are having an impact on all levels of management, but in rather different ways at different levels; sometimes in agreement with the predictions of various scholars and sometimes contrary to these predictions.

This chapter is concerned primarily with the influence of information technology on the management of the Petro-Chem Refinery. Again, the first section presents samples of the many prognostications on information technology's impact on management. The major portion of the chapter considers and evaluates the changes which have occurred at the refinery.

The Predictions

The increased interest in information technology has lead to many prognostications concerning its influence upon the management process. The following predictions may be considered representative of those found in the management literature:

Jobs at today's middle management level will become highly structured. Much more of the work
will be programmed, i.e., covered by sets of operating rules governing the day-to-day decisions that are made.\footnote{1}

A quotation used in the preceding chapter is again pertinent.

A radical reorganization of middle management levels should occur, with certain classes of middle management jobs moving downward in status and compensation (because they will require less autonomy and skill), while other classes move upward into the top management group.\footnote{2}

"There seems little doubt that the computer will have a substantial effect on management. It will 'automate' many routine (and even some not-so-routine) decisions; it will sharply cut back on the number and status of middle managers. . . ."\footnote{3}

These preceding quotations were concerned with the changing content of middle management jobs. Top management, according to some writers, will also feel the effects of information technology. For example, Leavitt and Whisler predict that "... top management will take on an even larger proportion of the innovating, planning, and other 'creative' functions than they have now."\footnote{4} In agreement with this view, George Strauss concludes:

\footnote{1}{Harold J. Leavitt and Thomas L. Whisler, "Management in the 1980's," \textit{Harvard Business Review}, XXXVI, No. 6 (November-December, 1958), 41.}

\footnote{2}{\textit{Ibid.}, p. 42.}

\footnote{3}{George Strauss, "Organization Man - Prospect for the Future," \textit{California Management Review}, VI, No. 3 (Spring, 1964), 7-8.}

\footnote{4}{Leavitt and Whisler, \textit{op. cit.}, pp. 41-42.}
It seems likely that jobs in top management will become more creative and demanding. Once freed of details of routine analysis, top managers will be free to engage in long-range planning and human development. Functional specialization (in particular, analytic thinking-ahead on specialized problems) will become more important at the top, and relations among top managers will be increasingly collegial rather than hierarchical. Particularly among the functional group, analytical skills will become all important and there will be a premium upon being an innovator and a non-conformist.  

Burlingame, in commenting on the predictions of many writers, best summarizes these prognostications in the following words:

Recent progress in information technology has been so rapid that various observers have predicted the elimination of middle managers and the reversal of the trend of the last decade toward decentralization in business. Computers and the associated technologies, the argument runs, will make better decisions of the type now made by middle managers and will make them faster. Companies will find it possible to process and structure relevant information in such a comprehensive fashion and so quickly that decentralized responsibilities will be withdrawn and non-computer decision making limited to a top-level elite in the organization. Apparently the manager's work in the future will be depersonalized and personal satisfaction will have to be found in activities pursued outside working hours.

The general thesis of these and other predictions is that information technology will have a revolutionary impact on the management process. According to this thesis there will be a drastic reorganization of middle management, where jobs

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are to become highly structured and programmed, decision making will be "automated," and many middle management functions will be taken over by top management.

This chapter considers the evidence found at the Petro-Chem Refinery concerning changes in managerial functions and jobs due to information technology. An evaluation of the predictions and the changes found at the refinery is presented in the latter part of the chapter. Again, no attempt is made to answer each prediction specifically.

The Effects on Managerial Functions

This section can be considered a description and examination of the changes in managerial functions which were expressed or implied in the preceding chapters. The management functions under consideration are decision making, planning, and controlling. Changes in the function of organizing were described fully in the preceding chapter and will not be re-examined here. Through development of these functions, it is believed that the important aspects of the process of managing will be generally covered.

Top Management Functions

The managerial functions of planning, organizing, and controlling can not be performed without making decisions. Planning, for example, is in itself a decision making process since it consists of choosing between alternatives. Organizing
consists of how to group activities, determining who should be in charge, and how much authority he should be delegated. Finally, control implies a decision to whether or not plans and objectives are actually being accomplished, and, if not, what action should be taken to correct the deviations.\footnote{Harold Koontz and Cyril O'Donnell, \textit{Principles of Management} (third edition; New York: McGraw-Hill Book Company, Inc., 1964), pp. 135-156.}

The structure of a business organization and the content and activities of the management jobs within it reflect the organization's processes of decision making and the flows of information used to reach those decisions. Information technology is a means of organizing information, of relating it to various managerial decision problems, and, in some instances, of working out decisions based on predetermined and programmed rules. Since decision making is a critical characteristic of the management job and since the raw material for decision making is information, the use of information technology implies changes in the content of many management jobs.

The problems that managers face at various levels in the organization can be classified according to how well-structured, how routine, or how obvious they are when they arise. On one hand, there is a category of decisions which is highly programmed. They are routine and repetitive and follow tested rules. Examples of such decisions include routine inventory
replacement of standard items, routine engineering calculations, and routine handling of company payroll.  

In contrast, the category of nonprogrammed decisions contains decisions which are not routine but are complex demanding special consideration. Examples include decisions to produce a new product line, to reorganize the organization along different lines, and decisions concerning policy changes in the area of industrial and public relations. There are also decisions which lie between the programmed and nonprogrammed, the well-structured and ill-structured, and the routine and non-routine which also take special consideration. 

Different information-processing and decision-making techniques are used in dealing with the programmed and nonprogrammed categories. Therefore, the differences in the type decisions made by top, middle, and lower management are significant in understanding the influence of information-processing technology on decision making. The influence has not been the same on all levels of management. The resulting changes in the decision making process are therefore diverse at the various levels of management.

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9Ibid.

Decision making. The nature of the problems with which the top management of the refinery is typically concerned is not the kind that can be programmed. These problems are, generally speaking, either of a long-run policy making nature or of a coordinating nature such as attempting to harmonize the interests of employees, suppliers, and customers. Policy making decisions include such major decisions as determining the facilities needed to produce the volume of output allocated to the refinery, the degree of mechanization and automation, organizational structure, and labor and personnel policies. Consequently, information technology has had very little direct effect on the decision making process of top management. 11

Certain decisions, however, may be improved through the organization of more comprehensive information in reports presented to upper management. These reports are more comprehensive because more variables are examined or new areas of analysis are included in the investigation. The basic content of these reports, in many instances, does not appear to have changed extensively despite improvements in the

fact-finding and analysis stages performed at lower levels of management. According to one member of top management:

The impact of information technology has not materially changed the information that reaches me, since essentially, the same type information is prepared. The important difference is that it is prepared with much less effort by the various groups under me. These groups have been able to work on a greater variety of subjects or extend their operations as a result of not having to spend as much time preparing or processing information. Computers, data processing, and other techniques have helped in that respect, but the contents of the reports have not changed.\(^{12}\)

A subordinate of the Petroleum Products Manager shared this view: "...the information we send up the line has always been supplied by hand, not by machine. I think the biggest difference is that we supply him better, more factual information."\(^{13}\)

The information handling techniques, while providing a factual base, still fall short of the requirements for taking action, unlike situations where "automatic" decisions can be made. The final assessment of the risk and the decision to act is made by a manager integrating the factual information with the less well-defined elements in the situation.

The speed in which data can be processed and placed in report form does not seem, in many instances, to be of any

\(^{12}\)Statement made by the Petroleum Products Manager in a personal interview, August 25, 1964.

\(^{13}\)Statement made by Section Head, Long Range Economics and Budgets, August 25, 1964.
particular significance to the type decisions made at this level. In other words, the speed of information, in terms of hours or days, is practically never vital to long range decision making. Top management receives reports from lower levels at set time intervals or upon request. "Exception" reports, often oral, of extraordinary occurrences are made when necessary.

Faster reporting time, however, is of interest to top management as they are vitally interested in any change in the information system which will furnish them more comprehensive operating results of the various product groups. The important point is the use they make of this information. As previously stated, upper management normally does not need faster reporting time for long range policy decisions, but rather for communicating or coordinating the needs of the various divisions with one another. The Petroleum Products Manager had this to say concerning his responsibilities:

... The part I play is one of a communication center. I make sure that the Mechanical Division is aware of the critical needs of the Process Division and vice versa and that the Technical Division is applying its efforts in the area of most help to the entire organization.15

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Many top level decisions, of a coordinating nature or otherwise, are made by small groups of managers or by the entire management committee. These managers, of course, rely heavily on the reports from divisional heads. These management groups have developed an over-all point of view concerning the entire refinery which supersedes that of any particular segment of the organization.

A small group of management personnel consisting of the General Manager, the Assistant General Manager, the Product Managers, and the Administrative Manager normally meet briefly each day to coordinate the refinery operations and to assess the impact of a particular decision on all parts of the organization. Decisions made by this group are not operational decisions in the sense of regulating the activities of divisions or departments. Rather, they are, as previously mentioned, more of a coordinating nature.

The impact of the new technology on top management has improved the basis of human decision making due to the availability of broader, more comprehensive information. Decision making has not become routine and mechanical. The attributes of information technology, that is, speed, relevance, and accuracy, play only an indirect role in this high-level decision making. Certainly if operative management has access

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16 This is a typical result of information-processing techniques. For example, see Harold Koontz and Cyril O'Donnell, *op. cit.*, p. 154.
to a larger amount of information for consideration, an increased range of alternatives to examine, and increased speed in examining each decision situation, the reports going to top management should be improved. Top management can be confident that these reports, either written or oral, are based on factual information and this, in turn, should sharpen their perception of the refinery's system of operation.

In connection with top management decision making, it is significant to state again that there has not been any major change in the organizational policy in terms of centralization or decentralization of decision making. Nominal movements only were noted and these were in the direction of shifting minor decisions from men to machines. These shifts in decision making occurred in the realm of middle or operating management and can not be construed as occurring within the province of top management. An examination of changes in the decision making processes of lower management is undertaken in a later section of this chapter.

Planning. Planning is defined here as the selection between alternative courses of future action. In this regard, planning and decision making are closely related since decision making may be construed as consisting of defining a problem, establishing alternative courses of action, and selecting between these alternatives.  

17Koontz and O'Donnell, op. cit., pp. 135-156.
Planning is a function of every manager at every echelon in an enterprise. However, the type of planning in which a manager engages depends upon his position in the organizational structure. Top management planning has to do with broad overall programs and policies important to the company as a whole. Intermediate planning (i.e., planning by lower top management or upper middle management personnel) has to do with the direction of effort to accomplish top level programs. Operational planning is, of course, a function within each department and is related to the scope of authority delegation of the manager.

This section is concerned with a discussion of the effects information technology has had on top and intermediate level planning within the refinery. Operational planning and the changes which have occurred in this area are examined in a later section.

Information technology has not penetrated the echelon of top management to change the nature of the planning process. The reason for this is that planning of this kind involves factors of judgment, experience, imagination, and creative thinking which can not be quantified or programmed.18

The contribution that information technology makes at this level is an indirect one. Since more comprehensive and more detailed information can be organized and presented to

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18 John Dearden, op. cit., p. 43.
upper management on a regular basis, they can think in terms of the total organization and the coordination of all activities toward the accomplishment of goals and objectives.

Improvements which have been made tended to occur at a level below that of top management. Managers involved in the planning process at this intermediate level include those who are on the border line between upper and middle management, such as those on the divisional head level.

Simulation, one of the relatively important planning tools, is used to supply information directly to this level. For example, simulation techniques are used in some phases of the preparation of the capital budget. An economic model is utilized whereby proposed capital investment projects are analyzed according to their yield and the length of time required to produce the yield. The economic model is a cash-flow type of program where a list of expenditures to be made and savings which are to be derived from the investment are submitted as inputs to the computer. The determination of the relative attractiveness of each proposal is then made by the computer and submitted in report form to management for their consideration.

A related example where simulation is used in the planning process is in the forecasting of refinery operations. Simulation techniques are used in preparing ten-year forecasts which take into consideration such factors as the large source of crude oil from off-shore exploration and expanding markets,
such as the company's growing market in the Southeastern states. If the forecasting results are optimistic, then management can submit proposed investments in capital equipment to meet this demand into the capital budget. These proposed investments are then analyzed in relation to other proposals. On the other hand, if the forecasted outlook is pessimistic, very likely any decision concerning expansion of operations will be postponed.

The allocation of lube oil manufacture has already been cited as an example of a fairly high-level decision through the use of the computer. This allocation is, of course, also an example of intermediate planning for the manufacture of the refinery's share of the lube oil.

Again, in relation to the type of planning required of upper management, the examples cited above are still fairly low-level in terms of over-all company operations. Improvements have been made in the planning process; however, most of them have occurred in what is normally considered the province of middle and lower management. Changes in the planning process at these levels are discussed in the latter part of the chapter.

Controlling. Control is defined here as those actions taken to assure that operations adhere to predetermined plans. This section and the section examining middle management control are, therefore, occupied with the measuring and reporting on performance. Again, it should be noted that all
the managerial functions discussed in this chapter are interwoven with one another. Therefore, control also consists of planning and decision making activities.

The information that a manager receives gives him the opportunity for corrective action and is his basis for control. Control can not be exercised without such information. Different echelons of management receive different types of information. At supervisory levels, certain information is required for control purposes. In the next higher echelon of management, the character of required information changes; some information is deleted, some is added. Finally, the top echelon of management receives only summary reports, unlike the detailed operating reports of lower management.

If information is considered the basis for control, then computers and management science techniques, according to some prognostications, should push control over performance to higher levels of management. However, an upward shift in control has not occurred at the Petro-Chem Refinery. Its philosophy of decentralization of control and decision making has, to a small degree, been extended downward in the organization.

It is significant to note, however, that the Petroleum Products Manager will soon have the means for more centralized control if so desired. This is in reference to the installation of 1050 IBM Transmitter Sets in the Oil Movement Department and in the administrative office. To date, the plans are to have the information concerning oil inventories
centralized in the main office and then distributed to the Head of the Oil Movement Department for his decisions for control over these inventories. Although top management will have the information available for direction over these activities, centralization of control is not anticipated.

Despite the above example of the potential means of centralizing control over operative performance, speed of decision making is not a vital factor at this level. The normal control decisions of upper management are not routine, and, furthermore, there are not a large number of them to be made. Consequently, the speed of reporting and the speed of decision making are often not vital factors.¹⁹

Information technology has penetrated the top level of management to a very small extent and has had very little affect on the functions of top management. Certainly improvements in the managerial functions of decision making, planning, and controlling have been made. What was formerly done is now being done better and the improvements are, so far, only a matter of degree. Furthermore, these improvements are taking place somewhere short of top management levels.

**Middle and Supervisory Management Functions**

Although information technology has had very little direct affect on the functions of upper management, the same

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¹⁹John Dearden, *op. cit.*, p. 43.
can not be said concerning middle and supervisory management. Changes and improvements have been observed in many aspects of the primary activities of decision making, planning, and controlling. The effects of information technology on decision making are considered first.

**Decision making.** The problems facing middle and lower management are somewhat different than those of top management. Some of these problems can be classified as being well-structured and routine and can be programmed on the computer. Any change in the decision making process has consisted primarily of shifting to the computer certain types of routine decisions which were formerly made by individuals at this level. These decisions are usually repetitive and easily adaptable to "automatic decision making."

The decisions that are not subject to automatic treatment at this level are ones to which an individual must devote his skill, attention, and imagination. Decisions of this nature require judgment and experience rather than computation and organization of facts, which information technology does best. 20

Many of the decisions which were formerly made by management personnel are now made through the use of the computer. Examples of these automatic decisions may be found in the

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operations of the Stores Department, Purchasing and Traffic Department and in the gasoline blending operations of the Oil Movement Department.

Computer "decisions" in these areas are made in accordance with specific rules which are incorporated into the computer program. Application of information technology to inventory control, routine purchasing and gasoline blending, require the factors affecting decisions in these areas to be defined completely and be expressed in quantitative terms. Although the computer "makes" the decision, the determination of the factors which are programmed into it remains the responsibility of the operating department that formerly made the decision.

A trend taking place in decision making at the level immediately above that of automatic decision making is distinguishable. Generally speaking, this trend is taking place at the department head level. Until the advent of information technology, a man of intelligence, judgment, and experience was necessary to make decisions based upon the facts that could be accumulated. Very often these facts were late because of the difficulty in assembling and processing them, inaccurate because of the methods by which they were assembled, and incomplete because of the limitations that existed in fact gathering. A gap existed between the condition indicated by the available data and the decision which was made through intelligent interpretation of the facts.
An example of a situation of this type existed in the Oil Movement Department before the inception of Project O, Operations Analysis. At that time, tank gauge measurements and control over the various inventories of oil products were done manually. Such a long period of time was required to detect any deviations that the Department Head could not make optimizing decisions concerning allocation of production of the various products. With the inauguration of the Operations Analysis phase of the EDPM Master Plan, the means of gathering the necessary control information quickly and the means whereby better decisions could be made were obtained.

With the advent of information technology, it became possible to assemble more facts more quickly and more accurately; more important, it became possible to make many of the analyses that department heads normally made. The information can be presented to these middle managers with statistics which are so complete that the required lines of action are explicit; what is left is really no decision at all, but rather a recognition of what obviously must be done. In many instances, a clear indication can be made of the way in which it must be done.

Improved decisions have resulted from the advent of computer technology and management science techniques. Decisions are better in the sense that more alternatives can be examined and this may result in optimum or near-optimum decisions. In searching for the solution of complex problems, such as found
in gasoline blending or refinery simulation, efforts are directed at obtaining the best solution rather than a near-optimum solution. The decisions may be better in the sense that the speed in which computations can be made permits management to consider all relevant factors, rather than only a few as before. 21

A greater degree of flexibility in decision making has been established because the high speed in which information is made available permits changing decisions in view of changing conditions. There have been some substantial reductions in the time required for assembling and processing large amounts of data due to some phase of information technology, particularly the integrated information system. This information system permits information to be disseminated quickly and accurately throughout the organization. Thus, in addition to relieving middle management of much of the burden of routine paper work, this dissemination of information allows management to delay a decision when necessary and allows a certain degree of flexibility in the organization.

Planning. Planning has already been defined as the selection between alternative courses of action (see page 111). The type planning required of management personnel at middle and lower levels of the organization is somewhat different.

from that of top management. Operational planning, under discussion here, concerns the short range plans normally made at the departmental level.

The similarity between planning and decision making was noted previously. The definition of planning used here implies the determination of a problem situation, the determination of alternative courses of action, the evaluation of these alternatives through the collection and analysis of relevant facts, and the selection of a course of action. Since the decision making process involves essentially the same steps or procedures, the two functions are obviously intermingled. Planning involves decision making, and decision making involves planning.

A more precise determination of the problem area has developed since information technology, particularly the EDPM Master Plan, has permitted a more careful consideration of relationships.

The integrated information system allows some combination of parts of the over-all planning that was formerly made separately. The most noticeable example of such combinations was observed in the area of refinery operating plans.

The processes involved in such an operation are very closely interrelated, to such an extent that changes at one stage inevitably affect the succeeding stages. Formerly, these various stages had to be separated for purposes of detailed planning because of the size of the job involved. Computer simulation models are now being used to permit
planning of these stages as a part of a single effort so that the interrelationships can be considered.

Combinations of separate parts of over-all planning were also observed in connection with inventory control. The relationship between physical handling, purchasing, and availability of material for operating purposes has been recognized and considered together as parts of a single problem. A related example was noted in the applications of Project P, which includes payroll, personnel statistics and manpower scheduling in one application.

The ability to establish a more precise definition of problems has been particularly valuable to management. By being able to move a substantial part of the clerical work out of the operating departments, management has been able to concentrate on their basic functions. For example, in the Purchasing and Traffic Department, the shift of invoice checking and follow-up functions to the computer has permitted the buyers to spend more time on their basic purchasing functions, and permitted the supervisory buyer and the assistant purchasing head to concentrate on their supervisory duties. The same thing applies to the Head of the Stores Department and his assistant. Through the mechanization of inventory control, they are able to devote their attention to analytical work. Finally, the establishment of the computer library containing engineering models and problems has permitted the engineering departments to reduce much of the burden of routine calculation.
The increased use of mathematical and statistical techniques requires a more careful consideration of problem definition. The successful use of many of these techniques requires a very careful definition of objectives and the factors involved. The relationships among these factors and their relative importance must be specified, usually in quantitative terms. The nature of the problem has not been changed by this more careful consideration, but it has resulted in clarifying the problem to an extent not previously done in many instances.

Evaluation of alternative courses of action has also undergone improvements. The principal difference of what was done in the past and what is being done is the possibility now of examining an increased number of available alternatives. In the past, planners have been forced by time limitations to select for examination only those few alternatives which looked most promising. Sometimes this procedure resulted in good plans. But in some instances the "best" plan would not be discovered. This has been found, for example, in some of the technical applications studied. The use of linear programming and other mathematical techniques, such as those in the refinery simulation programs and in design work, has resulted in measurably better plans through an examination of more alternatives.

Collection and analysis of pertinent facts has also been improved, due primarily to the above mentioned techniques.
The first of these changes is the systematic collection of more facts. In some instances a collection of basically the same type information, with some refinements, takes place. In Project O, for example, the same basic facts are gathered faster and utilized to an increased extent in operating the processing units. In other instances, there is a collection of different kinds of facts believed to be more pertinent to the problem involved. A case in point is the material lists which are provided for use by the engineers in planning unit over-hauls.

An improved and more complete collection of facts means that in some instances the analysis is based on facts rather than assumptions. Simplifying assumptions are often made where the fact-gathering process is costly and time-consuming. In some parts of the computer applications examined, the assumptions formerly made were eliminated and replaced with the pertinent facts. This happened, for example, in some parts of the refinery simulation program.

A second type of change involved in the collection and analysis of pertinent facts is the more consistent and systematic analysis of these facts, often amounting to standardization of the analytical process. This has occurred in such instances as the gasoline blending applications and all the applications which use such statistical techniques as multiple correlation. Once a method of analysis is established for
these applications, it is programmed into the computer and used consistently each time the planning problem arises.

**Selection of a course of action**, the final step in the planning process, has been affected by changes in the preceding steps. Therefore, changes have resulted in the final selection or decision in the way of better decisions, the timing of decisions, and greater flexibility in the planning process.

These changes were discussed somewhat under the area of decision making. Better decisions, it will be recalled, are obtained through the extensive examination of more alternatives. The optimum solution is sought, rather than just settling for a feasible one. These decisions are also considered better in that many of the inconsistencies inherent in human consideration of alternatives are removed.

An important dimension of information technology is the ability to reduce the planning period required in many activities throughout the refinery. By being able to process a large amount of data and to process it quickly, the lapse in time between the decision and the anticipated event becomes very small. The process of constant adjustment of plans to unanticipated situations has reduced the necessity of establishing long range plans to handle these situations. If the refinery can readjust estimates or plans very quickly and very frequently, operating plans need not be established as far in the future as they were in the past. Changes in
the timing of these decisions have repercussions throughout the refinery.

The organization has achieved a greater degree of flexibility than was formerly possible because of the possibility of deferring decisions. Decisions which have been made can be changed to meet unanticipated situations much more rapidly and efficiently. This has been demonstrated in several of the computer applications, one of the more noticeable of which is found in the Oil Movement Department. In the past, several weeks would pass before the results of a decision could be known and evaluated. Reporting time has been reduced to the extent that in many instances the results can be known in a few hours. Management can then countermand any decision which may be causing adverse or unexpected results. For example, decisions concerning the disposal of surplus inventories of oil products can be made quickly due to the speed of the feedback of central information.

This increased flexibility and change in timing has implications in the area of efficient utilization of resources, both manpower and material. The period of time that labor and material are tied up in inventory has been reduced. Because of the automatic decision making in the area of inventory, there is less possibility of losses due to obsolescence.

The impact of information technology has probably been more important in the planning area than any other. However, the planning processes within the refinery have not been
revolutionized. Rather, the changes which have been noted have been in the nature of improving upon these processes. These improvements can not be considered revolutionary, and furthermore, they are occurring within the area of middle and lower management rather than that of top management.

Controlling. The process of control has already been defined as those actions taken to assure that operations adhere to predetermined plans (see page 114). This section is concerned with the changes in control which have been observed at the middle and supervisory levels of management.

The nature of control that is exercised where "automatic" decisions are made by the computer does not require continuous supervision as in the past. For example, the refinery until fairly recently has used electronic data processing equipment for controlling its catalytic cracking operations. In a petroleum cracking tower, the operation is dependent on several factors: the composition of the crude oil introduced into the operation; the effect of the chemical catalyst being used; the temperature; and the speed of chemical reactions occurring within the tower. All of these elements and more are capable of being sensed by mechanisms located inside the cracking tower. Formerly, this information from the sensing mechanisms was led back through electronic circuits to a control panel, where the various conditions were indicated by a series of dials, tubes, lights, and other communication devices. An engineer watching over the panel could control
the operation of the tower whenever the operation got out of hand. Temperature controls could be instantly brought to bear if the temperature rose too high. If the catalytic action was too low, more of the catalyst could be introduced.

Early in the operation of control systems of petroleum cracking towers, engineers found that it was seldom that a single factor went astray and needed adjustment. To maintain the continuous-process operation in its optimum operating condition throughout a run, the engineer usually must control several functions simultaneously, for the total operation can be described and controlled only in terms of the interdependence of several factors. Now, installations have been built which control the cracking tower or other continuous processes on the basis of a mathematical formula - linear programming. All elements affecting the speed and efficiency of the operation are represented in the formula, which is then built into a computer. The computer in turn automatically controls devices which can alter conditions in the cracking tower. When one or more elements within the tower begin to get out of line, the computer senses the deviation, applies it to the mathematical formula, calculates the adjustments necessary to bring the operation back into proper balance, and proceeds to actuate devices which do this within the tower.

Continuous supervision over operations, such as the type just described, to see that performance conforms to plans, is not necessary. If the computer program has been properly
written, the computer can be expected to adhere to its instructions with a high degree of consistency. This kind of change in the control process was observed in all applications in which routine decision making was transferred to the computer.

The scope and use of operational control reports has changed. For instance, the speed in which control information now reaches management is important in almost every application described in Chapters II and III. The Head of the Oil Movement Department considers speed to be the greatest of all the improvements in the reporting system. The nature of the control he exercises over the activities of his department has been improved greatly due to improved reporting time.

Improvements in the accuracy of reports were also noted in the various applications of information technology. In the past, a major source of error, either intentional or unintentional, was found in the manual computations required by these reports. Since the computer can perform a great number of uninterrupted operations without manual intervention, a major source of error has been eliminated. The improvement in accuracy did not occur at the final report level, but at the level where the final reports were prepared. The effort required to find and correct the errors before the final reports were prepared, was decreased greatly.

As the speed and accuracy with which operating reports were prepared and disseminated throughout the ranks of middle
and lower management, an increase in the confidence of operating personnel was observed. Departmental managers, assistants, and foremen all have increased confidence in their decisions and ability to perform their jobs.

The two preceding sections of this paper examined the effects of information technology on the managerial functions of top, middle, and supervisory management. Although there have been tremendous advances made in improving upon the processes of decision making, planning, and controlling, these improvements are evolutionary rather than revolutionary. The direction of these improvements is in modifying present processes, not in overturning them. The bulk of the improvements has occurred at lower levels, not in the upper management levels of the refinery.

The Effects on the Nature of Management Jobs

This section considers the nature of the management jobs within the refinery and the effects information technology has had upon them. As management organization and functions change, the very nature and role of the managerial job changes also. Research studies conclude, however, that the degree of impact on individual managers varies with the managerial level on which the individuals operate. In the opinion of Herbert Simon: "There is undoubtedly a rough, but far from perfect correlation between a manager's organizational level and the
extent to which his decisions are programmed. As in the case of managerial functions, information technology has had different effects at different levels of management. This should not be surprising in view of the differing effects of information technology on management functions.

**Top Management**

There have been numerous changes in the nature and content of the top management jobs at the Petro-Chem Refinery. These changes are the evolutionary adjustments of management to meet the complexities of business operations in a dynamic and forceful organization.

The organizational responsibilities of top management have been unaffected by information technology. The men in top positions still hold full responsibility for the total accomplishments of the refinery. For example, the Petroleum Products Manager stated that his responsibility was in implementing policy, adhering to the general philosophy of the refinery, and coordinating the efforts of the divisions reporting to him. Information technology has not materially affected his over-all responsibilities in these areas.

**Coordination of activities.** With more comprehensive information which can be organized and presented to top

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management on a regular basis, the possibility for greater integration of effort has been realized. Top management is able to coordinate operations better because of this unified effort and because of more information at their disposal. In addition, the managers involved in group decision making have the opportunity to view the refinery as a total entity rather than as a group of related activities.23

Although upper management has been essentially unaffected by the new technology, it has actively supported the development of the different aspects of information technology. At this level, management is concerned with such issues as: (1) the return versus the substantial costs of computer hardware; (2) the merits of increasing the speed and scope of information concerning company operations; and (3) the reliability of new machines and systems in view of the difficulties in case of breakdown. Such matters are only indirectly associated with questions of the over-all impact upon organization and upon managers. Top management seems relatively unconcerned, at least to all outward appearances, about any possible effect on middle management. In addition, without exception the members of upper management interviewed

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insisted that the nature of their positions had not been affected by information technology.24

**Skill requirements.** In this connection, the fact should be noted that upper management has not needed, at least to date, a high level of technical competence in regard to information technology. At this level, the managers are highly intelligent and have picked up quickly a basic working knowledge of computers, simulation, and other techniques. Most phases of information technology call for increased technical skills at lower levels. Managers at higher levels, however, need to know less about the details of the mechanisms of information technology or the operations of the refinery.25 The General Manager, for example, is not as concerned with operating details as with problems concerning personnel relations and the development of future managers.

Information technology does not affect all levels of management in the same manner. This fact was particularly true concerning the functions of management at different levels and was apparent in the nature of management jobs. The following section describes the changes evident in the

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24Gilbert Burch in his article, "Management Will Never Be the Same Again," *Fortune*, LXX, No. 2 (August, 1964), 204, points out that this may be a reaction of top officers who prefer not to discuss realistically the effects of information technology on middle management positions as well as their own.

the nature of middle and supervisory management positions. It will be noted that the changes examined in it are more significant than those regarding the nature of top management jobs.

**Middle and Supervisory Management**

Information technology has affected the nature of the jobs of many middle and supervisory managers within the refinery. As automation of information-processing improved, a transfer of responsibility for making programmed decisions from man to machine occurred. In many instances, a reduction in the amount of discretion and judgment exercised at this level accompanied this transfer of decision making. However, the effects of the new technology on the nature of the supervisor's job has been slightly different from that of middle management.

**Supervisory Management**

The supervisor's job involves a number of planning activities oriented toward work accomplishment - such as scheduling men to jobs, establishing priorities on accomplishment of jobs, and determining some optimal sequence of operations for a given job. In addition to these activities, supervisors normally spend a substantial amount of their time on personnel problems - such as motivating, establishing
better human relations, and communicating orders and policies to employees.

**Job content.** A certain portion of the supervisor's job can be programmed extensively. In the early applications of information technology the more obvious and routine kinds of information analysis and decision making were programmed into the information system. Examples of this can be seen in the changes in the purchasing agent's job, manpower allocation aspects of the foremen's job, and in the foremen's jobs who blend the different grades of gasoline on the computer. At these lower levels of management, the predictions by many writers (see the first section of this chapter) concerning the extensive programming of these jobs seems to have some validity.

Nevertheless, the portion of the supervisory job regarding human contact with employees can not be programmed. As the importance of information technology grows and as more elements of the supervisor's job are subjected to regulation and programming, the direction or supervision of personnel should also assume greater importance.  

**Skill requirements.** The skill requirements of the supervisor or foreman have perhaps been affected more by the new technology than middle management. It is this level

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of management which requires improved technical skills in the various techniques and applications of information technology. Section foremen, for example, in the gasoline blending operation utilize an IBM 1620 computer to optimize the blending of grades of gasoline. The supervisory buyer, as well as other buyers, in the Purchasing Department is required to have extensive knowledge of computer programming in order to carry out purchasing activities. Finally, foremen throughout many divisions are required to make the allocation of men to jobs in connection with the company's payroll and personnel system. These foremen have to allocate workmen based upon priority of jobs, backlog of jobs, and the skills available to handle these jobs. The skill required of the foremen in making these allocation decisions certainly has been altered.

**Middle Management**

Moving now to the next level of management, the department head level, the impact of information technology on the nature of these positions has been somewhat different. The integrated information system has removed a substantial portion of the paper work and routine decision making activities from these jobs. Extensive programming of these jobs has not been evident. The work changes involved consist primarily of

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bringing order and efficiency to a part of the job which was formerly very time-consuming and frustrating. These jobs became more orderly and perhaps more rewarding to the occupants.

**Job content.** There are two kinds of things happening to job content. On one hand, there are some tasks that are pulled completely into the integrated information system and disappear entirely as a separate job. On the other hand, there are tasks that disappear only in part. Again, an example of this situation would be the purchasing function which consists largely of statistical processing work, but also involves selection of vendors. The statistical work can be taken away completely, leaving the buyer with only a small part of his former job. He may take on more of this remaining work, with fewer people now involved in the function, or this part of the work may be expanded in various ways. But, whatever is done, the task content is changed fairly drastically.

**Programming of routine decisions.** The programming of some of the low-level activities of the middle manager in many instances leaves him free to concentrate on the more rewarding and creative aspects of his job. John A. Beckett has researched this area and concluded that many managers "feel more satisfied with their work than they did before." The reason is that the computer increases their efficiency and enables them to do a better job than they did before the
For example, the job of the Head of the Packing and Shipping Department has become somewhat easier due to Project S of the EDPM Master Plan. Freed of many routine decisions and furnished with improved operating information, he now has turned his attention to working closer with headquarter's personnel in the development of improved customer relations. He is concerned with improving service and in improving upon the packaging of oil products.

In connection with this, he has been working recently with the personnel of the parent organization to improve upon the quality of the company's interium oil can. The refinery is currently using a fiber-type can which has met some opposition from customers. In conjunction with headquarter's personnel and can suppliers, he is testing a light-weight steel can, equal in cost to the fiber can, to meet customer requirements.

Skill requirements. The skill requirements of most middle managers have not been materially affected by information technology. Certainly with the introduction of different phases of information technology within their


29 This evidence agrees with the opinions of many scholars. See Herbert Simon, "The Automation of Management," op. cit., p. 521.
departments, these men were required to improve their technical skills. Complete competence over computer applications or mathematical techniques has not been required in most situations.

Since one of the first accomplishments of the integrated information system was to relieve many department heads of their routine paper work and to furnish them with improved operating information, a certain amount of analytical thinking has been encouraged. With faster, more factual, and more appropriate operating details in their possession, these managers normally analyze this information more closely in order to improve upon the operations of their departments. Nevertheless, there has not been a basic shift in skill requirements.

Elimination of Personnel

There have been certain areas in the refinery which have experienced a considerable reduction in personnel, such as accounting and other clerical areas. Reductions of personnel in operating departments have also occurred which have affected the contents of managerial jobs. In the past, many managers have measured the importance of their jobs in terms of the number of people they supervised. Very often the individual's compensation was, at least in part, related to the number of personnel supervised. With the introduction of information technology into operating departments, the
assumption was sometimes made that the manager's job had increased in importance and content, while he felt that it had decreased in importance since the number of people reporting to him had diminished. Understandably, in some areas managerial resistance to information technology appeared. The subject of resistance to change is deferred to a later section of this chapter.

Information technology has also played a part in reducing the number of middle and supervisory management personnel in the refinery. This reduction was evident in the preceding chapter in connection with the various departmental organization changes which have occurred. It was noted that many of the organizational adjustments did not result solely from the introduction of information technology into the refinery. Therefore, many of the personnel changes, elimination of jobs, and combinations of positions could not result directly from information technology. The recession of 1957-1958 not only caused a reduction in the number of non-exempt employees from the minimum wage and overtime pay provisions of the Fair Labor Standards Act, but also in the number of exempt or supervisory personnel. However, information technology did exert considerable influence toward reducing the number of management personnel in certain areas. These areas were normally ones in which the transfer of routine decision making, analysis, and paper work to the computer has occurred.
Examples of elimination of managerial positions. An example of a reduction in supervisory personnel may be found in the Stores Department. In 1956, when the integrated data processing system was first introduced, the department consisted of a department head, two assistant department heads, two section foremen, and eight first-line supervisors. In 1959, the department consisted of the department head, an assistant, and the eight first-line supervisors, an elimination of three supervisory positions. In these three years the total departmental workforce was reduced to half its 1956 number.

Another example of management personnel reduction was observed in the Purchasing and Traffic Department where with the consolidation of the two departments, the position of traffic manager was eliminated. Also one of the supervisory buyer positions was abolished because of a lighter work load. Management personnel in the Oil Movement Department have also been affected by the various aspects of information technology as have management personnel within engineering departments. The combination of the Distillation and Cracking Departments is a case in point. When these two departments were consolidated in 1963, three management positions were eliminated.

Reasons for reductions. The Head of the Oil Movement Department believes that information technology is a major reason for the reduction in middle and lower management ranks. He also is convinced that the middle management level
will continue to diminish in the refinery. According to him:

... I think that what is going to disappear in the organization is the middle level of management. I think there are going to be fewer and fewer departments, department heads, and assistant department heads. I doubt that there will be fewer section supervisors because I think that the wringing out there has already been done.30

Other management personnel share his views. For example, the Petroleum Products Manager felt that the number of department heads "... has decreased drastically, and part of this is due to having more information available within the organization."31 The Section Head of Process Engineering stated: "A large portion of middle management's job is devoted to supervisory functions. To the extent that information technology has reduced the number of people, it has also reduced the number of middle managers."32

The changing job content and nature of the middle and lower manager's job, together with the decreasing number of personnel due to the influence of information technology, has resulted in increased concern at these levels. In the

30Statement made in a personal interview, August 19, 1964.
areas of management most affected, management resistance to change has been observed. This is the subject of the following section.

The Human Element

The problems of man-machine relationships created by the introduction of information technology within a human organization have been largely ignored until now. This section is concerned with the problem of management resistance to change and how the company attempts to overcome it.

Management resistance to change. Information technology, like technological change, has important effects upon people. In many instances, those who are most affected by the change are also those who are responsible for initiating the change and planning for it. Departmental managers and supervisory personnel have assisted in installing some phase of information technology in their departments, but usually without understanding its full implications. Understandably, those who see their own positions threatened by a change are sometimes reluctant to adopt it.

Consider, for example, the reactions of a department head to the realization that the number of personnel in his department will be reduced drastically as a result of the installation of some part of the new technology. He certainly will not welcome information technology with open arms. In many instances, the importance of a supervisor's
position is judged, at least by himself, by the number of personnel supervised. The men often exhibit hostility and suspicion toward any phase of information technology which may affect them.

Operating divisions may make unrealistic demands upon the computer as a means of expressing their hostility toward it. They sometimes ask for impossible runs or make data changes at the very last minute. The information systems are quite vulnerable to this kind of hostility. Another area of vulnerability is that of data origination. The system is useless unless the basic information input is largely correct. Clerks sometimes test the computer by submitting wrong information.

The hostility or resistance toward the computer and its applications has also appeared in a somewhat different form — a mild harassment of the supervisors of the Computer Department. The supervisor in charge of data processing stated that he constantly received telephone calls at night or on week-ends from operating department managers. These managers enjoy informing him of the mistakes which they have discovered in the data processing programs. In most instances, the data processing supervisor could trace the mistakes back to the information furnished by these particular departments.

A portion of the management resistance to information technology is due to the natural disruption of work procedures and the elimination and consolidation of management
positions. The ranks of middle and lower management have been thinned somewhat over the past few years, partially due to information technology. There is a belief among many of these managers that there will be further reductions at their level in the future. Some members of middle management are concerned over their future in the refinery. According to some experts, middle managers have often contributed to a slow down in office automation in other organizations. A survey conducted by the Institute of Motivational Research concluded that middle management is afraid that "its job will actually become obsolete" and "their fears have generally made most middle management resist computers."

Management resistance also stems from feelings of inadequacies or lack of understanding of operation research, applied mathematics, or electronic data processing and computer techniques. These techniques are usually too complicated for many managers to follow. Although middle managers are not expected to be competent in these areas, when they have no particular training in these subjects, a feeling of inadequacy may sometimes arise. Resistance to new ideas, either consciously or subconsciously, consequently follows.

Management development programs. The Petro-Chem Refinery has developed methods of combatting management

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resistance to change. Perhaps the most successful of these methods is the management training and development program, one part of which is a rotation program for future managers.

The men chosen to participate in this program receive a year or more of programming experience within the Computer Department. They normally come from various areas within the refinery. However, occasionally these trainees are selected from departments which share a project of the EDPM Master Plan. For instance, in the personnel information system (Project P) the group would be composed of men from each of the participating departments - such as Personnel, Medical, and Accounting Departments. After completion of their training, these men return to their respective departments.

The task force of trainees from different departments is constituted in this manner for two reasons. First, top management believes that the successful use of the integrated information system is dependent on the direct participation or "involvement" of personnel from the departments in question. Second, top management believes that future managers must have an increased level of sophistication with regard to data processing and computer techniques.

Not all managers have the opportunity or inclination to spend a year or two as programmers, and to compensate for this several programs for management indoctrination have been developed. Some of these programs have been general, designed
to communicate the broad concepts of computer applications to heterogeneous groups of managers and employees. Others have been much more specific, designed to accompany the development of systems in a particular department or function. An example previously cited was the description of the training sessions for managers which are conducted in the participating departments utilizing the personnel information system. These sessions are designed to create support and acceptance for new applications within the existing system and to stimulate the imagination of managers in terms of potential uses of the system.

In regard to these programs, they are sometimes resisted or only tolerated by operating managers. The data processing supervisor stated that often it was difficult to get departmental supervisors to attend these meetings. The usual excuse for not attending was that the person was "too busy" or that something had just occurred which demanded his "immediate" attention.

**Potential Impact in the Future**

After assessing the present influence of information technology at the refinery, it seems only natural to consider now its potential future impact. It has already been suggested that no major changes of revolutionary impact have occurred. The scope of the accomplishments in the applications of information technology, on the other hand, can be viewed as
extraordinary achievements. According to many scholars on the subject of information technology, business organizations have yet to experience the full impetus of the new technology. If this statement proves correct, it is reasonable to expect that future changes in the processing of information will take place at the refinery.

Future changes could occur in two ways. First, the applications of information technology could be extended to cover areas of operations not yet covered. The present applications can also be expected to be improved over time. Second, this expansion of information technology could bring pressure to bear on certain departmental organization structures, causing them to adjust to changed relationships.

Possible expansion of information technology. In assessing the possibility of an extensive expansion of information technology, it should be noted that there are changes and improvements constantly being made on the internal information system. Improvements take the form of processing information faster, including more variables in the analysis, and extending applications to new areas of internal information needs. Information now being processed will be processed faster and the same techniques will be applied to

more areas of similar nature. This probably has more significance to operative management than to upper management, at least in the planning and control areas. Nevertheless, with these improvements in information processing, upper management will have improved summary type reports on the operations under their jurisdiction. Long-range decision making, planning, coordinating, and controlling techniques should be improved.

Turning now to another aspect of information technology, the possibility of an extensive expansion of "automatic" decision making to the upper levels of management is unlikely. Automatic decision making and sophisticated techniques of quantitative analysis require decision rules to be specified and expressed in quantitative terms. The characteristics of the top management function are such that it is impossible for automatic decision making to penetrate that level of management.35

Any extensive expansion of automatic decision making is likely to occur only at the lower levels of management. In many instances, certain routine and repetitive decisions can be programmed for the computer. The indications are that automatic decisions are suitable for many aspects of the lower management jobs and that they can not as yet be made

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35See Auren Uris, op. cit., p. 56.
at higher levels. Even the expansion of automatic treatment at lower management levels does not seem likely to imply a revolutionary impact.

Possible departmental changes. The integrated information system (the EDPM Master Plan) may possibly cause further departmental adjustments in the future. The projects of the system cut across departmental lines on a horizontal basis resulting in increased flexibility, reduced costs, more timely reports, and increased accuracy. Project M is a good example. The basic data are material issues, receipts, and balances. The uses to which this information is put are re-order quantities and timing, purchases, cost reports, and checking and payment of invoices.

From this description of Project M, it is apparent that the operations of the Stores and Purchasing and Traffic Departments are interdependent. The present trend toward the improvement of this project may eventually break down the barriers between these two departments with the resulting reorganization of the two into one department. The significance of this reorganization would be of only a minor nature, however, and could not be construed as revolutionary since other companies have already made this type of change. The important point is that a small movement toward the

36George Strauss, op. cit., p. 8.
integration of departments utilizing the same horizontal flow of information or functions has begun.

Summary and Evaluation

In analyzing the effects of information technology on the management of the Petro-Chem Refinery, it is significant to point out that there have been changes in the management process and in the very nature of many management jobs. The changes have been in the nature of an evolutionary process, not a revolution with sudden dramatic breakthroughs in the management processes of decision making, planning, and controlling.

There are primarily two areas in which information technology has affected management. First, the application of computers to decision making has affected lower and middle management. Second, the processing of information at lower organizational levels has affected top level decisions by furnishing a more precise base for decision making.

Applications of Computers to Decision Making

Decision making has been improved throughout the organization, with the earliest and greatest progress in the middle and lower levels - the areas where the computer solutions are easier. If, as one business manager has observed: "... the reach of an executive is determined by the
information system at his command," the reach of many middle managers has been extended by the development of the EDPM Projects. The improvements in the management information system have occurred essentially because of three basic processes.

First, the quantification of selected data has substantially improved not only the amount of facts in a specific report bearing on a specific decision area, it has also improved the information content. Increased quantification of selected data requires a thorough knowledge of the particular information system or project under consideration, as well as a greater clarification of exactly what information is needed in that project. A better understanding of the decision making process accompanies this increased emphasis on problem definition.

Second, decision making has also been based on the evaluation of a wider range of alternatives and of current factual data. This has been made possible through operations research and simulation techniques using data supplied by the integrated data processing system. John R. Spellman has this comment concerning decision making: "Perhaps the greatest immediate impact over the next five years, will not be upon

the quality of decisions which are made by existing management operating in the existing organization environment.  

Third, the impact of a decision in one functional area on other functional elements of the refinery can be more easily measured, and, as a result, upper management gains a more comprehensive view of the refinery. As pointed out by Buckingham, one of the direct consequences of automation in general is that "there is an increase in the quantity and accuracy of information and speed with which it is obtained. Management can have a clearer picture of its over-all operation and by knowing the consequences of alternative courses of action it can act more rationally." Top management decisions are possible which optimize company goals rather than the goals of any particular functional area.

**Processing of Information at Lower Levels and Its Effects on Middle Management**

In the middle and lower management areas, as information processing and automatic decision making have been applied with increasing frequency, the content and nature of many of these jobs has changed. Indeed, many of the routine "decisions" are now handled by the computer system. However, there is little evidence to support the charge that middle management

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jobs will become highly routinized and down graded. Anshen points out that:

Predictable gains in automated information-processing will bring about a substantial transfer of responsibility for making programmed decisions from managers to machines. However, this need not lead to a withering away of middle management. Rather, automation will open new opportunities for more effective performance of the decision implementation functions that often are scanted or handled within an unduly narrow context.

Although there has been some change in the job responsibilities of some middle and lower management personnel, and even some elimination of positions, these adjustments can not be considered revolutionary. Moreover, information technology has not lead to the predicted radical reorganization of middle management. Nor has it lead to more responsibility for decision making being taken away from middle and lower management. Upper management makes its decisions from the information it obtains from the information system. At the same time, middle and lower management have available the same information. Consequently, middle and lower management are now making decisions more in consonance with the thinking and policy of top management. Rather than to make decision making routine and mechanical, the major

40 Thomas Whisler, who originally made this prediction in 1958, now tends to question its accuracy. See "We Study the Executive," The Newsletter, Graduate School of Business, University of Chicago, XI, No. 2 (Summer, 1964), 6.

41 Melvin Anshen, op. cit., p. 77.
The impact of the new technology at the refinery has been to improve the basis of human decision making.

**Effects on Top Management**

The functions and responsibilities of top management have not been affected, except that top management has a more precise base for its decisions. As more accurate information is processed at lower levels and as more details can be considered, top level planning and controlling have been improved. There has not been, however, the predicted centralization of authority and decision making. Although there has been the establishment of a centralized data processing center, this is merely a centralization of information collection, not a centralization of decision making as the decisions are still left to the appropriate managers.\(^2\)

Automatic decision making has not penetrated the top level of management and is not likely to do so for many years. Nor has the basic managerial process been greatly affected by information technology. Commenting on the effect of the computer on decision making, Retter concludes:

> No matter how effective computers become, no matter how finely they can draw the difference between divergent courses of action, they cannot assume the basic functions of the manager.

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\(^2\)Ernest Dale, in a study of 32 corporations, discovered the same trend. He saw very little movement toward centralization of decision making. See Ernest Dale, *op. cit.*, p. 13.
Decision making will be greatly refined and improved by computers and data communications. But the decision itself will continue to be the responsibility of the manager.\footnote{Ray W. Retter, "Computers and Communications Provide New Concepts in Scientific Management," \textit{Advanced Management}, XXIX, No. 4 (October, 1964), 41.}

In a summary evaluation of the various predictions concerning the effects of information technology on management, the evidence of this study emphasizes that most of the prognostications are not now occurring in the refinery. There are, however, some elements of these predictions that can be seen to be valid. But, as was shown in the preceding chapter and again in the present one, these predictions, in general, are not now occurring in this company.
CHAPTER V

SUMMARY OF CONCLUSIONS

Purpose

This study was undertaken to test the hypothesis that information technology's effects on management and organization have been an evolutionary process rather than the revolutionary impact as predicted by many writers. In addition, the general thesis throughout this investigation has been that many of these predictions are too general to be completely valid in all organizations.

The paramount conclusion of this study is that the hypothesis has been proven valid in the company under investigation. Furthermore, the findings support the general thesis in that many of the predictions were generalizations without validity in the organization investigated. It must be noted, however, that the findings and conclusions of this study apply only to the company investigated.

Organizational Changes

The most notable organizational changes which can be attributed to information technology have occurred at the departmental level. In part, these adjustments were
initiated because of the integrated information system and the refinery's effort to plan and to manage the flow of information. Over a period of years the combination of several departments as well as a few managerial positions was the result of the type information programmed into the system. These organizational adjustments, generally speaking, were of a minor nature and can not be construed as being revolutionary.

The organizational principles of decentralization and the span of management are often considered to be concepts which are changed with the introduction of information technology into an organization. The philosophy of decentralization of decision making, however, has been affected very little. There has been a small discernible movement toward pushing decision making downward in some areas within the organization. In these areas many of the managers have been freed of routine analysis and many have turned to more creative and important work.

Although the span of management has been affected by many internal forces, two observations can be made concerning information technology's effects on the span of management. First, a clear-cut pattern of an increased or decreased span has not emerged at the middle management level. In some areas managers supervise an increased number of subordinates and in other areas a decreased number. An entirely different
observation can be made regarding the supervisory level of management. There has been a decrease in the span of management. Thus, information technology's effects have been somewhat different at various organizational levels.

Effects on Top Management

Top management's functions and skills have not been directly affected by information technology. Upper management's job, by its very nature, can not be directly affected by information technology at this time. Computer technology has not touched the problems faced by top management. Upper management is not concerned with routine analysis, and its functions of decision making, planning, organizing, and controlling are of such a long run nature that the very attributes of information technology, i.e., speed, conciseness, and accuracy have little, if any, effect on these functions.

The major effect on their functions has been an indirect one. These functions have been improved somewhat by the speed, accuracy, and compilation of information at lower organizational levels. The improvements occurring at the lower levels furnish a more precise base upon which top management decisions can be made. In addition, coordination of company-wide activities is more easily accomplished since upper management is able to gain a more comprehensive view of operations.
Effects on Middle and Lower Management

The effects of information technology on middle and supervisory management have been somewhat different from the effects on top management. Specifically, with increased information processing and automatic decision making in the routine activities of inventory control, purchasing, shipping, and oil movement, the content and nature of many middle management jobs have changed. Since much of the burden of routine analysis and paperwork has been removed from these jobs, management has been able to concentrate on their basic functions. In many instances, these jobs have become more rewarding and perhaps more satisfying to the persons occupying those positions. As the nature of the job changed, the skills required of the occupants also adjusted. In most instances, more analytical skills have become necessary.

The major impact of the new technology at the refinery has been to improve the basis of human decision making at the middle and supervisory levels. Decision making has not become routine and mechanical as some writers have predicted. As a consequence of having much of the same information available throughout the organization, middle and lower management are now making decisions more in consonance with the thinking and policies of top management. Such uniformity of policy action and decision making has resulted in a more efficient organization. Also, a greater degree of flexibility
has been developed in the managerial process, particularly at the middle management level. Flexibility has been introduced into the kind of planning and controlling in which plans can be changed quickly and results can be known quickly. Changes which have occurred in these processes were more evident at this level than at any other.

**Findings Versus Predictions**

The changes which have occurred in the organizational structure and in managerial jobs and functions are not significant enough to be called revolutionary. Furthermore, these adjustments occurred gradually over a period of years and did not appear suddenly within the organization. A large portion of the changes has taken place at lower organizational levels somewhat below that of top management.

The prognostications of many writers concerning information technology's effects on management have not occurred at the refinery. It is highly unlikely that many of these predictions will develop in the near future. In most instances, the findings of this study have been contrary to the predictions set forth in the literature. As evidenced by the findings at the company under study, it appears that many of these predictions were merely generalizations which proved to be too sweeping to be completely accurate.

In particular, the writers who predicted a recentralization of authority and decision making overlooked
organizational reality. In addition they again overlooked reality with the predictions concerning revolutionary impacts on top management functions; and again, when they predicted radical reorganizations and elimination of middle management, or relegation of middle management to positions of minor importance. It seems evident that these generalizations overestimated greatly the influence of information technology. Actually, this technology is not capable of making the changes and overturning established practices as predicted by many people. When it did influence management, different effects were noted at the various managerial levels, a fact some writers completely ignored in many instances.

In final evaluation of the various predictions concerning information technology, it is evident that many writers failed to look in depth at the questions and issues involved. Even though some predictions contained elements of truth, they appear to have been made without the benefit of a solid foundation of objective research. The evidence of this study has shown that extraordinary accomplishments have occurred in information technology, but these accomplishments have not constituted a revolution in overturning established managerial processes and practices at the Petro-Chem Refinery.
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**PUBLICATIONS OF PROFESSIONAL ORGANIZATIONS**


NEWSPAPERS

VITA

Robert Sexton Adams, the son of John Floyd and Jodie Adams, was born September 4, 1936, in White Oak, Texas. He was graduated from White Oak High School in May, 1955. In September, 1955 he entered North Texas State University where he received the Bachelor of Business Administration degree in August, 1958. After graduation he was employed as an automobile underwriter in an insurance firm and later as a foreman in an electronics company. He again entered North Texas State University in September, 1960 and received the Master of Business Administration degree in August, 1961. Serving as an Instructor of Business Administration, he taught one year at a college in Arkansas.

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