To the Graduate Council:

I am submitting herewith a thesis written by Denise Darcell Ford entitled "Design of a Conceptual Information System for Industrial Engineering Applications in a Manufacturing Organization." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Industrial Engineering.

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DESIGN OF A CONCEPTUAL INFORMATION SYSTEM FOR INDUSTRIAL ENGINEERING APPLICATIONS IN A MANUFACTURING ORGANIZATION

A Thesis

Presented for the

Master of Science

Degree

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Denise Darcell Ford

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DEDICATION

This study is dedicated to my mother and father, to whom I am immeasurably indebted. I could live a lifetime and would not be able to thank them enough for all the sacrifices the two of them have made through all these years. I thank God for having blessed me with such loving parents. My gratitude and admiration for my parents is exceeded only by my love. Mom and Dad, I love you both.

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ABSTRACT

The purpose of this study was to develop a tool which would assist managers in a manufacturing organization to optimize their company's operations. These operations have been identified and functionally categorized into four major areas: finance, marketing, personnel, and production.

A survey of relevant literature substantiated that complete information is essential in order to optimally manage operations. This survey also indicated that the most used tool to provide this information is the management information system. These systems, however, have fallen short of the ultimate goal of systems design--optimization of management.

This study proposes the incorporation of industrial engineering techniques in manufacturing information systems to overcome that shortcoming. Industrial engineers have the experience and expertise to better design management information systems so that they satisfy all criteria for their development and usage.

A conceptual model of such a system has been developed in this study. The model is based upon the integrated needs of the functional managers, the industrial engineering techniques required to meet those needs, and the necessary data for implementing the techniques.

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CHAPTER I

INTRODUCTION

Purpose of the Study

The progress of manufacturing companies toward computerization can be accelerated by applying the concept of the systems approach. This concept encompasses the analysis, design, and management aspects of a given system. That same concept forms the foundation of industrial engineering. Since its inception, industrial engineering has been involved with the synthesis of people, materials, and equipment into improved workable systems. The scope of these systems has expanded to include information; in conjunction, so has the scope of industrial engineering. With the aid of the computer, the manufacturing industry potentially may reap great benefits from this growth.

Long years of experience with manufacturing systems has prepared the industrial engineer (IE) for developing total information systems applicable to the operations of that industry. His educational training heightens that preparation by building expertise in those quantitative techniques which may be applied to solving managerial problems. Many of the newer techniques available to the IE, such as operations research (OR) techniques, allow him to optimize the solutions to these problems and increase the reliability of managerial decisions. The IE's background in designing systems, along with his experience in the manufacturing industry and his technical training, equip him with all the tools for creating a total management information system (MIS)--one which operates from a central data base and applies optimization techniques to the data to produce accurate information. This information may then be used by managers for making decisions which not only affect their particular functions, but other functions individually and the company as a whole.

To assist company managers in solving the broad range of problems which will develop as a result of increased automation, the IE must take on the role of information coordinator. In this capacity, he will be responsible for providing managers with accurate information (the design stage of the systems approach) and for verifying the validity of that information (the analysis stage of the systems approach). Managers use this information to plan and control the operations of their functions. It helps them in deciding among alternative courses of action and in measuring the performance of those actions in accordance with company objectives.

The availability, timeliness, and reliability of this managerial information depend upon the accuracy and timeliness of the data used and, in turn, greatly affect the reliability of managerial decisions. Thus, accurate timely data seem to be the foundation of effective decision-making. The strength of this foundation lies in the efficient execution and coordination of all activities associated with the accumulation, correlation, storage, and dissemination of the data and the use of this data by all concerned in the optimization of management decisions. It is these activities with which the IE must be concerned in order to facilitate the management of company operations.

The various areas in which the IE is involved ideally situate him to identify and analyze the company's many informational needs. Because of this involvement he not only is aware of problems in specific functional areas, but he is also cognizant of how those problems and their solutions impact other areas. Thus, it seems appropriate that the IE should be involved with the development of an integrated information system for the manufacturing enterprise; one which considers the structure, dimensionality, and consistency of the data which are used to provide information necessary for managing the entire organization. It also seems appropriate that the IE should be involved if the company's objective is to optimize the management of its operations; considering the tools available to him for increasing the quality of the data and in turn, the quality of the information upon which managerial decisions are based. An optimal management information system will not be available, however, without the establishment of a sound knowledge base for total information and the application of optimization techniques for greater reliability in that information.

This thesis develops a conceptual model of such an information system for a manufacturing firm, from the perspective of the IE. The development applies the concepts of the systems approach. The analysis of the system is based on a "top-down" view of the firm. It studies the operations from the overall objectives of the firm down to the activities of the functional areas, determining which data become part of the central data base. The design phase follows a "bottom-up" approach, studying each data element in the system and trailing it to its end users to ensure that it is stored in the most efficient form and is readily available. Both the analysis and the design are performed with the objective of obtaining a system which optimizes both functional and company objectives. The value of such an information system lies in the achievement of this goal. With such a system, managers will be able to achieve the dual aims of management and optimization which is not being met by existing systems. Presently, computerized management information systems have the capability for obtaining the management goal, but most have failed to take advantage of the mathematical techniques which would allow them to optimize their management. This optimality can be achieved by incorporating the systems approach to ensure that sufficient amounts of adequate timely data are stored efficiently in the data base for all users and by applying those mathematical techniques which would optimize the information being received by the managers and consequently, all company operations.

Limitations of the Study

This study is oriented from the perspective of the industrial engineer in a manufacturing firm. It emphasizes industrial engineering techniques applied to managerial problems, the information flows among the operating functions, and the common pool of data used by those techniques. Only those classes of information necessary to illustrate the concepts described have been included. Other detailed requirements needed by upper management or some outside organizations have been omitted.

The system presented is an abstract, functional framework of a manufacturing management information system. It is a conceptual model, and no attempt has been made to program it. Also, no attempt has been made to implement the model and therefore, the management aspect of the systems approach which was adopted has not been executed or tested.

Statement of the Problem

Information is the essential ingredient of effective management. The contribution of MIS's is the integration of related data into a system which outputs information from the focus of the entire organization, to facilitate management of operations. This contribution, however, has not been fully realized. In an article entitled "Blueprint for MIS," Dr. William Zani states:

> Traditionally, management information systems have not really been designed at all. They have been spun off as by-products while improving existing systems within a company. No tool has proved so disappointing in use. I trace this disappointment to the fact that most management information systems have been developed in the "bottom-up" fashion--an effective system, under normal conditions, can only be born of a carefully planned, rational design that looks down from the top, the natural vantage point of the managers who use it. (51)

Not only has the design of MIS been inadequate, but the lack of appropriate data has also proved to be a hindrance to their usefulness. With adequate amounts of correct data, industrial engineering techniques could be applied within the MIS to improve the quality of the information received by managers and, concurrently, the effectiveness of the MIS. Frequently, the data which is available is either erroneous, untimely, or incomplete; thus, so is the information fed to management and, in turn, so are the decisions which are based on that information. As the amount and timeliness of correct data increase, so do the reliability and usefulness of the information provided to the managers and the reliability in the decisions which are based on that information.

Thus, Zani's statement "No tool (MIS) has proved so disappointing in use," is readily understood when considering the inadequacy of design plus the lack of appropriate data. What is required, then, is an improved approach toward the design of the MIS and greater assurance that appropriate data are included and are available to all users requiring it.

DePorter (12) states that there are four generally accepted hierarchical purposes for information systems. They are visibility, control, management, and optimization. This hierarchy is depicted in Figure 1. Visibility is necessary for control, control must be realized in order to establish management, and management, control, and visibility are necessary to achieve optimization. Many information systems provide visibility; some provide control; a few enable management; but, rarely does one provide optimization. Yet, optimization can be achieved by incorporating the industrial engineering techniques of OR. Indeed, according to DePorter, it is a paradox that OR is in a state of decline because of insufficient data, and MIS's are a disappointment because they have failed to achieve optimization which

OR models could have provided! It appears that the time has arrived for the IE to design a conceptual information system incorporating the industrial engineering optimization techniques and ensuring that organizational information needs are satisfied.

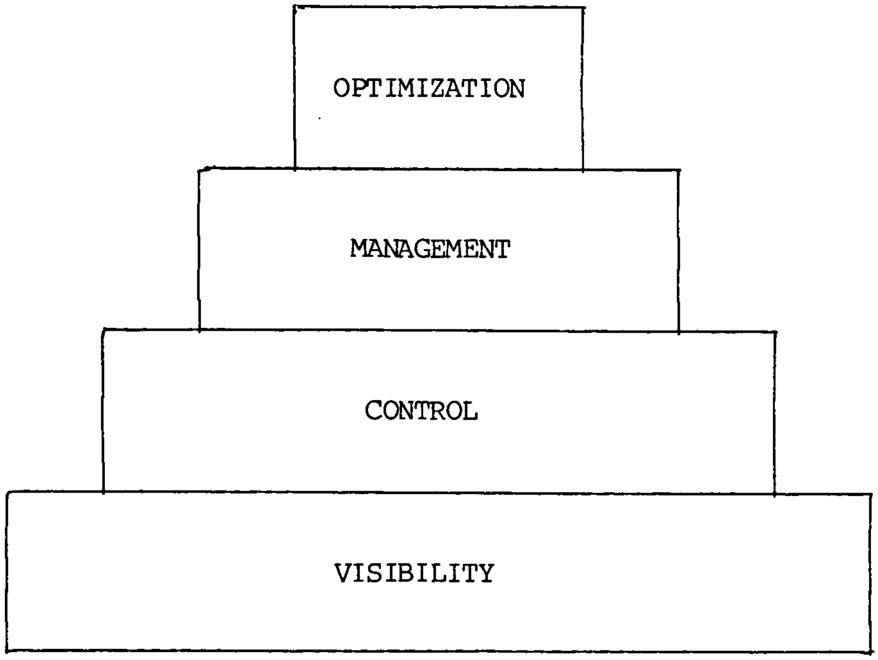

Figure 1

Purposes for Developing Management Information Systems

As the manufacturing industry increases computerization, its informational needs will increase in complexity. This complexity all but demands that the IE use the computer to apply many of its quantitative techniques. Not only will the computer be used for computations, but also as a data repository. Systematically and logically developed operational data made into a common corporate resource will facilitate the application of computer-based systems to industrial engineering methodologies, enhancing the measurement and control of functional performance.

The functions of the firm are concerned with such activities as product quality, production control, inventory control, personnel management, cost control, and sales forecasting. Grouped functionally, these form subsystems of the company. For the purposes of this paper, those subsystems are as follows: Production, Finance, Marketing, and Personnel.

Managers in each of these subsystems must be concerned with the planning and the control of the activities in their particular subsystems. In planning, they must consider alternative proposals and determine the consequences of each alternative with respect to the objectives of the particular function, as well as those of the overall firm. The controlling aspect requires the identification of deviations from desired results and the implementation of corrective actions to obtain those results.

Each manager must accumulate and process a vast amount of data to obtain usable information. The Personnel manager requires such data as the job title and description, base rate for the job, the number of hours worked by the employee on a particular job per time period, and other specific data about the employees. The Production manager needs to know inventory levels for raw materials, work-in-process, and finished goods; production capacity of each manufacturing operation; sales orders for each finished product; and units on order for each raw material. The Marketing manager is interested in the sales history of each finished product, sales orders for each finished good by region, and production costs of each finished product. The Financial manager needs such data as sales forecasts for each finished good, customer orders for each product, purchases of raw materials, and employee time charges--all in terms of quantity and dollars.

In any production facility a certain amount of interrelatedness exists between and within the functional areas. This interrelatedness means that one decision is dependent on another. For example, sales requirements must always be considered along with finished goods inventory levels in determining the production requirements. As a result, subsystem decisions must be viewed as system decisions because their consequences may have impacts beyond the bounds of the particular function.

The data requirements of the various subsystems may also be interrelated. In the past, data have been stored (either functionally or in a central data base) in the structure and dimensionality of the office of primary responsibilty. Thus, Marketing might project sales (demand) in terms of units per month, while Production schedules its operations in term of units per week to meet those same sales projections. This inconsistency in dimensionality requires timely and thus, costly conversion of common data used by different subsystems to obtain needed information; and must be overcome to provide an efficient information system.

Although the complexity due to the varied demands on the data call for using the computer, the need for timeliness presents a case equally strong to justify computerization of the system. Also, the vast amount of data which must be stored and manipulated by the system requires sophisticated means of handling and processing. The third generation computers provide the capability to have a comprehensive information system, along with commercial software packages which can receive, store, sort, retrieve, and print large volumes of data at high speeds with a high degree of accuracy. The usefulness of such capabilities is embodied in the well-planned and implemented system.

The time-sharing capability of the third generation computers allows the simultaneous sharing of time on a single computer by different users from remote locations. A functional manager has the capability to input, modify, or read data pertaining to his particular area while other managers are making changes to the data in their respective areas.

These computers have also increased the amount and types of information used in an organization. Some of these types include such quantitative techniques as simulation, linear programming, queueing theory, inventory theory, and PERT models. In fact, the usefulness of simulation is due to the advances in digital computers which allow thousands of simulation runs in a relatively short period of time. Also, without the speed and the storage capabilities of these computers, application of linear programming to actual manufacturing problems would be impossible. In essence, the computer made possible the practical application of many quantitative techniques adopted by the IE.

The IE uses these modern techniques and other more traditional ones to aid in solving managerial problems in the functional areas of the firm. Included in these problems are sales forecasting, distribution planning, materials requirements planning, and production planning and scheduling. Some of these activities have already been computerized, and with further developments so will others.

Hence, the scope of industrial engineering applications in the manufacturing environment is expanding due to increased automation in both the production and the information processes. The third generation digital computers has enabled the IE to adopt new techniques and to computerize traditional ones. The challenge for the IE is to bridge the gap between information systems and operations research in the manufacturing firm in a synergistic manner. The concept will build upon a common data base whose elements will have some meaning to all functional managers.

Summary

In summation, the IE appears uniquely qualified as a "systems" engineer and strategically located within a manufacturing firm to develop a conceptual information system that will assure proper structure, dimensionality, and consistency of the data and will promote the four hierarchical purposes of information systems. The interrelatedness of the IE function and all other manufacturing functions suggests that the IE has much at stake in accomplishing this feat. The purpose of this study is to provide the foundation for such an achievement.

This thesis is divided into six chapters, including the introductory chapter. Chapter II, "Background of Industrial Engineering," traces the history of the development of the discipline and its quantitative techniques. Chapter III, "Research of Current Literature," reviews the development and usage of comprehensive management information systems and the IE's role in their development and implementation in the industrial environment. The fourth chapter, "Management and Information Needs," is subdivided by the four managerial functions identified. It presents a "top-down" analysis of the company to determine the data required to provide information to the managers. Each section consists of a description of the function, a definition of the managerial information needs by functional activity, the identification of the industrial engineering techniques to meet those needs, and the data required to implement the techniques. The fifth chapter, "System Integration," examines all data elements and techniques described in the previous chapter to determine common usages among the subsystems, identifies the data's source and user organizations, and assigns system-oriented dimensions. The purpose of this chapter is to perform a horizontal synthesis of information requirements via a "bottom-up" approach which will maximize the usefulness of the system. The last chapter summarizes the results and states the conclusions and possible areas of further research.

CHAPTER II

BACKGROUND OF INDUSTRIAL ENGINEERING

Since the system designed in this study incorporates both traditional and modern industrial engineering techniques, it is important that the development of the field and its tools be examined. This examination should foster an understanding of how the IE's role in the management of industrial operations has expanded during the life of the discipline(33, 44,47).

Industrial engineering originally developed to meet the need for organized factory operations during the industrial revolution. These factories were new complex systems which needed coordination and direction to operate efficiently. Thus, the systematic approach of industrial engineering came into being.

The first applications of industrial engineering were in the manufacturing firm. Those first techniques applied to industrial situations laid the foundation for the discipline and form the core of "traditional" techniques. Included in this group are methods engineering, work measurement, wage and job evaluations, and plant facilities and design.

Frederick W. Taylor, the "father of industrial engineering," developed the systematic approach to methods improvement in 1883. He divided a task into individual work elements so that they could be studied separately, giving rise to motion and time studies. He is also credited with first applying the scientific approach to management.

Taylor's principles for effective management proposed that industry management must (1) develop a science for each element of an employee's work, (2) scientifically select and train employees, (3) establish friendly cooperation with employees, and (4) assume responsibility for activities which are of managerial nature. His first principle laid the base for motion and time study.

Frank and Lillian Gilbreth extended the motion and time study in 1912 by developing micromotion study, which permitted jobs to be designed with standard times known in advance. This technique consisted of studying the basic elements of movement with the aid of motion pictures. Also developed during this time was the Gantt chart by Henry L. Gantt. It is most used in production control for loading and scheduling work on machines. Another development of this time was the standard-cost system by Harrington Emerson.

Those pioneer developments in industrial engineering marked the era of the "efficiency experts". The next stage of developments began the reshaping of the field into a science from an art. Merrill Lott developed point rating for applications to job evaluation in 1925; F. W. Harris converted inventory models into mathematical terms; and W. A. Shewart, in 1924, introduced the statistical control chart which is used in quality control applications.

The basic ideas of Taylor, the Gilbreths, and Gantt had been successfully formulated by 1920. By 1930 many companies in the United States were applying the theories of time and motion study. The 1930's marked the introduction of human factors as an industrial engineering application. The pioneer of applying behavior science to industrial situations was Elton Mayo with the Hawthorne studies. The results of this study were published in 1939 and paved the way for such theories as the hierarchy of needs proposed by Abraham Maslow in the 1940's; the work motivation theories of Frederick Herzberg in the 1950's; and the Theory X and Theory Y of Douglas McGregor in the 1960's. These theories are applied today in job design, job enrichment, and wage payment analysis.

Many of the modern industrial engineering techniques had their genesis during the 1940's. The Work-Factor system was developed in 1945; and MTM, another predetermined time standard procedure, was developed in 1948 by H. B. Maynard. Operations research was first developed and utilized during World War II. A major development in this area was the simplex method for solving linear programming problems by George Dantzig in 1947. Other developments in the operations research era include the establishment of the duality theorem by Kuhn and Tucker in 1951; the development of the Ratio Analysis method for solving linear programming models by Ferguson and Sargent in 1954; Bowman's proposal of the distribution model of linear programming in 1956; and the Search Decision Rule developed by Taubert in 1968.

The 1950's and the 1960's focused on systems analysis, value analysis, network planning techniques, and the development of new mathematical tools. These developments were enhanced by the development of the ENIAC computer in 1946 and the subsequent improvements in computer hardware and software. PERT and CPM were developed in the late

1950's for project planning and control. The impact of the computer on industrial engineering techniques continued through the 1970's, when industrial engineering moved into the realm of systems engineering. That impact is also being felt in the 1980's by the increased automation of production and information processes.

Today, industrial engineering principles are applied across such disciplines as management, statistics, operations research, human factors engineering, systems engineering, and management science. The industrial engineer also uses the techniques of these disciplines as tools in solving managerial problems, in particular, statistics and operations research.

In the manufacturing environment, the industrial engineer may be involved in such activities as methods engineering, materials handling, plant layout and location, human factors engineering, quality control, systems design, and engineering management.

Table 1 shows some applications of industrial engineering in the manufacturing environment by the functional areas in this study. Figure 2 adds another dimension, industrial engineering techniques, to Table 1. It shows the techniques which might be applied to any one of the applications in any of the functional areas to optimize management of the entire firm.

Table 1

Industrial Engineering Applications in a Manufacturing Environment

FUNCTIONAL AREA	INDUSTRIAL ENGINEERING APPLICATIONS
1. PERSONNEL	1. Analyses of labor returns Allocation of personnel Ergonomic studies Wage Payment Analysis Job Evaluation Manpower Forecasting
2. MARKETING	2. Location of warehouses Distribution cost analysis Routing of vehicles Mathematical modelling of consumer markets Sales forecasting Optimization of the sales force Allocation of territories Routing of salespersons Allocation of advertising effort
3. FINANCE	3. Measurement of cost control effectiveness Pricing and discount systems Financial forecasting Decision theory System design Investment analysis Selection of most profitable products, product mix, and operations
4. PRODUCTION	Design and layout of handling systems Stores systems design Design of stock control schemes Forecasting demand Optimization of ordering policies Purchasing department operations Production forecasting Production planning Scheduling and workshop loading Sequencing of machine utilization Quality control Acceptance sampling and inspection Maintenance/replacement policies

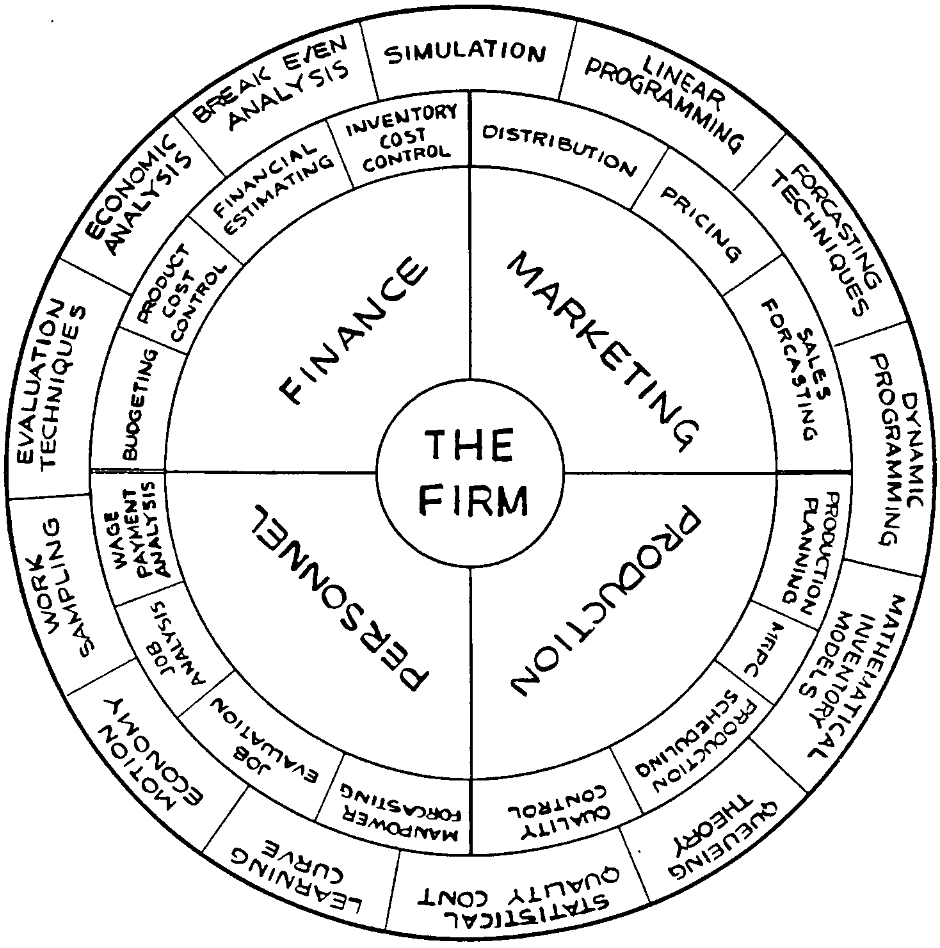

Figure 2

Industrial Engineering Techniques Used
To Optimize Company Operations

CHAPTER III

RESEARCH OF CURRENT LITERATURE

Management information systems have in recent years become a popular subject in business writings. A review of this literature was made to determine the state of the art in their development and the IE's role in their design and implementation. Of primary interest was the literature on comprehensive systems involving quantitative techniques. Most of the articles found, however, concentrated on systems oriented to specific company functions.

The concept of a totally integrated information system is still relatively new. In fact, management information systems were not used in industry until 1960 (11), and that first one was a market-oriented, batch-process retrieval system. The breakthrough in using management information systems as tools for controlling operations occurred in 1964. The Western Electric Company in Kansas City computerized a parts shop for production and inventory control (29). This marked the beginning of systems which not only stored data, but contained mathematical routines for analyzing that data and provided standard reports to management for system feedback.

Progress in developing and using complete systems was slow in coming, however. In the late 1960's, companies began to attempt to develop system-oriented models called corporate planning models. In 1969, 63 firms from a sample of 1,900 (3.32%) in the United States were actually using corporate planning models. These attempted to describe the complex inter-relationships among a corporation's financial, marketing, and production activities in terms of a set of mathematical and logical relationships which were programmed into the computer (18). Another survey in 1976 showed 346 firms out of a sample of 1,881 (18.39%) were either using, developing, or planning to develop a corporate planning model. Tables 2, 3, and 4 represent some of the results of that survey (36).

Table 2

Application of Corporate Models

Applications	Percentage of Users
Cash flow analysis	65
Financial forecasting	65
Balance sheet projections	64
Financial analysis	60
Profit planning	53
Long-term forecasts	50
Budgeting	47
Sales forecasts	41
Investment analysis	35

Table 3

How Corporate Models Are Used

Use	Percentage
Evaluation of policy alternatives	79
Financial projections	75
Decision making	58
Corporate goal setting	46

Table 4

Forecasting Techniques Used in Corporate Models

Forecasting technique	Percentage
Growth rate	50
Linear time trend	40
Moving average	22
Exponential smoothing	20
Non-linear time trends	15
Adaptive forecasting	9

The majority of the models identified in both of these surveys were found to be primarily financial in nature. They were mostly used to evaluate operating and investment strategies. One of the early pioneers in developing these large-scale corporate financial models was the Sun Oil Company (19). This model was begun in 1965, and was the first in the eventual development of corporate management information system. It simulated the company's entire physical operations to provide projections of financial performance.

Another model developed in the early 1960's is the Hotpoint system of the General Electric Company (27). The Hotpoint model consists of three interrelated systems: the decision-making system, the management information system, and the physical material system. The management information system serves as the liaison between the decision-making and the production functions. Three subsystems are integrated to form the management information system. They are the marketing, financial, and manufacturing systems. This is one of the earliest attempts at developing a "total" information system.

The 1970's brought greater attempts at implementing general system models. One of the earliest attempts at developing such a model is the TROPICS by the B. F. Goodrich Company (17). This terminal-oriented system was developed in 1970 to provide operational, engineering, purchasing, and sales personnel with a common source of current data. This system, however, was limited in its ability to perform quantitative analyses.

The mechanics of implementing a total system involving massive quantitative analyses has been the stumbling block for effectively implementing such systems. Not only do the sizes of the variables and the equations pose a hindrance; but the quantitative techniques required, namely integer and zero-one programming and branch and bound procedures, have not been sufficiently developed to permit their practical application (40).

Attempts are continuing, however, at implementing these total systems; managers have come to realize the importance of decision-making within the realm of the entire company. The greatest problem, however, continues to be the lack of readily available data. Vast quantities of time and money have been expended in attempts to model the total corporation, but the models often became obsolete before the project was complete due to ineffectiveness of the mathematical tools which were used (41).

Only a few of the articles found discuss the direct involvement of the IE in the design and implementation of total information systems. Young (50) considers management information systems as another application area as well as a new tool for the IE. He compares the MIS to the production system with which the IE is accustomed to working. The raw material,which is data, is converted into a finished product called information; and this conversion consumes such costly resources as manpower, computer power, and data storage facilities. Morris (34) not only concurred with Young, but he went even further to say that the IE's functions in the planning and controlling of operations necessitates his involvement in the development of such systems. These systems may be used by the IE to facilitate his support of managerial decision-making.

Other articles concerning the IE concentrated on the impact which the computer has made on the discipline's role in industry. Malcolm (31) states the computer is redefining the profession by accelerating its development along analytic lines, changing it from "people" engineering to "systems" engineering. Because of automated production lines, the conventional techniques of time and motion study are no longer as applicable in measuring the work and contribution of operators. Many conventional techniques and applications are no longer adequate and are becoming less important. The area of increasing importance to industrial engineering is data processing, especially since many of the control systems (e.g. cost, production, and inventory) using industrial engineering techniques require the storing, analyzing, and comparing of large volumes of data. Other authors (16, 21, 22, 49) expand on the concept of the "new" IE as a result of the computer. Bishop and Miller (4) see this "new" IE as one who will continue to be involved in traditional areas, but with an expanded sphere of involvement; in addition to his involvement in such new areas as management information systems, computer-aided design, and computer-aided manufacturing .

Parks and Collins (37) made one of the strongest of statements in the recognition of the impact of computer applications in the primary areas of concern to the IE: "The computer must be recognized as having the most significant impact on productivity since the time of Frederick Taylor and the Gilbreths."

In summary, much literature could be found on the state of the art of MIS development, but little is available on the IE's role in that development. The reason is that this is a new area of application, and the MIS is a new tool for the IE. All indicators, however, point to the emergence of a "new" IE; one in the mainstream of computerized operations and the computerized control of those operations.

CHAPTER IV

MANAGEMENT AND INFORMATION NEEDS

Introduction

The value of an information system lies in its usefulness. In order to develop an applicable system full consideration must be given to its analysis and its design. The systems approach calls for detailed analysis, planned design, and total management; thus providing a means for structured development. Accurate analysis calls for a "top-down" approach which looks down from the vantage point of the managers who will use the system. Development of a useful design calls for a "bottom-up" approach so that accurate information will be sent to the managers. Figure 3 demonstrates the concept of "top-down" analysis with "bottom-up" design. The left-hand side shows the data getting into the data base, the analysis; the right-hand side shows the information getting to the managers. This chapter represents the left-hand side of the figure. It examines the informational needs of the major functional areas of the firm; identifying the managerial activities, the industrial engineering techniques used to supply information in performing those activities, the data required to implement each technique, and the data resulting from each technique. Each area is studied separately, but not independent of one another's activities.

The system developed will be based upon the integration of these four subsystems. This integrated system will collect the interactive components into a central file to which all will contribute. This chapter identifies the components, clarifies their sources, the interactions of the elements, and the basis for the design of the central data base.

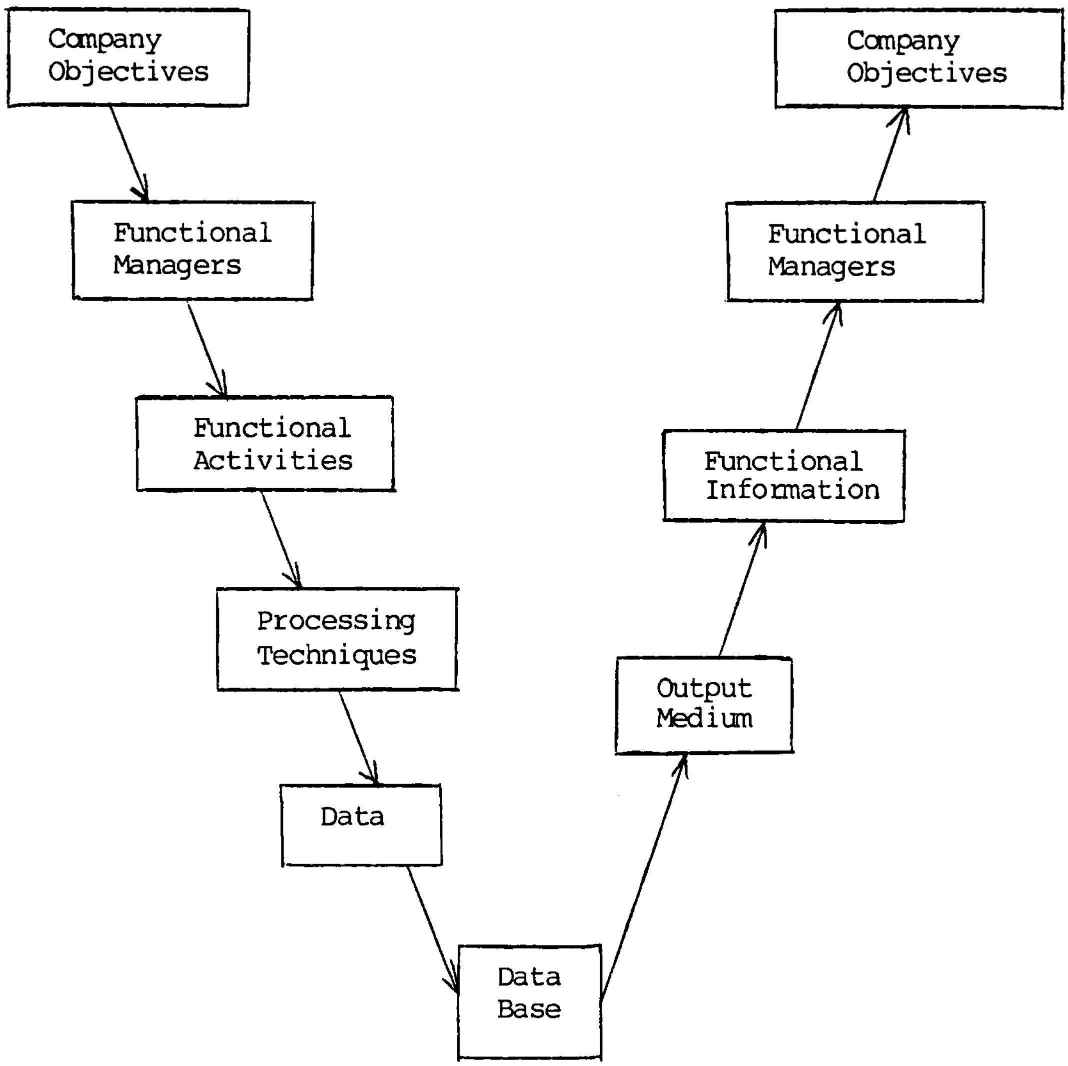

Figure 3

Top-Down Analysis with Bottom-Up Design

The Financial Subsystem

The financial manager's primary objective is cost control, which in turn leads to profit maximization for the firm. He is concerned with company performance in comparison to the financial plan; the cash flow of the firm; and the financial impact of such policies as capital investment, depreciation, make-or-buy decisions, and merger-acquisition decisions. The activities which use industrial engineering techniques include the following:

1. Product Cost Control
2. Inventory Cost Control
3. Financial Estimating
4. Budgeting

The following sections expound upon the techniques and the data required to implement them. Also given is the source of each data element.

Product Cost Control

Cost accounting information of interest to the IE is that information needed to control product costs. The product costs of major concern are the costs of direct labor and material. These costs may be allocated among specific products; they also tend to change and are thus subject to control. The overhead costs also affect product costs, but they are not associated directly with any product, and are difficult to trace and to control.

Not only is the IE involved in controlling the costs of established products, but he is also involved in determining the economic feasibility of new products.

One of the techniques used by the IE to determine the profit contribution of a product is the break-even analysis (15). This analysis is based on the relationships between product costs and revenues. The break-even point occurs where sales will exactly cover total costs. Data required to perform this analysis include the following:

1. Sales price per unit from Marketing, (P)
2. Material cost per unit of output from Inventory, (M)
3. Labor cost per unit of output from Payroll, (L)
4. Total fixed cost from Budgeting, (TF)
5. Total volume of output from Production, (Q)
6. Total variable cost per unit of output, (V)

The results from this analysis include the number of units at the break-even point (Q^*), and the break-even dollar value of costs and revenues (D) where $Q^* = TF/(P-V)$ and $D = TF/(1-V/P)$.

Inventory Cost Control

The inventory costs of primary concern to the Financial manager are those costs which may be controlled by changing the lot size. These costs are primarily the variable costs of procurement or setup and the cost of carrying inventory. As the number of orders for an item increase due to small order quantities, the cost of procurement increases, while the cost of carrying inventory decreases. The challenge to the financial manager is to minimize the total inventory cost by estimating ordering and carrying costs and buying the quantity resulting in the lowest total cost.

The model for determining annual ordering costs is $OC = P(D/X) + CX$ where OC is the annual ordering cost, P is the preparation cost per order, D is the annual demand, X is the lot size, and C is the unit cost per lot (42).

The annual holding cost model is $HC = CI(X/2) + CIM$ where HC is the annual holding cost, I is the annual interest rate, and M is the minimum safe inventory level (42).

In summary, the inputs for this function include the following:

1. Setup/Purchasing cost, from Production Planning/Purchasing.
2. Expected annual demand, from Marketing.
3. Lot size, from Material Requirements Planning.
4. Unit Cost, from Purchasing.
5. Annual interest rate, from Cost Accounting.
6. Safety stock level, from Material Requirements Planning.

and the outputs per inventory item are the annual ordering cost and the annual holding cost.

Financial Estimating

Financial estimating involves the determination of costs associated with the manufacture of a product, the development of a system, or the rendering of a service. These estimates help the manager screen uneconomical proposals and thus choose the more profitable ventures. The costs associated with the manufacture of a new product may be estimated by adopting the value of the production costs of a similar product, or it may be based on a mathematical analysis.

The product costs to be estimated include direct material costs, direct labor costs, and overhead (5). The cost of the materials may contribute the largest part of the product cost, and may be obtained from material price lists. Inputs for the estimate of direct material costs per unit of output include identification of the material (MID), the unit of material (U), the price per purchased unit (R), and the amount of purchased units used per unit of output (N).

The output is the estimated cost of direct material per unit of output (M^*), where $M^* = (R) \times (N)$.

The estimation of direct labor costs per unit requires the estimated number of man-hours needed to produce a unit of output (H^*) and the labor rates (W), where H^* may be computed by multiplying the number of steps per process (S), by the number of processes per unit (P), by the number of hours per step (H). The output is the estimated cost of direct labor per unit of output (L^*), where $L^* = (H^*) \times (W)$.

Indirect costs are commonly distributed for estimating purposes by rates determined by cost-accounting methods. The estimated number of direct labor man-hours is multiplied by a given rate for factory overhead. Thus, the estimated overhead cost $(O^*) = (L^*) \times$ (overhead rate); this rate may range from 40 to 60% and is supplied by Cost Accounting.

Budgeting

Budgeting involves the allocation of monetary resources in the firm. Information used in developing operating and/or capital budgets range from sales forecasts to replacement equipment requirements. Management often uses the sales forecast to set general budgeting guidelines which are used to compare actual and budgeted expenditures.

In establishing budgets, management must decide how funds should be allocated and which projects should be funded. The IE plays a major role in this financial decision-making. His involvement includes the analysis of alternative investments, single investment analysis, and purchase/produce analyses.

Most manufacturing companies have opportunities to invest funds internally at attractive rates. A common rule used to determine desirable investments is to invest in the ones yielding the highest anticipated rate of return (ROR). The rate of return is that interest rate at which the present worth of the cash flows of a project is zero.

In analyzing individual proposals, the ROR is compared with the firm's standard of attractiveness (MARR), the minimum attractive rate of return. If the ROR is less than the MARR, the proposal is generally rejected. Choices among alternative proposals require assumptions about the cash flows for the same number of years for all alternatives. The ROR may be found by using the trial-and-error method. The input is the net cash flow for each year of the expected life of the project (CF), and the output is the calculated ROR.

The model used in analyzing alternatives is as follows (43):

$$0 = PW\ (i) = \sum_{t=0}^{n} CF\ (1+i)^{-t}$$

where n is the expected life of the project.

Another method to compare alternatives is the Present-Worth method which compares alternatives by converting each cash-flow series to an equivalent amount at time zero. The input is CF for each year of the expected life and MARR. The output is the equivalent present-worth amount. The selection criteria is the proposal with the maximum present-worth value. (In using this method to analyze individual proposals, a value greater than zero makes the proposal acceptable.)

Both methods previously mentioned require that alternative proposals have the same expected life. To compare alternatives with different lives, the Annual-Cost method is applied. This method makes alternatives comparable by converting estimated cash flows to equivalent uniform annual amounts throughout the lives of the proposals. The objective is to find the alternative with the minimum annual cost.

The required input include the first cost (PC), MARR, the estimated future cost (FC), and the estimated life of the proposal (n). The output is the equivalent annual cost (AC). Following is the model for this method (43) :

$$AC = (PC - FC)\ \frac{i(1 + i)^{n}}{(1 + i) - 1} + [(FC)\ x\ i]$$

Another approach to analyzing alternatives is to calculate the cost of borrowed money. This procedure involves the same trial-and-error method as used for finding the unknown rate of return. The difference is that borrowing involves an initial positive cash flow followed by a series of negative flows.

The interest rate obtained is the effective rate at which money is being borrowed. The input is the net cash flow for each year of the loan (F), and the output is the calculated interest rate. The model is as follows (43):

$$0 = PW\ (i^{*}) = \sum_{t=0}^{n} F(1+i)^{-t}$$

Although only one technique per management activity was presented, other techniques might be used to solve the problems. The various techniques which might be applied to solve managerial problems in the financial subsystem are shown below in Table 5.

Table 5

Industrial Engineering Techniques
Used in the Finance Activities

TECHNIQUES	ACTIVITIES			
	Product Cost Control	Inventory Cost Control	Financial Estimating	Budgeting
Linear Programming	X	X		X
Inventory Models		X		
Break-Even Analysis	X			
Dynamic Programming		X		X
Economic Analysis				X
Simulation	X	X	X	X

The linear programming technique may be applied in any of the activities which have an objective to minimize costs or to maximize profits, limited resources, and linear relationships among its variables. In the financial activities, costs are minimized and money is considered a limited resource.

The break-even analysis may be used in any activity involving a relationship among the cost, price, and volume of an alternative--whether that alternative is a product, equipment, or a service. Its application to budgeting was not detailed, but it is applicable in deciding on facility and/or equipment investment. It assists in choosing among possibilities that produce differing mixes of the capital investment and operating costs necessary to handle a given volume of output at a specific price. Thus, in this application, the costs are calculated rather than the break-even point.

The inventory model, economic analysis, and work measurement techniques are limited to specific applications in the finance subsystem. The inventory model and work measurement techniques are used in other subsystems, but economic analysis is a technique used almost exclusively in the financial arena.

The Marketing Subsystem

To help the company achieve its ultimate goal of maximum profits, the Marketing manager works toward maximizing the company's percentage of the total market. That percentage is shown by the firm's market position, indicating how well possible customers are responding to the company's products. In order to reach the customer, the manager must consider such factors as the product, its price, forecasted and actual customer demand, advertising, distribution, and customer satisfaction.

The IE's involvement in the Marketing subsystem includes such activities as sales forecasting, optimal plant location for efficient distribution, and establishment of prices.

Sales Forecasting

Accurate prediction of future demand affects nearly all industrial functions. The operating budget of each department, inventory levels, the size of the labor force, purchasing activities, production activities, and capital investments are all affected by the predicted level of sales. The IE's involvement includes the estimation of how many of each item will be demanded and sold, and when the demand will occur.

Forecasts for each sales item may be made for several time intervals. The time period for which the forecast is made can be determined by the type of method used. Forecasts of a month or less may be used in scheduling manpower, inventory control, and production planning. Forecasts for periods from a month to a year may be used in planning the impact of seasonal variations in demand. Forecasts for periods longer than a year are used to make plans for new products and for studying changes in production mixing.

The short-range forecasts typically use time-series models; the mid-range forecasts use regression analysis; and the longer-range forecasts use such techniques as the Delphi technique and market surveys. Because the latter kind of forecasts are so far into the future that objective methods can not be used effectively, they will not be considered in this subsystem.

The forecasting function requires that both data on historical sales and data of up-to-date sales statistics be maintained. This data is used as input for calculating the sales forecasts. These calculated forecasts will become input to production planning, inventory control, and distribution planning.

The forecasting technique used in this study is exponential smoothing. The demand is forecast by averaging demand history through the assignment of weights. Some of the advantages of this method include minimal storage of historical data and the ability to perform sensitivity analysis by varying the weight factor. A noted disadvantage is the slowness of the model in catching up with a consistent trend. In order to overcome this disadvantage, a revised smoothing model will be used which incorporates a measure for the trend. That model is as shown below:

$$S = \alpha x_t + 2(1-\alpha)S_{t-1} - (1-\alpha)S_{t-2}$$

The variables for the model are

α, the weight factor, $(0 < \alpha < 1)$;

x_t, the sales forecast for period t;

S_t, the forecast for the period t;

S_{t-1}, the forecast for the previous period; and

S_{t-2}, the forecast for period t-2.

The inputs for the model are the product identification from Production, the weight factor from Management, sales for the previous periods from Sales, and forecasts for the previous two periods from Marketing; the output is the period forecasts which are sent to Production and to Advertising.

Distribution

Distribution includes all activities involved with providing customers with the right products at the right time while minimizing the cost to do so effectively. Some of the activities include determination of plant and/or warehouse locations, stock allocation, and development of transportation policies. The Distribution manager must also select the source if orders can be filled from more than one stocking location.

The IE provides this manager with information on ideal warehouse locations and channels of distribution. A linear programming method, the Transportation Model, is often used to select the location which minimizes the transportation costs.

The inputs for each item are as follows:

1. Item identification
2. Transportation costs per mile
3. Supply points (Plants)
4. Demand points (Warehouses)
5. Availability per plant
6. Demand per warehouse
7. Distance between each plant and warehouse

and the outputs are the total transportation costs between the plants and the warehouses, and the distribution assignments.

The mathematical form of this model (26) is as follows:

$$\text{Min } Z = \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij} X_{ij} \quad \text{, subject to}$$

$$\sum_{j=1}^{n} X_{ij} = A_i \qquad i = 1,2,3,\ldots m$$

$$\sum_{i=1}^{m} X_{ij} = B_j \qquad j = 1,2,3,\ldots n$$

where m is the number of plants, n is the number of warehouses, X_{ij} is the number of units shipped from plant i to warehouse j, C_{ij} is the transportation cost per unit from plant i to warehouse j, A_i is the number of units available at plant i, and B_j is the number of units demanded at warehouse j.

Pricing

The price of a product often determines whether or not customers will buy it; thus, determination of a price is important to the success of a product in terms of sales, and ultimately in terms of profits.

The pricing procedure depends on the product and the market in which the product will be sold. For example, a standard product in a competitive market will be priced slightly lower than a specialized product in a closed market. The procedure used in this subsystem applies to standard products. For these products the selling price must be sufficient in the long run to cover all costs of production, administration, and sales while providing for a reasonable margin of profit.

This procedure (15) establishes the production costs (direct materials, direct labor, and overhead) as the base price of the product and then adds a markup to cover the fixed costs of administration and sales plus a percentage of production costs (usually from 40 - 60%) as profit. The inputs are as follows:

1. Product identification from Production
2. Unit labor cost from Payroll
3. Unit direct material cost from Inventory Accounting
4. Unit overhead costs from Budgeting
5. Unit selling and administration costs from Management

and the output is a unit selling price for each production item.

Table 6 shows those techniques which the IE might apply to solve problems in the Marketing subsystem. Those techniques shown include some which were not defined explicitly within the text, but are viable alternatives to apply to the problems of the given activities.

Table 6

Industrial Engineering Techniques
Used in the Marketing Subsystem

TECHNIQUES	ACTIVITIES		
	Sales Forecasting	Distribution	Pricing
Linear Programming		X	
Break-Even Analysis			X
Dynamic Programming		X	
Queueing Theory		X	
Forecasting	X		
Simulation	X	X	X
Price Theory			X

The Personnel Subsystem

The personnel subsystem represents the flow of information about the employees in the company. The primary responsibilities of this subsystem are forecasting and planning of the company's manpower needs, maintaining an adequate work force, and controlling the personnel policies and programs of the firm.

Finding the IE active in this company function is not uncommon, for the IE has traditionally been dubbed the "people " engineer. He may be found evaluating and analyzing jobs, analyzing wage payment policies, forecasting manpower needs, and negotiating employee benefits.

Job Evaluation

Job evaluation involves the appraisal of the value of a job in comparison to other jobs. This is accomplished by either ranking, grading, comparing factors, or assigning points (33, 44, 47) . The first two methods are qualitative in nature and will not be discussed in this study. The latter two result in a numerical job value based upon an analysis of the major job components. A dissimilarity between the two is that factor comparison states results in terms of wages for each job while point rating uses dimensionless points which are converted into dollar values.

Factor comparison analyzes jobs on the basis of such factors as mental requirements, skill requirements, physical requirements, responsibility, and working conditions. All jobs are rated on each factor. Then each job is ranked on the basis of its average rating among the factors, and wages are allocated among the factors and compared against the rankings.

Point rating requires that jobs be broken into component factors which are further reduced to degrees to reflect their weights as job components. The weights of each factor are summed to give the total points for the job. The total job points are compared against the salaries, and this relationship is then used as a basis for evaluating other jobs.

The inputs for this function include the job identification, description, specifications by factors, evaluating factors, and point assignments for each factor. The output is a numeric evaluation; for factor comparison, that will be the dollar worth of the job, and for point rating it will be a comparative number used as a basis for establishing comparative dollar values for jobs.

Job Analysis

A job analysis determines the characteristics of a job by evaluating the activities, required facilities, worker qualifications, and working conditions The results of this analysis is a major input to the job evaluation process.

Motion and time studies take the job analysis a step further. The motion study analyzes the body movements used to perform a job, and the time study determines the standard time for an operator to satisfactorily perform it (33, 44, 47).

The motion study not only considers the hand and body motions of the operator, but it also considers the the raw materials, the process, and the tools required. One of the methods used (33) in motion studies is Methods-Time-Measurement (MTM).

MTM uses standard time values for movements required in performing a job. The time required to perform each operation of a job is totalled to obtain the time to perform the job.

The time study method made famous by the IE is the stopwatch timing. The procedure is to clock the time it takes for an operator to perform each element of an operation. The inputs for the job analysis are operation identification, job elements identification, element start time, element finish time, time for allowances. The outputs include the elements' time, the standard time for the job, and the normal time for the job. The normal time is the total of the element times, and the standard time is the normal time less the time for allowances.

Wage Payment Analysis

The value of the job and the qualifications of the worker effect the wages . Those wages influence the quality of the people working in the firm, which in turn influences the company's competitive edge. Extraordinary wages may restrict the potential for profit by increasing the product cost, however. Thus, the IE must assist in finding the salary which will strike a balance between these factors.

The wages of interest in this subsystem are those paid to production workers. These wages are directly attributable to production output, and may be based on either an hourly rate , an incentive rate, or some combination of the two.

The most common payment of wages is the hourly, or so called day rate. It is used for both highly skilled and unskilled workers, short-run production jobs, and jobs which are machine paced.

There are several work models by which wages may be computed (35). The straight piece-work model pays wages for each piece produced on a job. The mathematical model is $W = RT(A/S)$, where R is the hourly rate; T is the actual time worked; A is the actual output per hour; and S is the standard output per hour. The output, W, is the weekly wage rate. The shortcoming of this model is that the employee's weekly wage decreases proportionally as his actual work output falls.

In order to insure the worker a base rate while also providing an incentive for greater production; the following model may be used to calculate the weekly wage rate:

$$\begin{aligned} W &= RT \qquad &\text{for } A < S \\ &= RT\,(A/S) \qquad &\text{for } A > S \end{aligned}$$

In the event that the company also wants to give the employee an extra bonus as an incentive for greater output the following model may be used to calculate the weekly wage rate: $W = RT\ [\ 1 + k(A/S - 1)\ ]$ for $A > S$. The value of k depends upon the plan used, but it normally ranges from 1/2 to 1.

Manpower Forecasting

Given the sales forecast, the Personnel department can estimate manpower needs before they actually arise. This activity often employs industrial engineering techniques. Generally, the level of the labor force changes directly with the demand. To alleviate peaks and valleys in the personnel levels, however, the IE attempts to smooth the manpower requirements for the planning period. The objective of the schedule of laborers for each time unit of the planning period is to meet production requirements (expected demand) while minimizing the payroll cost for the period.

The inputs for this activity include the following:

1. Required man-hours to produce a unit, from the Job Analysis
2. Unit variable cost less labor, from Cost Accounting
3. Scheduled production or the forecasted demand, from Marketing
4. Straight-time labor rates, from Payroll
5. Overtime labor rates, from Payroll
6. Cost to change the level of the labor force, from Production

The outputs per time period are

1. Straight-time labor force level,
2. Overtime labor force level,
3. Change in labor force from one period to another, and
4. Estimated labor cost for the period.

One mathematical model used (42) by the IE to forecast manpower needs follows:

$$\text{Min } Z = \sum_{t=1}^{n} c_{it}X_{it} + l_t W_t + l_t' O_t + e_t w_t + e_t' w_t'$$

$$\text{s.t.} \quad W_t = W_{t-1} + w_t - w_t'$$

$$O_t = U_t + \sum_{t=1}^{n} m_i X_{it} - W_t$$

where c_{it} is the variable cost of product i during period t, less labor; X_{it} is the scheduled production of product i during period t; l_t is the straight-time labor rate; l_t' is the overtime labor rate; W_t is the straight-time labor force level; O_t is the overtime labor force level; e_t is the cost to increase the labor force; e_t' is the cost to decrease the labor force; w_t is the positive change in the work force level; w_t'

is the negative change in the work force level; U_t is the undertime labor force level; and m is the required labor force to produce one unit.

Table 7 presents the various techniques which the IE might apply to the problems accounted by the activities of the Personnel subsystem.

Table 7

Industrial Engineering Techniques
Used in the Personnel Subsystem

TECHNIQUES	ACTIVITIES			
	Job Evaluation	Job Analysis	Wage Payment Analysis	Manpower Forecasting
Linear Programming				X
Forecasting				X
Learning Curve	X	X	X	
Simulation				X
Motion Economy		X		
Work Sampling	X	X	X	
Evaluation Techniques	X		X	

The Production Subsystem

Production includes all processes and resources involved in the transformation of raw materials into finished products to be sold to customers. The Production manager's objective is to make products on schedule at an optimum cost. To meet this objective, he must plan the production on the basis of the sales forecast,schedule the planned production, and control the process to minimize possible problems. Before the process may begin, however, adequate material must be on hand; and before it can be considered complete, the product must be in satisfactory form for shipment to the customer and/or to distribution points. Since the IE is greatly utilized in the production department, he may be found participating in all of these activities.

The following discussion of the production activities begins where the process begins--with the planning for needed materials. The discussion then moves to the development of the production plan to its scheduling and implementation, and then to inspection of the final product.

Materials Requirement Planning and Control

Most companies spend a considerable amount of time and money converting raw materials and sub-assemblies into finished products. It is the responsibility of Materials Requirement Planning and Control (MRPC) to ensure that the production process has adequate amounts of the right materials at the right time. Other functions of this activity include determining when and how much raw materials to order, monitoring the status of outstanding purchase orders, and controlling the level of raw materials in inventory. To meet these responsibilities, the function may be further divided into Inventory Control, Stock Maintenance, and Purchasing.

Inventory Control determines the inventory levels to be maintained in support of a given production level. Stock Maintenance sees that inventory levels are maintained through purchasing materials to replace those items used by production; it also determines the quantities and timing of purchases. Purchasing handles the actual ordering of materials.

The IE's involvement includes the establishment of economic lot quantities for ordering replenishments. This lot is ordered when the stock on hand reaches a pre-determined order point based both on estimates of the lead time and on the expected variability in demand during the lead time. This is an EOQ-reorder point system.

An alternative to this system is time-phased requirements planning which ties the control of materials to the production schedule of the final product. The timing of orders is based on a date that is exploded back from the date of the final product production, rather than on a reorder point.

The model used (26) to calculate the Economic Order Quantity (EOQ) follows:

$$EOQ = \sqrt{2AD/h(1-D/P) - (sD^2)/h(h+s')} \qquad \sqrt{(h+s')\ /\ s'}$$

where A is the fixed cost of placing an order, from Purchasing;

h is the annual inventory holding cost per unit from Cost Accounting;

D is the annual demand rate, from Marketing;

P is the annual production rate, from Production;

s is the shortage cost per unit, from Inventory Accounting; and

s' is the annual shortage cost per unit, from Inventory Accounting.

The EOQ determines how much to order, but this quantity must be ordered at the right time to ensure continuous operations. If the reorder point has not been established, the IE may calculate it as follows : ROP = lD - O - b; where l is the lead time, b is the number of units short, and O is the number of units already on order.

In summary, the inputs for MRPC are as follows:

1. Material identification
2. Amount of material required per product
3. Lead time
4. Expected product demand
5. Amount of material on hand
6. Amount of material on order
7. Amount of material short
8. Ordering/Set-up cost
9. Material holding cost
10. Material shortage cost per unit per time period
11. Material shortage cost per unit short
12. Annual production rate

The outputs include the expected material usage per period, the EOQ, the date the material was ordered, the date the material was received, the actual amount of material used by production, and the ending inventory.

Production Scheduling

The production scheduling function sequences and times the production of the finished products. The schedule is based upon sufficient supplies of materials, labor, and equipment to meet the production requirements stipulated in the production plan. Either the inventory level or the production level or both may be fluctuated to meet this schedule. In either case, unwanted costs are incurred. The manager attempts to minimize these costs by producing a schedule which minimizes such fluctuations.

The following model (42) is used to produce a "smooth" production schedule:

$$\text{Min } Z = a'\sum_{i=1}^{k} u(i) + a''\sum_{i=1}^{k} v(i) + t'\sum_{i=1}^{k} y(i) + h\left[\sum_{i=1}^{k}\sum_{j=1}^{i}\{p(j) + y(j) - d(j)\}\right]$$

$$\text{st. } p(i) < p_{max}(i) + \sum_{i=1}^{k}[u(i) - v(i)], \quad i = 1,2,3,\ldots,k$$

$$y(i) < y_{max}(i) + \sum_{i=1}^{k}[u(i) - v(i)]$$

$$\sum_{i=1}^{k} d(i) < \sum_{i=1}^{k}[p(i) + y(i)]$$

$$p(i) < u(i) + p(i - 1)$$

where the inputs are a', the cost of adding one extra unit of production capacity; a'', the cost of removing one unit of production capacity; t', the overtime cost per unit; h, the inventory holding cost per unit; d, the demand forecasted per period; p_{max}, the maximum regular time production capacity per period; y_{max}, the maximum overtime capacity per period; r, the overtime units that can be produced for each added unit of regular production capacity; and k, the number of planning periods.

The outputs are $\rho(i)$, the regular production per period; $y(i)$, the overtime production per period; $u(i)$, the number of units of added capacity per period; and $v(i)$, the number of units of subtracted capacity per period.

Production Planning

The production plan allocates available productive resources to the production requirements as determined by the sales forecast. Those forecasts, converted into a time-phased production program, provides dates and quantities for each item over the planning horizon.

The inputs to this planning process include the expected demand from Sales Forecasting, capacity availability from the Production manager, raw materials availability from MRPC, and production efficiencies from the Production manager. Its outputs become inputs to production scheduling and distribution planning.

The IE often uses linear programming models for production planning. One such model is the one below (26):

$$\text{Max } Z = \sum_{i=1}^{n} (r_i - c_i)X_i$$

$$\text{st. } \sum_{i=1}^{n} a_{ik}X_i < b_k \qquad k = 1,2,3,\ldots K$$

$$X_i < D_i \qquad i = 1,2,3,\ldots n$$

$$X_i > L_i \qquad L > 0$$

where the inputs for each item i during each period k are r, the revenue from selling one unit; c, the variable production cost; D, the expected demand; L, the required minimum production level; and for each resource k, b, the amount of resource available and a, the amount of the resource required for each product i. The outputs for each product are X, the amount of the product to produce; the used capacity for each operation; and the amount of unused capacity for each operation.

To obtain rough approximations for planning weekly operations, the following model may be used (42):

$$R = \frac{(E - S + \sum F)}{N}$$

where the inputs for each production item are E, the desired inventory at the end of the period; S, the actual inventory at the beginning of the period; F, the sales forecast for each week; and N, the number of weeks in the planning period. The output is R, the weekly production rate for the product.

Two documents of concern to this function are the Bill of Materials (BOM) and the Route Sheet. The former identifies the material components of the product, and the latter indicates the sequence of operations in production.

Quality Control

The function of Quality Control is to determine quality standards and measurements to ensure that those standards are maintained and practiced. The quality of products being processed; of incoming materials; and that of outgoing products must be controlled.

To control processes while in operation, the IE may use such statistical quality control tools as the X chart and/or the R chart (35). The X chart is a plot of measures of central tendency. Random samples are taken from production which has been run since the last sampling. The controlled variable is measured for each piece in the sampling and the mean of these measurements is computed. The result is a point on the X chart which, hopefully, is within the control limits.

The parameters for the X chart include X (the mean of the sample) and (the standard deviation of the observations). These parameters are used to calculate the central tendency, the upper control limit, and the lower control limit. These computations are as follows:

$$\bar{\bar{X}} = \frac{1}{n}\sum_{i=1}^{n} \bar{X}_i$$

$$UCL = \bar{\bar{X}} + 3\,\sigma/\sqrt{n}$$

$$LCL = \bar{\bar{X}} - 3\,\sigma\,/\sqrt{n}$$

and $$\sigma = \sqrt{\frac{\sum(\bar{X}^2)}{n} - \left(\frac{\sum \bar{X}}{n}\right)^2}$$

where $\bar{\bar{X}}$ is the central tendency (overall mean); UCL is the upper control limit and LCL is the lower control limit.

The R chart plots the variability of the data. The central tendency R, the center line on the chart, is the range of the i samples.

The computations are as follows:

$$R = \frac{1}{n} \sum_{i=1}^{n} R_i$$

$$UCL = R + 3\ \sigma_R$$

$$LCL = R - 3\ \sigma_R$$

and $$\sigma_R = \sqrt{\frac{\sum (R^2)}{n} - \left(\frac{\sum R}{n}\right)^2}$$

The x and R charts used together give added assurance that the process has not drifted out of control. Again, these tools measure the quality of in-process products. To measure the quality of incoming materials and outgoing products another tool is used, acceptance sampling. This sampling results in either accepting or rejecting the lot on the basis of a given feature.

Table 8 presents the alternative techniques which might be applied to the problems encountered in the management of the activities in the Production subsystem.

Table 8

Industrial Engineering Techniques
Used in the Production Subsystem

TECHNIQUES	ACTIVITIES			
	Production Planning	Production Scheduling	MRPC	Quality Control
Linear Programming	X	X	X	
Inventory Models			X	
Dynamic Programming		X	X	X
Queueing Theory		X	X	
Statistical Quality Control				X
Simulation		X	X	
Forecasting	X		X	
Learning Curve	X	X		
Heuristic Models		X		

Summary

By adopting the "top-down" approach, this chapter identified the elements for the central data base needed to meet the objectives of the functional managers while also meeting those for the company. Each element in the data base is the responsibility of one of the functional areas. That responsibility consists of inputting and updating the data. Figure 4 displays this concept for the four functional areas analyzed in this chapter. It shows the direct relationship between the functions and the contents of the data base. The outer layer is the elements created by the areas, the second layer, and the central focus is the data base which is kept current by each responsible functional area.

Crucial to the usefulness of the data base created as a result of this analysis is data consistency. The data must be accurate and in the proper form to provide information to all users. This characteristic of the data is pursued in the following chapter.

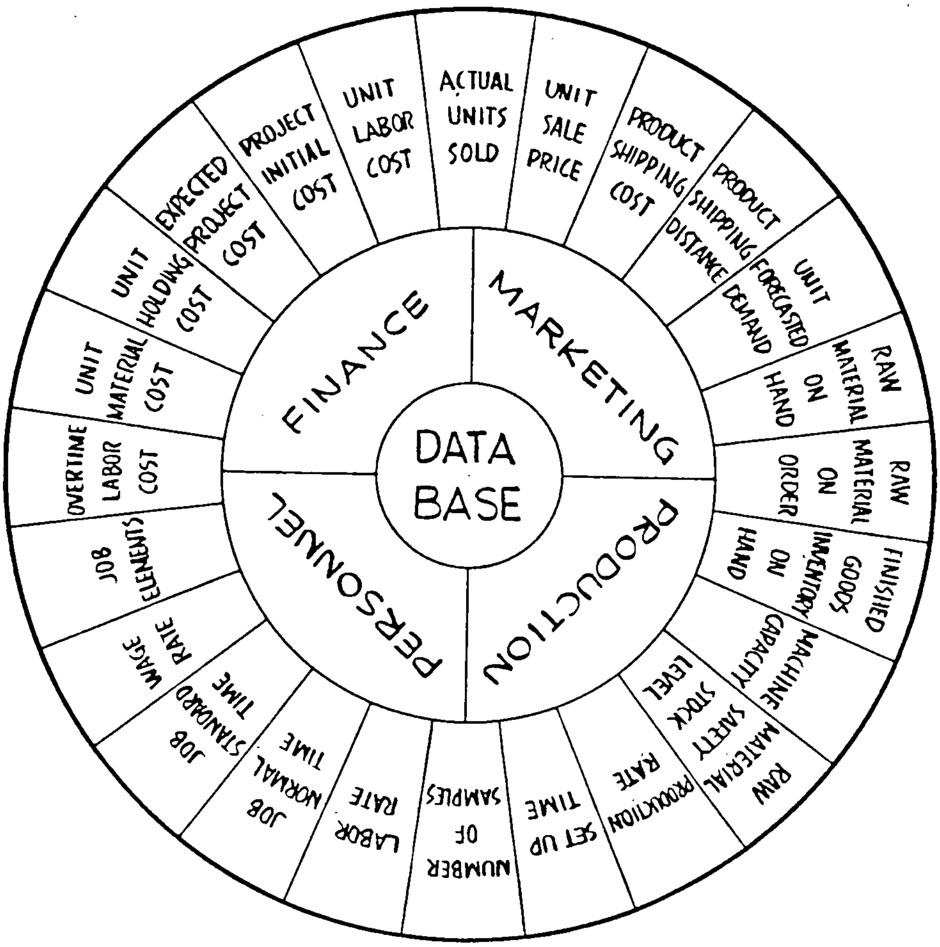

Figure 4

Inward Flow of Data

CHAPTER V

SYSTEM INTEGRATION

Introduction

This chapter presents a horizontal synthesis of both the data and the techniques required to obtain information for source and user subsystems. The first section examines the various techniques in reference to the subsystems and activities in which they may be applied.

The second section analyzes the data elements with respect to the functional areas in which they are used or from which they originated. The elements are assigned dimensions which will facilitate their usage and minimize conversions by the user subsystems.

Although the systems analysis may take place vertically, within a function, the results must be presented horizontally to show inter-function usages of the data. For example, the components of inventory control are not only of concern to production, but to finance and marketing as well. To ensure that all end users receive complete information, a "bottom-up" approach is adopted for the design of the information system. That approach represents the right-hand side of Figure 3.

The managers of each subsystem receive information from the data base through such mediums as charts, graphs, simulation models, reports, tables, and linear programming models. These devices present processed data in a form meaningful and useful to the managers. This concept is shown in Figure 5. It depicts the transition of the data into information for the four major end users.

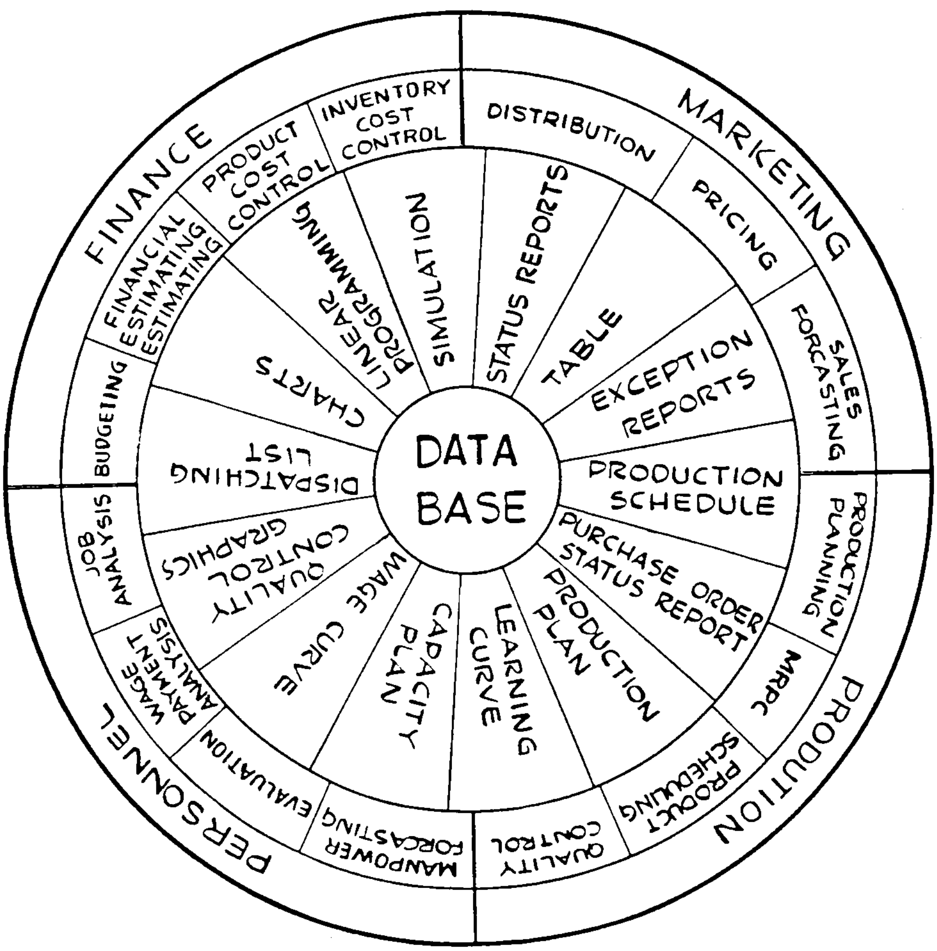

Figure 5

Outward Flow of Information

Integration of Techniques

The outer layer of Figure 2 shows the techniques used by the IE in solving managerial problems in a manufacturing environment. The majority of the techniques (with the exception of statistical quality control, evaluation techniques, and economic analysis) may be applied to activities in several areas. Table 9 shows the interactions between these techniques and the four functional areas.

Linear programming may be applied in any activity which has an objective to minimize or maximize; limited resources; and linear relationships among its elements. In finance, the objective generally is to minimize costs or to maximize profits within the limitations of available funds. In marketing, transportation costs are to be minimized within the limitations of available units. In personnel, the objective is to minimize labor costs within the constraints of available and/or maximum allowable manpower. Production may use this technique in such activities as product allocation and product mix. In both cases, the objective is to minimize production costs within the constraints of machine availability and raw material availability, respectively.

Mathematical inventory models are of primary interest to finance and production. Finance is concerned with the cost of maintaining goods in inventory and lost revenues as a result; while production is interested in having ample supplies for meeting its schedules. Both areas use the same model, but from a different perspective - dollars for Finance and quantities for Production.

Table 9

Application of Industrial Engineering Techniques in MIS Subsystems

TECHNIQUES	FUNCTIONAL AREAS			
	FINANCE	MARKETING	PERSONNEL	PRODUCTION
Linear Programming	X	X	X	X
Mathematical Inventory Model	X			X
Break-Even Analysis	X	X		X
Dynamic Programming	X	X	X	X
Queueing Theory		X	X	X
Statistical Quality Control				X
Simulation	X	X	X	X
Motion Economy			X	X
Economic Analysis	X			
Forecasting		X	X	X
Learning Curve			X	X
Heuristic Model		X		X
Work Sampling			X	X
Evaluation Techniques			X	

Break-even is generally used to identify the profit potential of a particular choice or to identify the most profitable from among the choices presented. It may be applied to those situations containing a relationship among the costs, the revenues, and the volume. Finance may use it to calculate the price of a new product, given the cost and the volume; production to calculate the volume, given the costs and the price; and marketing to compare alternative plant locations.

Queueing theory analyzes waiting-lines and develops policies to increase movement through the system in order to avoid bottlenecks and other hindrances. The typical elements of a queue situation are the arrival distribution , the service distribution, the number of service channels, the service discipline, the maximum number of customers allowed in the system, and the calling source (44). The results of the analysis include the queue length, the number of customers in the system, waiting time of a customer, and the time a customer spends in the system. Marketing uses this activity to improve its transportation flow from plants to warehouses, and production uses it to help eliminate or reduce bottlenecks at work stations.

Motion economy is used to simplify jobs and to reduce their work content. It is used in personnel to ensure that the available manpower is being used effectively, and by production to ensure that the job is being performed efficiently. This study analyzes the elements of a job and the human motions required to execute those elements.

Forecasting attempts to predict future behavior of such entities as the product market and the labor force. Marketing forecasts future product sales, using past sales performances in its projections. Personnel forecasts the demand of manpower. Production uses forecasting in developing production plans for projected product demand. Because of these required forecasts, historical records by time period must be maintained for sales, employee levels, and warehouse demands.

The learning curve is primarily a training tool. It plots the productive output of an employee as a function of time. It is based on the premise that the greater the experience, the greater the output in a shorter period of time. It is used by personnel for training employees and by production to establish production schedules.

Heuristic models are used in those situations where analytic techniques are not operable; they rely on logic and common sense. They may be used in production for assembly line balancing and operation sequencing (15). Marketing's distribution activity may use heuristic models to solve such problems as facilities location, routing, and the establishing of itineraries for salesmen.

Work sampling consists of intermittent, instantaneous observations of work activity. Personnel uses this study to determine the percentage of productive time expended by an employee. Production uses it to determine the normal time required to perform an operation.

Simulation and dynamic programming (DP) may be applied in all of the areas. These techniques were not detailed in the last chapter because they were considered alternative techniques. Simulation is used to obtain approximate solutions. It consists of a model which uses either historical or fictitious data to determine how the results may be affected by various situations.

DP is used in problems requiring a sequence of decisions. For example, production schedules made in one month affect the inventories at the end of that month, which in turn affects the production plans for the next month upon which the schedules for that next month will be based. Finance may use DP in its budgetary activities; personnel in determining its labor force size; and marketing in its distribution activity. All of these activities are based on time-dependent situations.

The techniques outlined in this section help the IE to focus on important considerations in managerial problems, to quantify those considerations, and to report them in a form which the manager can use for decision-making. Although they may not guarantee optimal solutions, they will provide an objective analysis of the input data. This makes the identification of the required data even more important. The next section explodes those identifications for the manufacturing firm.

Integration of Data

Data are the basic elements of each subsystem. Some managerial problems affect several areas and they must be solved with respect to the elements of each area in which they will have an impact. Other problems, however, may be unique in nature and their impact is confined within one functional area. The areas in which each data element is either a value used only in computations within that area, represented by a "C"; an output of the subsystem, shown by an "O"; or an input, represented by an "I", are identified in Table 10. Those elements unique to a particular activity can be identified by an absence of "I" values in its row. The other elements are of importance to several activities and must be considered in the analysis of the interfaces among the subsystems. Some of the key interfaces are described in the remainder of this section.

The marketing subsystem generates a sales forecast for each finished product. Historical sales and recent sales statistics data are required to make that forecast. The forecast may be for one year with monthly time intervals and quarterly updates. The sales forecast then becomes input for production planning, distribution, manpower forecasting, and MRPC activities.

This monthly forecast is used by production to develop weekly production plans for each product. The plan is based on the quarterly updates, which are divided into thirteen weekly intervals. Production also uses the forecast to determine when to order raw materials to meet the production plan which is based on the forecast. This activity must be performed in conjunction to developing the production plan, so it is based on the same weekly forecasts.

The marketing activity distribution uses the monthly sales forecast to ensure adequate stocks of materials at each warehouse location in anticipation of demand. Like production planning, distribution also develops its schedules on a weekly basis.

The personnel subsystem uses the sales forecast to determine manpower requirements to insure that production will meet the expected demand at a minimal cost of labor, avoiding fluctuations in the labor force size and required working time.

The production subsystem provides a production plan of anticipated dates and run quantities for each item at each plant over the quarter, in weekly intervals. The plan also calculates target levels for inventories. Generally, this plan will be updated monthly.

Inputs for developing the production plan other than the sales forecast include the capacity availability, raw-materials availability, production efficiencies, and equipment requirements. The plans may require revision as a result of feedback on actual production schedules and current inventory levels. The plan also requires the product specifications and the process description from the design group.

The production plan becomes input for the production scheduling, MRPC, and distribution activities. Production scheduling takes the weekly plan and develops daily schedules for moving the raw materials through manufacturing to distribution. MRPC uses the plan to determine if adequate materials are on hand to meet the plan; and if not, to determine how much to order and when. Distribution uses the plan to develop daily shipping plans from the plants to the warehouses where needed.

The production activity of scheduling develops a timetable for the movement of materials, work-in-process, and finished goods through manufacturing and distribution. Daily schedules may be developed each week for two to four weeks ahead. Inputs other than the production plan include the availability of raw materials, the amount and location of work-in-process in the plant, the work force availability, and the status of the machinery.

The outputs include a daily notification of available finished products to distribution and a daily notification to MRPC of raw material withdrawals.

MRPC determines how much of each purchased material should be ordered and when to order, and controls the inventory levels of these materials. The inputs include the production plan, a bill of materials for each product, current raw materials inventory levels, current production schedules, and vendor information.

The outputs include an up-to-date status report of raw materials stocks and a schedule of raw materials due in. The primary recipient of these outputs is production scheduling.

The distribution activity monitors inventory activity at the plants and warehouses, and on a daily basis decides where to place the finished products from each plant and how these products are to be shipped. Inputs include the production plan , the production schedule, up-to-date inventory stock status, and the sales forecast. This information must be available by finished product for each stocking point.

Pricing, like distribution, is an activity of the marketing subsystem. An effective pricing policy requires the coordination of such inputs as product costs from the finance subsystem, unit output volume from production, and sales forecasts for each product. The output is a unit selling price which will enable the firm to receive a satisfactory return on its investments. It is used by the finance subsystem internally in product cost control and by production planning in determining output volume for break-even purposes.

The personnel subsystem provides the system with information pertaining to the employees and their jobs. The manpower forecasting activity determines the required number of laborers needed by production in order to meet the production plan. Its inputs include the sales forecast from marketing,labor rates from payroll, and the required man-hours per unit from production. The output is the forecasted labor force (straight time and overtime). The primary recipient is the production subsystem for its scheduling activity.

Other activities of the personnel subsystem are wage payment analysis and job analysis. Wage payment analysis provides optimal wages for each job, and job analysis provides standard times for performing each job. Inputs for these activities include hourly wage rates from payroll and actual output from production. The standard time is used by production in scheduling and the wages are used by finance and internally by personnel.

The finance subsystem is responsible for cost control. The primary inputs include annual inventory costs which are used by MRPC and unit cost information which is used by marketing in its pricing activity and internal to the finance subsystem by the budgeting activity.

These subsystem interfaces are vital considerations in designing the integrated system. The design must not only consider the position of the originator and the needs of the users, but also the form in which the data is to be stored. In fact, the form is contingent on those other two factors. The next section presents the required data in a form deemed most efficient in meeting the needs of all users.

Table 10

Data Analysis

ELEMENTS	FINANCE				MARKETING			PERSONNEL				PRODUCTION			
	Product Cost Control	Inventory Cost Control	Financial Estimating	Budgeting	Sales Forecasting	Distribution	Pricing	Job Evaluation	Job Analysis	Wage Payment Analysis	Manpower Forecasting	MRPC	Production Planning	Production Scheduling	Quality Control
Output Unit Sales Price	I						O						I		
Output Unit Material Cost	I		C				I					O			
Output Unit Labor Cost	I		C	O			I				C				
Product Total Fixed Cost	I		O				I								
Product Total Varible Cost	C						I				I	I	I		
Output Volume	I						I						O		
Product Break-Even Point	O														
Product Break-Even Cost	O														
Annual Order Cost		O										I			
Order Prep Cost		I										O			
Annual Product Cost		I				O					I	I	I	I	
Cost per Lot Ordered		C													
Production Lot Size		I											O	I	I
Purchase Lot Size		I										O			
Inventory Holding Cost		O										I		I	
Annual Interest Rate	O	I													
Safety Stock Level		I										O			

Table 10 (Continued)

ELEMENTS	FINANCE				MARKETING			PERSONNEL				PRODUCTION			
	Product Cost Control	Inventory Cost Control	Financial Estimating	Budgeting	Sales Forecasting	Distribution	Pricing	Job Evaluation	Job Analysis	Wage Payment Analysis	Manpower Forecasting	MRPC	Production Planning	Production Scheduling	Quality Control
Shortage Cost Per Unit Short	I	I										O			
Shortage Cost per Unit/Period	I	I										O			
Units Short		I										I	O		
Type Material		I	I									I	O		
Material Unit Price	I	I	I				I					O			
Material per Product	I	I	I									I	O		
Actual Time Per Product	I		I										O	I	
Normal Time per Product			I						O		I		I		
Standard Time per Product			I						O		I		I		
Job Labor Rate	I		I					I	I	I	I		I		
Production Processes			I											O	
Steps per Process			I											O	
Standard Time per Step			I						O					I	
Employee's Name								I	I	I	I				
Employee's Job								O	I	I	I	I			
Hours Charged										I				O	

Table 10 (Continued)

ELEMENTS	FINANCE				MARKETING			PERSONNEL				PRODUCTION			
	Product Cost Control	Inventory Cost Control	Financial Estimating	Budgeting	Sales Forecasting	Distribution	Pricing	Job Evaluation	Job Analysis	Wage Payment Analysis	Manpower Forecasting	MRPC	Production Planning	Production Scheduling	Quality Control
Pay Period	I			I						I	I		I	I	
Net Cash Flow				I											
Present Worth				O											
First Cost				I											
Future Cost				I											
Salvage Value				I											
Equivalent Annual Cost				O											
Expected Life				I											
Weight Factor					I										
Past Forecast					I							I	I		
Previous Sales					I										
Transportation Costs						I									
Plant Location						I									
Warehouse Location						I									
Plant Supply						I									
Warehouse Demand						I									
Plant/Warehouse Distance						I									
Plant/Warehouse Units Shipped						O									

Table 10 (Continued)

ELEMENTS	FINANCE				MARETING			PERSONNEL				PRODUCTION			
	Product Cost Control	Inventory Cost Control	Financial Estimating	Budgeting	Sales Forecasting	Distribution	Pricing	Job Evaluation	Job Analysis	Wage Payment Analysis	Manpower Forecasting	MRPC	Production Planning	Production Scheduling	Quality Control
Unit Selling & Admin Costs							I								
Job Description								I	O						
Job Rating Factor								I							
Factor Specification								I	I						
Job Element									I						
Time Allowances									I						
Element Time									C						
Job Normal Time									C						
Job Standard Time									O						
Standard Output										I					
Actual Time Worked										I					
Weekly Wage Rate										O					
Incentive Factor										I					
Overtime Labor Rate											I				
Work Force Change Costs											I				
Material Inventory		I										I	I		
Lead Time												I			

Table 10 (Continued)

ELEMENTS	FINANCE				MARKETING			PERSONNEL				PRODUCTION			
	Product Cost Control	Inventory Cost Control	Financial Estimating	Budgeting	Sales Forecasting	Distribution	Pricing	Job Evaluation	Job Analysis	Wage Payment Analysis	Manpower Forecasting	MRPC	Production Planning	Production Scheduling	Quality Control
Safety Lead Time												O	I		
Annual Rate of Production												I			
Material Usage		I					I					O			
Date Ordered												O			
Date Received												O			
Beginning Inventory												I			
Ending Inventory												O			
Production Efficiency													O		
Min. Required Production													I		
Weeks/Period													I		
Prdt Beginning Inventory													I		
Prdt. Ending Inventory													I		
Setup Time														I	
Operation Sequence Number														I	
Max. Regular Time Capacity														I	
Max. Overtime Capacity														I	
No. Employees											O			I	
No. Machines														I	

Table 10 (Continued)

ELEMENTS	FINANCE				MARKETING			PERSONNEL				PRODUCTION			
	Production Cost Control	Inventory Cost Control	Financial Estimating	Budgeting	Sales Forecasting	Distribution	Pricing	Job Evaluation	Job Analysis	Wage Payment Analysis	Manpower Forecasting	MRPC	Production Planning	Production Scheduling	Quality Control
No. 8-hr Shifts											I			I	
Cost to Change Unit Capacity														I	
Overtime Cost per Unit														I	
Overtime per Unit														O	
No. Production Lots in Process													I	O	
Sample Mean															I
Mean Sample Mean															I
Sample Range															I
Mean Sample Range															C
Mean Range															I
Std. Dev. of Observations															C
Range Std. Dev.															I
Upper Control Limit															O
Lower Control Limit															O
Inspection Attribute															I
No. Inspected															I
No. Accepted															I
No. Rejected															

Data Dimensions

Those elements identified in Table 10 as outputs for a particular area must be entered into the data base by that area. This source area is responsible for entering and updating the data. That entry must be in a form meaningful and useful to the source area and all user areas. Although conversion in some circumstances is unavoidable, its complexity may be greatly reduced if the data are stored in dimensions readily applicable to the various techniques adopted by the user areas. Repetition may also be avoided if the data occurs as often as it will be needed by any one of the user areas.

What follows is a conceptual framework of the data base required to perform the managerial activities and the applicable industrial engineering techniques described in Chapter III. The data are listed according to their source areas. Those elements originating in the finance subsystem are shown in Table 11; those from the marketing subsystem, Table 12; those from the personnel subsystem, Table 13; and those from the production subsystem, Table 14.

Table 11

Finance Subsystem Data

Element	Occurrence	Dimension
Investment Net Cash Flow	N	$
First Cost	1 (Year 0)	$
Present Worth	1 (Year 0)	$(Calc)
Salvage Value	1 (Year N)	$
Equiv. Annual Cost	N	$(Calc)
Expected Life	1	Years
Rate of Return	1	%(Calc)
MARR	1	%
(The following must be entered for product i at plant j)		
Unit Labor Cost	12 (Monthly)	$
Material Cost	12 (Monthly)	$(Calc)
Variable Cost	12 (Monthly)	$(Totl)
Sell/Admin Cost	12 (Monthly)	$
Overhead Cost	12 (Monthly)	$(Calc)
Total Fixed Cost	12 (Monthly)	$
Break-Even Cost	12 (Monthly)	$(Calc)
(The following must be entered for inventory item k at plant j)		
Holding Cost	1 (Annual)	$
Ordering Cost	1 (Annual)	$
Shortage Cost	1 (Annual)	$

Table 12

Marketing Subsystem Data

Element	Occurrence	Dimension
Unit Selling Price (For each plant)	4 (Quarterly)	$
Forecasted Demand	12 (Monthly)	Quantity
Units Product i Shipped (From plant j to warehouse w)	4 (Weekly,Cur Month) Monthly Update	Quantity
Sales Orders for product i	4 (Weekly,Cur Month) Monthly Update	Quantity
Shipping Cost for product i (From plant j to warehouse w)	4 (Weekly,Cur Month)	$/Quantity
Product Identification	1 (Unique)	Text

Table 13

Personnel Subsystem Data

Element	Occurrence	Dimension
Job Identification	1 (Unique)	Text
Job Factors	7 (Max.)	Text
Factor Specifications	5 per Factor (Max.)	Text
Factor Rating	1 per Factor	Numeric Wt.
Job Element	10 (max.)	Text
Element Time	1 per Element	Minutes
Job Value	1 per Job	$
Allowance Time	1 for all Employees	Minutes
Job Normal Time	1 per Job	Minutes
Job Standard Time	1 per Job	Minutes
Standard Output	1 (Prdtn Operators)	Quantity
Employee ID	1 (Unique)	Text
Wage Rate	1 per Job	$/Week
Incentive Factor	1	%
Labor Rate	1 per Job	$/Hour
Overtime Labor Rate	1 per Job	$/Hour

Table 14

Production Subsystem Data

Element	Occurrence	Dimension
Material Order Date	1 per Order	MM/DD/YY
Order ID	1 per Order	Text
Material Receipt Date	1 per Order	MM/DD/YY
Work Period End	1 (Weekly)	MM/DD/YY
Material ID	1 (Unique)	Text
Material Cost for product i	1 (Each Product)	$
Material m Usage	4 (Weekly,Cur Month) Monthly Update	Quantity
Material m Unit Price	1 (At time of Order)	$
Material Shortage Cost	4 (Weekly,Cur Month) Monthly Update	$
Amount Product i produced at Plant j	4 (Weekly,Cur Month) Monthly Update	Quantity
Product i Economic Lot Size	1 (Weekly)	Quantity
Lot Type	1 per Lot (Weekly)	Text(B or M)
Material m Safety Stock Level	4 (Weekly,Cur Month) Monthly Update	Quantity
Actual Employee Output	Weekly	Quantity
Machine ID	1 (Unique)	Text
Machine Capacity	Weekly	Hours
Raw Material Inventory Level	Weekly	Quantity
Work-in-Process Inventory Level	Weekly	Quantity
Finished Goods Inventory Level	Weekly	Quantity

Table 14 (Continued)

Element	Occurrence	Dimension
Raw Material m in Product i	Weekly	Quantity
Production Rate Product i at Plant j	Weekly	Units/Hour
No. 8-Hour Shifts at Plant j	1	Quantity
Available Machines at Plant j	1 per Machine Type	Quantity
Setup Time	1 per Operation	Minutes
Operation Sequence for Product i	Each Step	Text
No. Samples of Product i	4 (Weekly,Cur Month) Monthly Update	Quantity
Observations per Sample	4 (Weekly,Cur Month) Monthly Update	Quantity
Sample Mean	With Weekly Samples	Quantity
Mean Sample Mean	1 Each Week	Quantity
Sample Range	With Weekly Samples	Quantity
Mean Range	1 Each Week	Quantity
Standard Deviation	1 Each Week	Quantity
Upper Control Limit	Weekly(Range & Mean)	Quantity
Lower Control Limit	Weekly(Range & Mean)	Quantity
Inspection Attribute	Each Sample	Text
No. Inspected	Each Sample	Quantity
No. Rejected	Each Sample	Quantity

These elements, stored in a central data base, form the core of the integrated, total manufacturing MIS. They were determined in the development of the subsystems as being necessary to meet the information needs identified for managing the key functional activities and optimizing the operation of the entire firm. Figure 6 shows how the data elements, when manipulated by the various industrial engineering techniques, provide information to the functional areas to perform their respective activities in conjunction with the goals of the firm.

The form in which these elements are stored greatly impacts the degree to which the functional areas contribute to achieving company objectives. Each area may use the same data, in conjunction with others, to obtain information of particular interest to its own operations. This information is then used to make decisions which may affect the other areas and the organization as a whole. This concept is demonstrated in Figure 7.

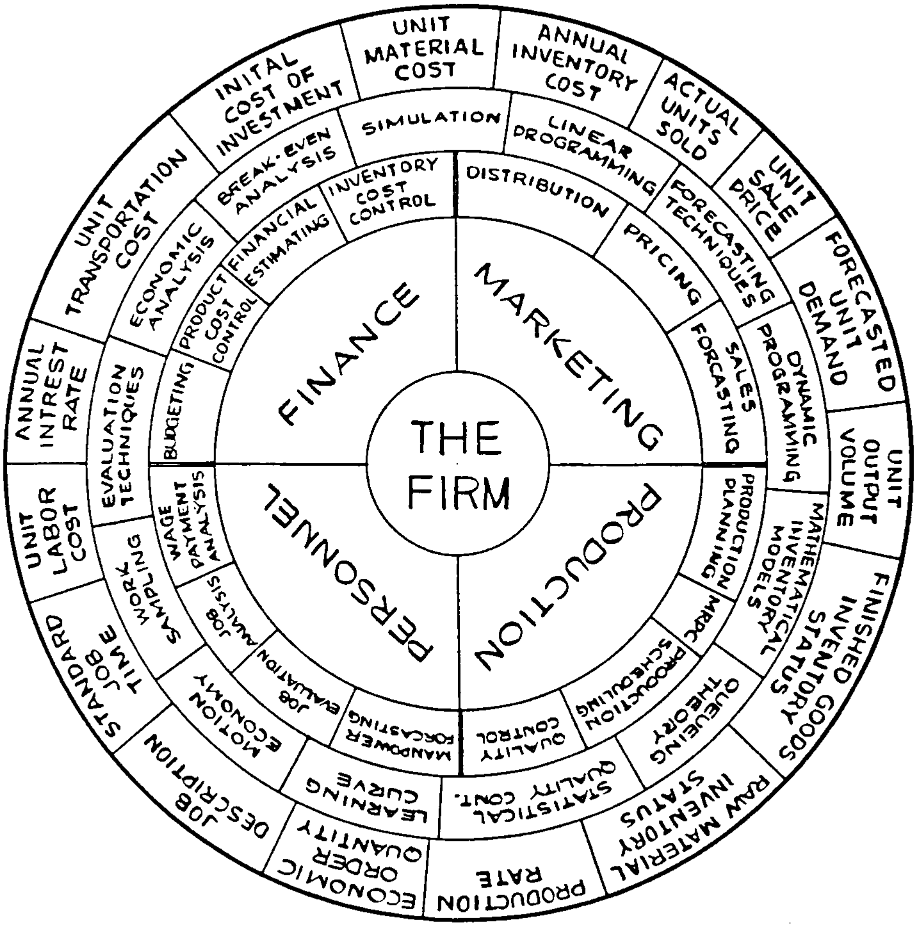

Figure 6

Management Information System Overview

FINANCE

```
Ordering Cost ----------->   +------------------+
Annual Demand Rate ----->    |  Linear          |   =====>   Inventory
Unit Purchase Price ---->    |  Algebra         |            Costs
Annual Interest Rate --->    |                  |
                             +------------------+
```

PRODUCTION

```
Ordering Cost ----------->   +------------------+
Annual Demand Rate ----->    | Mathematical     |   =====>   Economic
Unit Purchase Price ---->    | Inventory        |            Order
Annual Interest Rate --->    | Models           |            Quantity
                             +------------------+
```

Figure 7

Common Data for Diverse Information

CHAPTER VI

SUMMARY AND RECOMMENDATIONS

Summary

Industrial engineering developed to meet the managerial needs of the manufacturing industry during the industrial revolution. Although other industries have come to recognize the skills of the IE, the manufacturing organization continues to be the major user of the IE and his special talents. This usage has grown and changed through the years in conjunction with changes within the industry.

A major catalyst for these changes has been the computer. Computers have brought about increased mechanization and automation of both production and information processes. Computerization has also created new managerial problems and given a new face to old ones. The IE has had to keep abreast of this situation by developing new, innovative techniques and by adapting old ones to new situations.

Industrial engineering techniques have been applied in almost every facet of the manufacturing operation. Thus, the IE's position in the firm has allowed him to develop a sweeping view of the entire operation. This makes him the ideal candidate for establishing a means of managing the total company without disrupting the operations of particular functions, but ensuring that they operate in a manner which positively affects all areas of the firm.

The key to total managing is a total information system. In fact, one of the highest aims of MIS development is to provide a means for obtaining total management. Before this goal can be achieved, however, the system must first provide managers with increased visibility, which leads to greater control over operations. The effectiveness of the management is evidenced in the degree to which company objectives are met. The ultimate goal of MIS is to realize the highest degree, and thus optimize the management of a company's operations.

The ideal MIS accomplishes visibility, control, management, and optimization. The model developed in this study is one conception of such an MIS. It's components are shown in Figure 6. This figure summarizes the concepts presented in figures 2, 4, and 5. It incorporates all elements of the system.

The higher two objectives, management and optimization, are seldom realized in existing systems. As stated previously, total management relies on total information. Few systems, however, have been designed with enough detail or in a systematic manner so that they contain all data needed by their users. Often, when the data are present, the structure does not permit its usage by different users so that various types of information may be provided. A "top-down" analysis of the system identifies all users, their informational needs, and the data required to meet those needs. The data, stored in a central repository, must be structured so that minimum conversions are required and redundant storage is avoided. Several areas may require the same data to provide different information. The inventory cost control activity of finance requires many of the same data elements to determine inventory costs as the MRPC activity of production needs to determine the economic order quantity. This was shown in Figure 7.

Although the system may provide management, optimization does not follow automatically. The data, though present and in correct format, must be sufficiently processed to obtain the information for managers. The processing stage determines whether the information received will be useful enough to enhance the quality of the management. The industrial engineering techniques of operations research, when applied during the processing stage, allow the system to offer optimization.

Thus, by applying the systems approach for thoroughness, the technology offered by the computer for efficiency, and the optimization techniques of industrial engineering for effectiveness, the goals of MIS development are obtainable. The IE can bring the MIS to the forefront as a usable management tool.

Recommendations

This paper establishes industrial engineering as the ideal background for developing information systems which optimize the management of company operations. Because of this background the IE is the most likely candidate to build the interface between management and the MIS. The effectiveness of this interface depends on the application of the scientific analytical approach in integrating the physical, the human, and the informational activities of the organization.

Traditional areas of industrial engineering training include the optimization of physical and human activities and their integration in manufacturing organizations, but the inclusion of informational activities is a new arena for this discipline. The adequately prepared IE must receive formal training to master this new area.

The challenge to industrial engineering education is to prepare an IE who has enough knowledge of hardware and system support software to appreciate their roles in MIS design and operations; understands the business aspects of the firm well enough to incorporate informational needs into the MIS design; has a working knowledge of mathematical decision-making models needed to optimize the information furnished by the system; and has organizational and system-oriented training needed to implement an MIS to support managers in planning and controlling operations of the organization. Further study is needed to help educators develop programs which produce an IE with computer science, business, operations research, and traditional industrial engineering training interwoven in one curriculum.

This study emphasized the impact of the IE on the development and usage of the MIS. Little attention was given to the impact of the MIS on the activities of the IE. Not only is the MIS an application area for industrial engineering applications, but the MIS may also be an effective tool for the IE. The possibilities for the usage of this tool are yet to be fully explored.

There is little doubt, however, that the future of the MIS and the IE are destined to be interconnected and the determination of the impacts which they will have upon one another and upon organizational management will require further research.

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