STARS

University of Central Florida
STARS

Retrospective Theses and Dissertations

Summer 1972

The Operations Research Approach for an Effective Management Information System

Joel L. Mutzman
University of Central Florida, jmutz1@aol.com

Part of the Engineering Commons
Find similar works at: https://stars.library.ucf.edu/rtd
University of Central Florida Libraries http://library.ucf.edu

This Masters Thesis (Open Access) is brought to you for free and open access by STARS. It has been accepted for inclusion in Retrospective Theses and Dissertations by an authorized administrator of STARS. For more information, please contact STARS@ucf.edu.

STARS Citation
Mutzman, Joel L., "The Operations Research Approach for an Effective Management Information System" (1972). *Retrospective Theses and Dissertations*. 26.
https://stars.library.ucf.edu/rtd/26

F.T.U. LIBRARY
ARCHIVES

THE OPERATIONS RESEARCH APPROACH FOR AN EFFECTIVE MANAGEMENT INFORMATION SYSTEM

BY

JOEL L. MUTZMAN

A Research Report Presented in Partial Fulfillment
of the Requirements for the Degree
Master of Science

FLORIDA TECHNOLOGICAL UNIVERSITY

August 1972

ACKNOWLEDGEMENTS

I want to express my thanks and appreciation to Dr. Charles Proctor for his guidance, support, and concern for me throughout these years. Also I would like to thank his secretary, Miss Lois Meindl, who expediently answered many of the procedural questions.

I am greatly indebted to the fine efforts of my colleague, Mrs. Rachel Penne who proofread and suggested improvements for this report. My appreciation is extended to Mr. Don Sanders who completed the final charts.

Finally, I sincerely thank my wife Marlene for typing this report, and most of all for her encouragement and inspiration throughout these years.

PREFACE

This report serves as an overview to the design of an effective Management Information System (MIS) by incorporating the modeling techniques of an Operations Research (OR) approach. It will be shown that the consideration of OR input requirements mixed with the information requirements for a data base existing at the everyday accounting and operational level creates a responsible management control and decision-making tool.

This mix of OR and everyday information approach varies as a function of the managerial activities and the organizational level of effort. In lieu of designing a "total" MIS system, MIS designers should structure a loosely connected federation of MIS sub-systems using the appropriate mix which, for each of the operational, controlling, and planning activities, meets the problem-solvers' requirements.

A discussion of the background, definitions, and attributes of MIS and OR will be made in Chapters I and II prior to merging these two entities into a unified concept. Chapter III will develop this concept. A manufacturing organization environment will serve as a point of reference for the formulation of models in the application areas of

sales forecasting, production, manpower planning, inventory control, and machine center utilization.

I am not proposing a "pipedream" non-realistic approach to a MIS system design that will solve all of management's problems. However, by planting the seeds of OR modeling techniques in the early phase of the design and development, the MIS system will, like a tree, in 3 to 5 years bear the fruit of today's careful planning.

TABLE OF CONTENTS

Chapter

I. MANAGEMENT INFORMATION SYSTEMS 1

Background
Definition
Meeting The Needs Of The Organization
Position In The Organization
Attributes
Data Base--The Cornerstone
Something Is Missing

II. OPERATIONS RESEARCH 18

Background
Fundamental Phases
Modeling, The Cohesive Ingredient
Coordinating The MIS Design Effort

III. AN APPLICATION USING MODELING FOR MIS DESIGN. 32

Manufacturing Organization--Background And Assumptions
Sales Forecast Model
Financial Planning Model
Manpower Hiring Model
Schedule Product Mix Model
Economic Order Quantity Model
Production Floor Simulation
Models--The Building Blocks

IV. CONCLUSIONS 62

LIST OF REFERENCES 63

TABLE OF CONTENTS

(Continued)

APPENDIXES

A. FEATURES OF GENERALIZED DATA BASE SYSTEMS. 65

B. DATA MANAGEMENT SYSTEM (DMS). 68

C. SUMMARY OF SIMPLEX METHOD 79

LIST OF CHARTS

Chart		Page
1.	Management Matrix	6
2.	Organization Chart	10
3.	Management Matrix--Information Organizational Requirements	26
4.	MIS Design Coordination Flow	29
5.	Functional Model Chart.	34
6.	Financial Planning Model	40
7.	Schedule Product Mix--Model Graphical Solution	48
8.	Economic Order Quantity	51
9.	Production Floor Queue Analysis	54
10.	Discrete Simulation Processing Logic. .	56
11.	Overview of Model--Data Base Interface	60
12.	Communication System Design	70

LIST OF TABLES

Table | Page

1. Sample VBC File of Buckets 73

2. Sample Overlay 77

CHAPTER I

MANAGEMENT INFORMATION SYSTEMS

Background

The computer over the last decade has revolutionized the processing of enormous amounts of clerical and accounting data that today's complex organizations are required to handle. Initially the computer was touted as a high speed adding machine with a programable stored instruction set, but then came the development of third generation "multi-task" computers, internal processing speeds down to billionths of a second and mass data storage access devices; the information millenium was upon us.

These modern organizations rushed about updating hardware and software to store every bit of information into their data banks, under a new buzzword called "Management Information Systems" (MIS), but like money saved in a bank, the information stored must return a reasonable dividend. Charles H. Kriebel, at the 1972 Spring Joint Computer Conference, stated that there was "the notable lack of results in spite of great expectations...a dismal return for $40 billion dollars investment in equipment." (1)

Many experts in various disciplines have tried to define and justify MIS and this huge dollar expenditure. There are also the critics who feel that the acronym "MIS" could just as well stand for "Mismanagement" (2) Information Systems. It isn't the intent of this paper to quote the pros and cons of MIS; however, all could agree that, "MIS is presently in a pre-embryonic state--nobody is even quite sure what it will look like when it is finally born..., the pipedream of MIS is slowly turning into reality." (2)

Definition

A basic definition of MIS is now in order:

A Management Information System is a system of presenting information which will be used in a timely and meaningful way in the decision-making processes of management at all levels of an organization. A MIS presents information which is both "Quantitative and Qualitative."(3)

First, what is meant by quantitative information is information (or data) that is an expressed numerical or factual value. Qualitative information is information that has been derived from an analytical expression or a series of numerical relationships made up of quantitative and/or other qualitative information. The nature of this information is such that, when taken out of context, it implies or infers some decision or action.

This definition of MIS conforms to the two fundamental laws of management systems and sciences which Dr. Franz Edelman, Corporate Director of Operations Research at RCA, so aptly named the "Laws of Relevance." They are as follows:

> "Law I. No manager with responsibility for a business--or a part thereof--will base important decisions on the outcome of a process which he, himself, does not adequately understand.

> "Law II. Genuine management information consists of the quantitative (numerical) and the qualitative (relational) descriptions of the business issues at hand." (3)

Examples of the above MIS definition applicable to a manufacturing organization are: 1. The inventory warehouse manager needs to know the current count of a particular part (quantitative) and its economic order quantity--EOQ (qualitative), and 2. On the upper end of the management spectrum, the plant manager needs to know the dollar amount of excess inventory surplus on hand (quantitative) and what would happen to this surplus value (qualitative) if the Master Build Schedule of product lines was to change.

In most of today's MIS systems the quantitative information is more easily obtained by the warehouse manager than by the plant manager. However, to satisfy the plant manager's request, one would have to go through the time-consuming and costly procedure of massaging an entire procurement inventory system. A more realistic and timely method of obtaining the information is the OR modeling technique.

Meeting The Needs Of The Organization

MIS must service and meet the needs of the organization at all operating levels and across the major management activities as shown in Chart 1--Management Matrix. The horizontal axis depicts the three management activities--Planning, Control, and Operation. Each of the three levels of the organization--Corporate, General (Staff) or Department (Line) descends the vertical axis.[1]

The highest level of management activity is planning, which is concerned with information that covers broad areas of management concern. For example, representation of product and market structure, in the planning context and at the corporate level, is generally accomplished by modeling everything within like industry or regional areas. A manager is not burdened with the level of detail in which he deals directly with the individual part numbers or with an individual customer.

The control activity is concerned with interpreting the immediate portion of the long-range business plan at the corporate level and translating it into a more detailed short-term fiscal budget. An example of the general level

---

[1]Dr. Edelman presented a similar illustration called Coordinate Activity/Organization Matrix, (3), p.16.

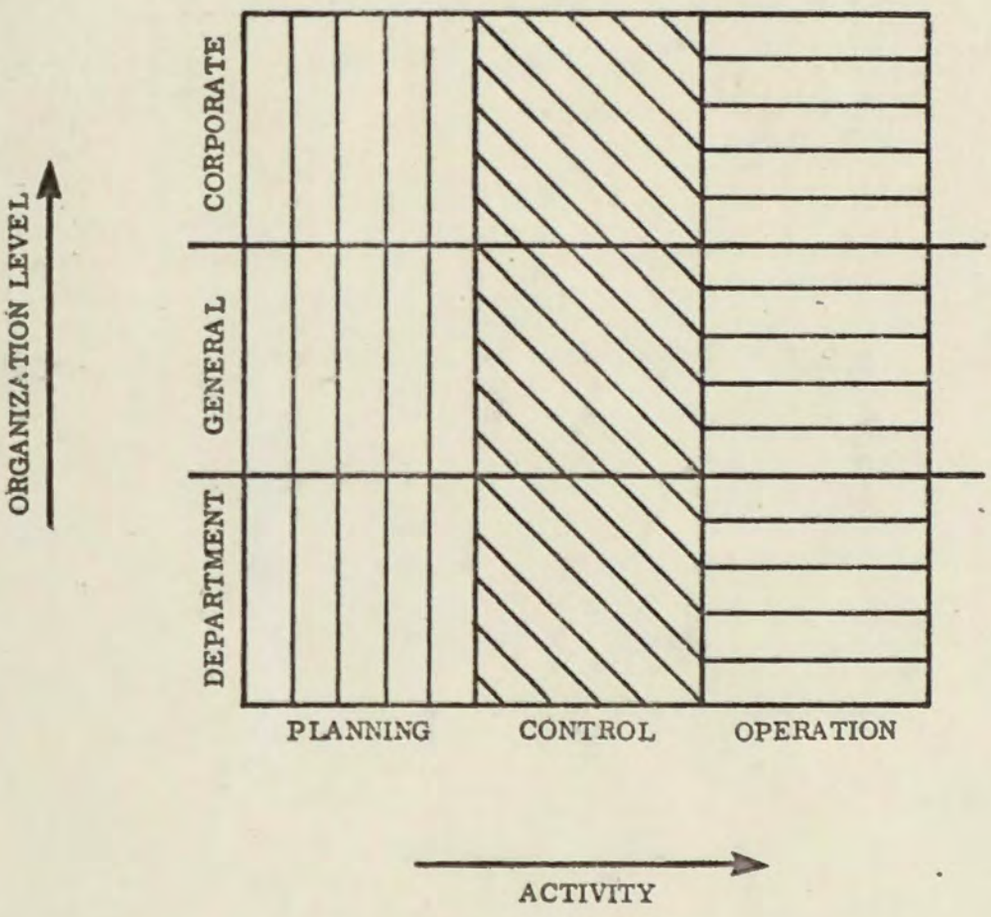


CHART 1
MANAGEMENT MATRIX

control activity is the translation of the business plan into a Master Build Schedule for production scheduling of the manufacturing plant. This is done by production schedulers who must allocate the resources of manpower and machines for optimal product line mixes. The control activity is also expected to signal the planning group if long- and short-term conflicts exist or are inconsistent with the business plan.

The last, but equally important, activity that an effective MIS design should service is the operation activity. This activity performs the everyday tasks of the organization and is concerned with collecting the actual quantitative information and signalling the control activity when corrective action appears necessary due to unusual conditions.

An example of this activity at the highest level would be a financial auditor flagging an overrun of actual capital expenditures against the approved capital budget for a division or plant. At the lowest level, an inventory manager may detect an inventory item is not in stock.

These activities require timely input and feedback, as stated in the MIS definition. For example, a MIS processes daily transactions at the operational activity. A MIS also functions to give managers of the

control activity a summary picture of an operating unit or group of units during intervals measured in weeks or months. In support of the planning activity, a MIS predicts or indicates trends over months or years, providing corporate or general management with the basis for determining major policies and directions.

Position In The Organization

In order that a MIS be responsive and meet the needs of the organization, MIS must be elevated to its rightful position and level in the organizational structure. In most organizations that have a so-called MIS design and development function, it is usually organized at the department level. The effectiveness of this function is quickly overridden and suffocated in the inter-departmental politics. The organizational entity of MIS should be set up at the corporate level or at least at the general level so that the needs of the various levels of organization and activities will be serviced with unbiased political fairness. The Organization Chart[2] serving as a sample arrangement can be seen in Chart 2.

Computer technology, Operations Research, and Informations Systems sub-groups fall naturally under the domain of the MIS functional unit. A MIS team effort consisting of specialists from these sub-groups can interface with the rest of the organization in order to come up with an effective system.

---

[2]Chart obtained from Dr. Max Croft of NASA, who was a guest speaker at DPMA Huntsville Chapter on June 21, 1972.

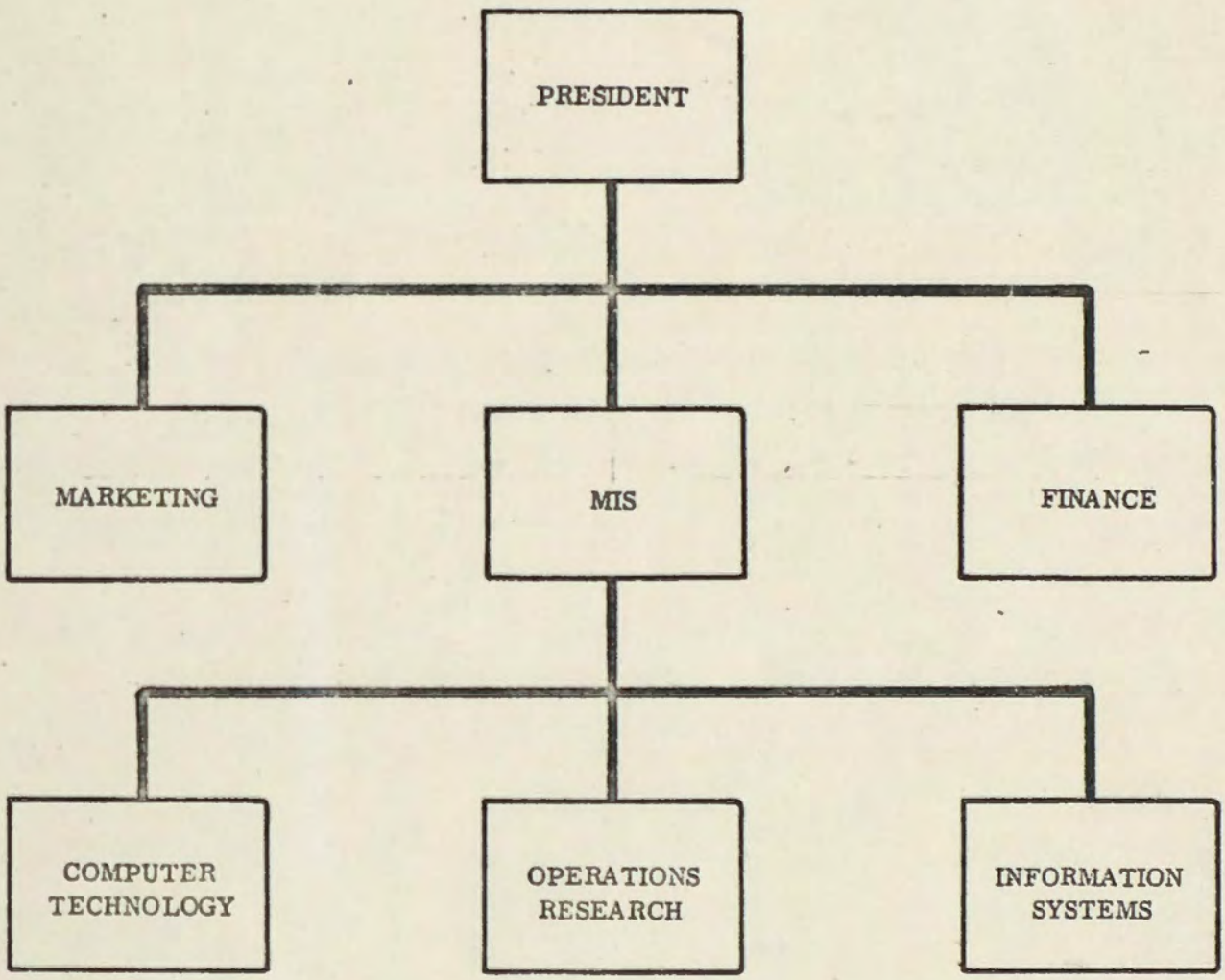


CHART 2
ORGANIZATION CHART

When MIS is given this equal status with the other functional units such as Marketing, Finance and Operations of the organization, effective lines of communication can be accomplished with all of them. Also, the overall long-range goals of top management are clearly visible and can be applied to the MIS design.

Attributes

The MIS activity functioning from this position in organization is most likely to develop and design a MIS system with the following attributes:

> "The system must have the capability to perform its intended functions in a manner suited to human action and decision making. In addition, the system must have a certain permanence or stability, which persists through changes in hardware, software, and development personnel. Contrasting with this, but equally important, the system must be responsive to inevitable changes in organizational requirements. Thus it must have an attribute of modifiability, whereby changes in its functioning and function can be accomplished in an orderly fashion by information systems professionals at the request of organization managers." (4)

The fourth attribute of a good MIS system design is Modularity. Modularity in the MIS design can be viewed as a collection of submodules with a moderate degree of integration existing among them. In most cases these are only a loose "federation" (5) of compatible and largely independent submodules. The issue is one of degree and whether the organization is monolithic or as diverse as a conglomerate.

Data Base--The Cornerstone

The key to success of any MIS is dependent on the structuring and formulation of the organization's generalized data base through which meaningful information and reports are the result of data retrieval and interpretation.

The effectiveness of the data base as the cornerstone of a MIS depends on the proper judgment of the MIS designer in his analysis of the types and requests for information and his anticipation of the utilization of redundant information throughout the various levels and activities of the organization.

The design of this data base, therefore, is a series of tradeoffs between: a) retrieval speed of the information against duplication of information, b) the number of user files and the type of storage devices to be used, and c) the data having a generalized structure or specific structure for each user file.

The MIS "Laws of Relevance" stated earlier are still pertinent in these following steps for development of a data base in keeping with user's needs:

1. "Understanding the information and its classification within the organization.

2. "Knowing the information flow through the organization.

3. "Data identification and categorization of the information.

4. "Data definition, description, structure." (6)

The first step--the understanding of the data--is closely aligned with the understanding of the organization needs. All too often, the detailed information intended for use at the operational activity is transformed for eventual utilization by the planning activity. The designers can see this transformation and understand its impact on the organization.

Step two follows step one because both fall under "Relevance Law I." Only by tracing the upward flow of information through the hierarchy of the organization, can that information be classified and understood at its proper level.

Robert V. Head put these two steps together in his following statement from his article in Datamation:

> "A popular approach is to classify data according to its usage, that is, whether it is intended for day-to-day operational usage, for control purposes, or for planning..." (7)

The third step, data identity and categorizing, helps the designer set up the relationships between inter-organizational functions specific data requirements and the pigeon-holing into the proper activity category. "Data analysis of inter-departmental forms with its variety of names and levels for the same kind of data" (6) should

determine what information is needed to reach decisions.

The fourth step, data definition, with respect to the user, refers to data base standardization and development of a user dictionary. The problem is to define every element of data that the MIS is to handle. The resulting definitions become the authority for each piece of data in all the user files that will be structured in the data base. The use of only authorized data names in the coding and structuring of the data base will slow the retrieval of such items but will help reduce redundancy and storage requirements.

From the data base management system (DMS)[3] software viewpoint, data definition and description becomes the main function of DMS. By entering the data into a data dictionary and defining its logical structure, the initial version of the data base is created. The data management system design and function is a topic in itself.[4] A statement of the capabilities of one type of DMS was defined by Mr. Jim Fry as:

> "...a set of generalized file processing capabilities which have a <u>hierarchical</u> data structure and a user interface to these capabilities. The user interface is a dual one: to interface data through a data description language, and to interface the generalized processing capabilities." (8)

---

[3]See Appendix A--Features of Generalized Data Base Systems.

[4]See Appendix B for an example of a Data Management System.

Something Is Missing

In the previous sections, the MIS concept was defined and its relation to the entire organization discussed. It was shown that a MIS must first meet the needs of all users of the management matrix. Also, MIS must be given an important functional position within the organization, preferably as a planning activity, in order that the four MIS attributes of capability, stability, modifiability, and modularity can be achieved within the well-structured foundation of the computerized data base. It was shown that the user of a MIS system needs two types of information--quantitative and qualitative.

Little more has to be said about the quantitative data since most MIS designers will incorporate this kind of information into the data base. However, the missing ingredient, and failure of existing MIS designs, is that they do not incorporate or properly envision the use of qualitative data in the data base. The intended MIS, which was to be a decision-making tool, falls short of the MIS user's objective. This MIS becomes just another information retrieval system for report generation and at best contains only on-line update and retrieval capabilities for everyday data at the operational level.

To correct this shortcoming, an Operations Research (OR) analyst should be a member of the MIS design team. The OR analyst could apply OR techniques and systems approach for developing the required qualitative information to meet the needs of management. The next chapter discusses the concept of the Operations Research approach and its function in the MIS design effort.

CHAPTER II

OPERATIONS RESEARCH

Background

Operations Research (OR) is a relatively new scientific discipline which was formerly founded on military necessity at the start of World War II. However, OR methodology and techniques have sprung from a certain class of problems with which older scientific disciplines, such as physics and chemistry, are concerned. This class of problems is called optimization.

The growth and maturing of OR has paralleled that of the computer's importance and usage in the complex modern organization. It has only been in the last twenty years or so, that today's organizations have sought the techniques of OR as an aid in management decision-making.

OR can be viewed as a tool of decision-making management as mathematical techniques are the tool for the scientist. Mathematics forms the cornerstone of Operations Research type problems, such as Linear Programming and Queueing Theory. OR attempts to solve real life problems by using mathematical modeling of close-form analytical

solutions, or time-consuming computer simulations.

> "Analytic models take almost no time for use. They are often, though not always, slightly less accurate than more detailed simulations. The results may generally be well understood by those with mathematical training." (9)

OR techniques seek the optimal solutions to problems which have limited resources and a multitude of constraints. In short, the objective of applying OR to the organization is "to provide managers of the organization with a scientific basis for solving problems involving the interaction of components of the organization in the best interest of the organization as a whole." (10)

Fundamental Phases

In order to apply OR modeling techniques to the design and planning of a Management Information System, a basic understanding of the fundamental phases of OR and the general way in which OR uses the systems approach to the solution of decision-making problems should be given.

Russell L. Ackoff outlined the following six major phases of an OR project:[5]

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

The first two phases are the most important to the design of the MIS system. The formulation of the problem and the recognition that a problem exists is necessary. Once the identification of the problem is well-defined, then the decision-making objectives can be stated within the scope of the overall goals of the organization.

---

[5]Russell L. Ackoff, "The Development of Operations Research as a Science", Operations Research, Volume 4, 1956. See also List of References 10.

However, these overall goals can become a paradox. For instance, a type of problem can exist in a manufacturing environment with different functions, each having its own conflicting objective functions to optimize. For example, the problems of establishing an optimal inventory policy are as follows:

> "Sales management generally wishes to have a wide variety of products to sell and promises a quick delivery to prevent the loss of sales. The economic function, logically, is the volume of sales, and inventories should be analyzed... to optimizing this sales volume.
>
> "The production management, on the contrary, seeks an intensive production schedule involving very little product variety,...which allows them to realize savings through mass production. The economic function that is set here is the unit cost of its product.
>
> "Financial management would like to see inventory handled so as to keep investment costs to a minimum...
>
> "The warehouse manager has still another objective in mind. As he sees it, the best possible inventory policy is the one that will give the lowest ratio of warehouse personnel salaries to inventory value, unless he prefers to optimize ease of handling." (11)

So we see four distinct examples of conflicting objectives for an inventory policy at each function in a manufacturing environment.

An approach to this problem is to translate all conflicting objectives to one common objective function, that is the minimization of costs in each operating function that is involved. Thus, if all operating functions can hold down their costs, then the total cost of

doing business can be held down to a minimum and the profit margins could be increased for the manufacturer.

This modular approach is called sub-optimization, which will be the influencing concept in the design of a federation of MIS sub-systems. This is a good reason why the MIS design and development group should be given at least an equal position of importance and authority on the organization chart.

The construction of the model or models, depends on the scope and complexity of the problem and the functional area to which it is directed. The model representation has two advantages over just the formulation of the problem:

1. The model reveals the key variables in the cause-and-effect relationships.
2. Modeling allows the MIS designers to examine the data requirements of the model and compare relationships to other systems.

This second advantage, which is central to the theme of this report, will be elaborated further in the next chapter with illustrated examples.

Dr. Franz Edelman stated the importance of the formal construction of the model and its data requirements in the following:

> "managers are very rarely interested in retrieving raw data for control or planning purposes, but additionally they want this data processed, filtered, condensed, distilled, interpreted,

> interrelated, etc. The rules for filtration, condensation, etc. are precisely what we mean by model and thus, a system without a model cannot possibly be an MIS." (3)

Although models can be over-simplified and be constructed too ideally and abstractly for the manager at the lower levels of the organization, nevertheless, those managers who are engaged in the activity of long-range planning at middle and higher levels need this abstraction just as they need the less detailed, summary information in their daily decision-making processes.

The remaining OR phases are not the predominant factors in the initial design and development of a MIS system and need not be discussed further.[6] However, they will become the measure of effectiveness of the MIS system as it evolves and is refined.

---

[6] C. W. Churchman, Russell L. Ackoff, and Leonard Arnoff have treated this subject matter quite thoroughly in their book, Introduction to Operations Research, Chapter 2. See List of References 10.

Modeling, The Cohesive Ingredient

The analysis and design of the OR model at the various levels of the organization becomes the cohesive ingredient in the establishment of a common data base for the MIS sub-systems. The following goals are achieved when this modeling exercise is carried out by the management and MIS designers:

1. Develop the necessary input and output of quantitative and qualitative information required in the model.
2. Know what additional data and relationships will be desirable to cross-link with other models, communicating through a common data base structure.
3. Capability of building a modular MIS sub-system that provides them the information they need at each of the appropriate levels.
4. Availability of the model outputs for decision-making at all management levels via the MIS data base.

This strategy of the modeling approach again encompasses the two basic "Laws of Relevance" as seen by the above results. That is, the user will better understand

the decision processes that the model depicts since he was part of the model exercise and design phase. Secondly, the appropriate requirements of quantitative and qualitative information will have been mapped-out.

Chart 3, the Management Matrix Information Organizational Requirements, helps illustrate this point. The chart is similar to the Management Matrix of Chart 1, but with the information requirements of the organization superimposed to illustrate the appropriate mix of the two types of information. The light area represents the requirement of qualitative information distributed throughout the organization and the darker area represents the requirement for quantitative information. For example, looking at the general level of an organization, the control activity shows the need for approximately half quantitative information and half qualitative information.

The second and third modeling goals put cohesiveness into the MIS System. As a model is constructed, the resulting information may be required as input to another model at a higher or lower function of the organization. Proper design of the MIS data base facilitates the second goal and promotes communication between the various models and information files of the data base.

The fourth goal is parallel to the sixth phase of an OR project "implementation" mentioned earlier. That is,

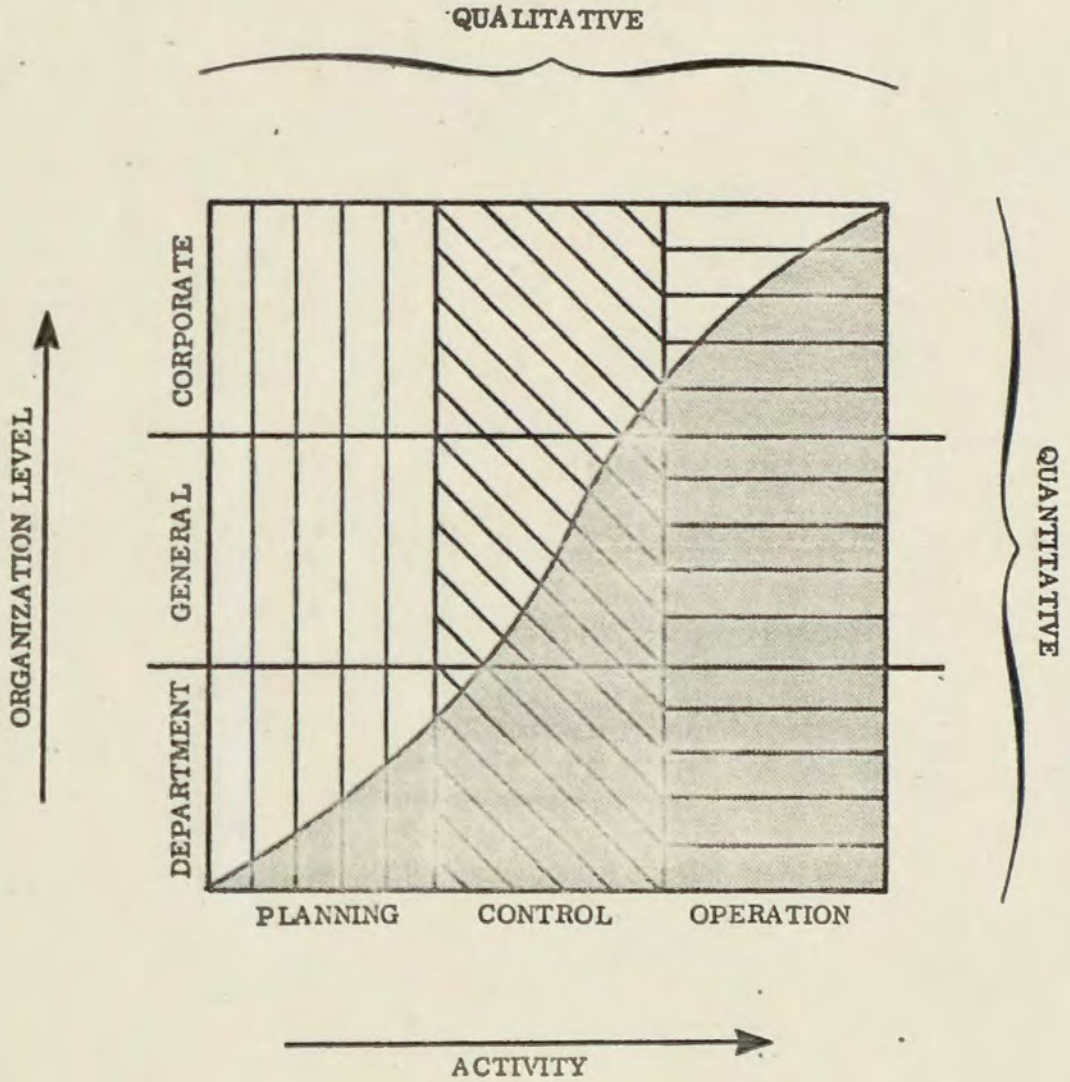


CHART 3

MANAGEMENT MATRIX - INFORMATION ORGANIZATIONAL REQUIREMENTS

one is ready to implement and to make available the model solution results. The inventory warehouse manager could apply the Economic Order Quantity (EOQ) derived from an EOQ model[7] to control stock levels at a minimum cost. Then the EOQs developed in this model are made available to a materials planning and control model through the common data base.

---

[7]See Chapter III, page 49.

Coordinating The MIS Design Effort

The OR modeling function can now be merged and coordinated with the MIS design function. The MIS Design Coordination Flow in Chart 4 illustrates the coordination between the MIS designers, the users, and the OR analysts that is necessary for formulating the specification for the design of a MIS system.

The manager's involvement and participation is required between the MIS function and the OR modeling function. That is, at each organization function, management should participate in a modeling exercise before the usual problems develop. It is not difficult to anticipate such problems developing in areas like inventory control or production scheduling.

The following steps merge the OR fundamental approach into the MIS design approach:

1. Define the MIS objectives for the particular function and user's needs and in terms of the overall organization's needs.
2. Translate the functional objectives to fit the long-range objectives of the organization.
3. Recognize and formulate the significant problem areas representing critical decisions,

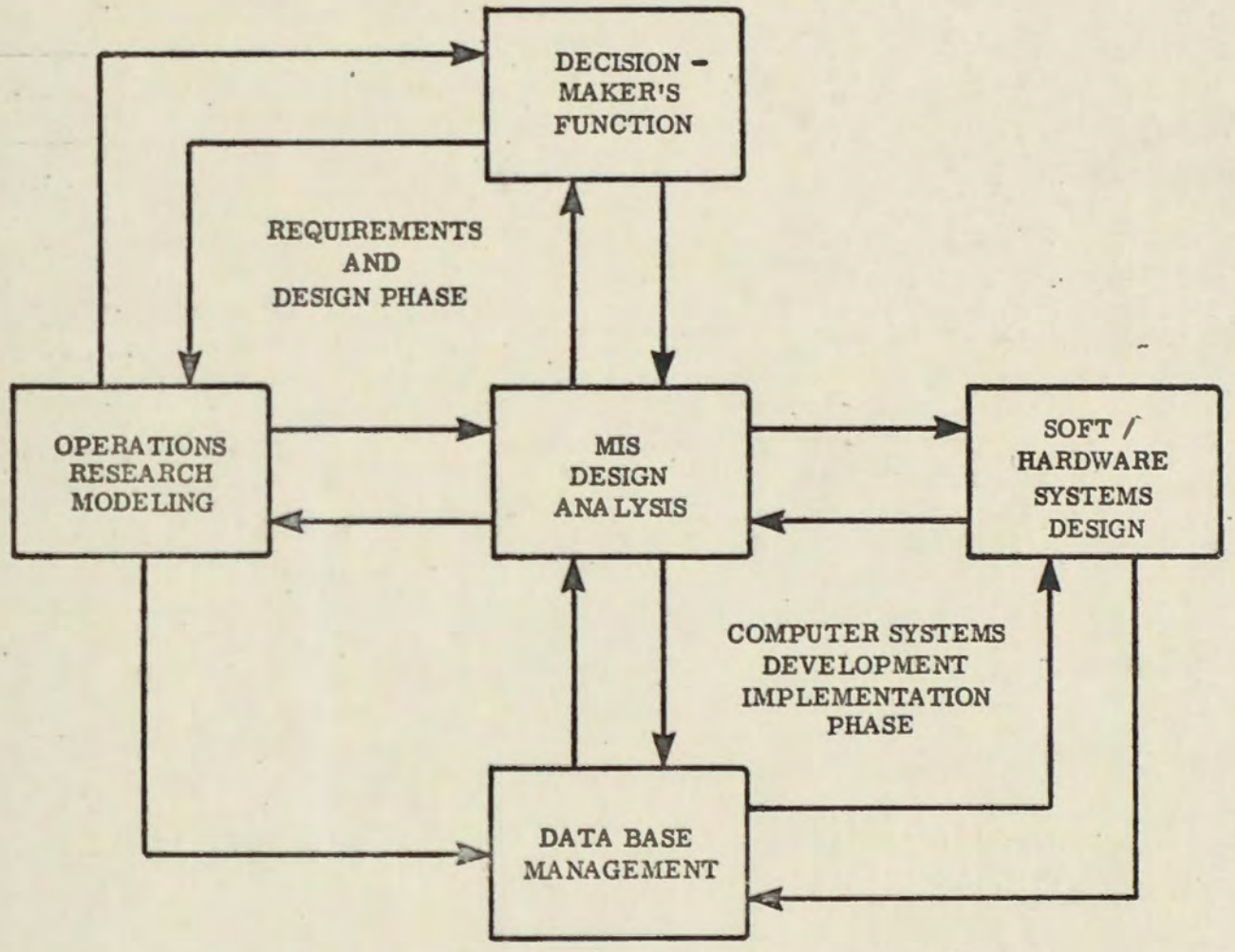


CHART 4
MIS DESIGN COORDINATION FLOW

which affect the specific functional area as well as interfacing with other functions.

4. Construct the functional model, choosing the appropriate OR technique.
5. Determine the input requirements and output information which best fulfill the objectives of the model.
6. Follow the steps for data base design using the model input and output requirements; together with the quantitative information within each sub-system's data file.
7. Review the design effort with all participating parties.
8. Recycle through the above steps, and "provide in the beginning for a feedback loop to refine the model as experience is gained in its exercise." (12)

The specific model need not be complicated, but should contain the critical factors and relationships representative of that function. Then these models can be integrated to establish the federated MIS data base.

Chart 4 shows that the MIS function also coordinates the computer systems design, development and implementation of the software/hardware and DMS systems function. This coordination of the design of these

systems is another topic beyond the scope of this paper.[8] Most current computer hardware capabilities and third generation software can adequately meet the MIS design requirements.

---

[8]See Appendix A for a DMS.

CHAPTER III

AN APPLICATION USING MODELING FOR MIS DESIGN

Manufacturing Organization Background And Assumptions

This chapter applies the concepts developed and the steps outlined in the previous chapters to describe how the OR approach and modeling techniques can be used to design an effective Management Information System. A manufacturing organization has been chosen as a point of reference, because it incorporates the various conflicting management decisions. It also points out the difficult information and coordination problems which result from the interface of many manufacturing operations.

A discrete type of manufacturing process will be assumed for this example.[9] The organization will be named the MO Company. The MO Company produces sofa and chair frames, which are made from raw wood stock. These frames

---

[9] "There are two types of manufacturing processes: (1) Process Manufacturing and (2) Discrete Manufacturing. The process manufacturing companies convert raw materials into finished products by a flow-through operation. The discrete manufacturing companies fabricate and assemble finished products from component parts or raw materials using a step-by-step operation." (13)

are shaped on lathing machines and then hand-drilled and assembled by skilled craftsmen, who are on an assembly line. The frames are sold to other companies, who in turn upholster and sell the finished chairs and sofas to furniture outlet stores.

The primary goal of the MO Company is to make a profit. However, it also has these other goals:

1. To expand new product lines.
2. To satisfy changes in customer demand.
3. To maintain and control a reasonably stable level of employment within the plant.
4. To minimize changeover and set up costs on individual production runs.

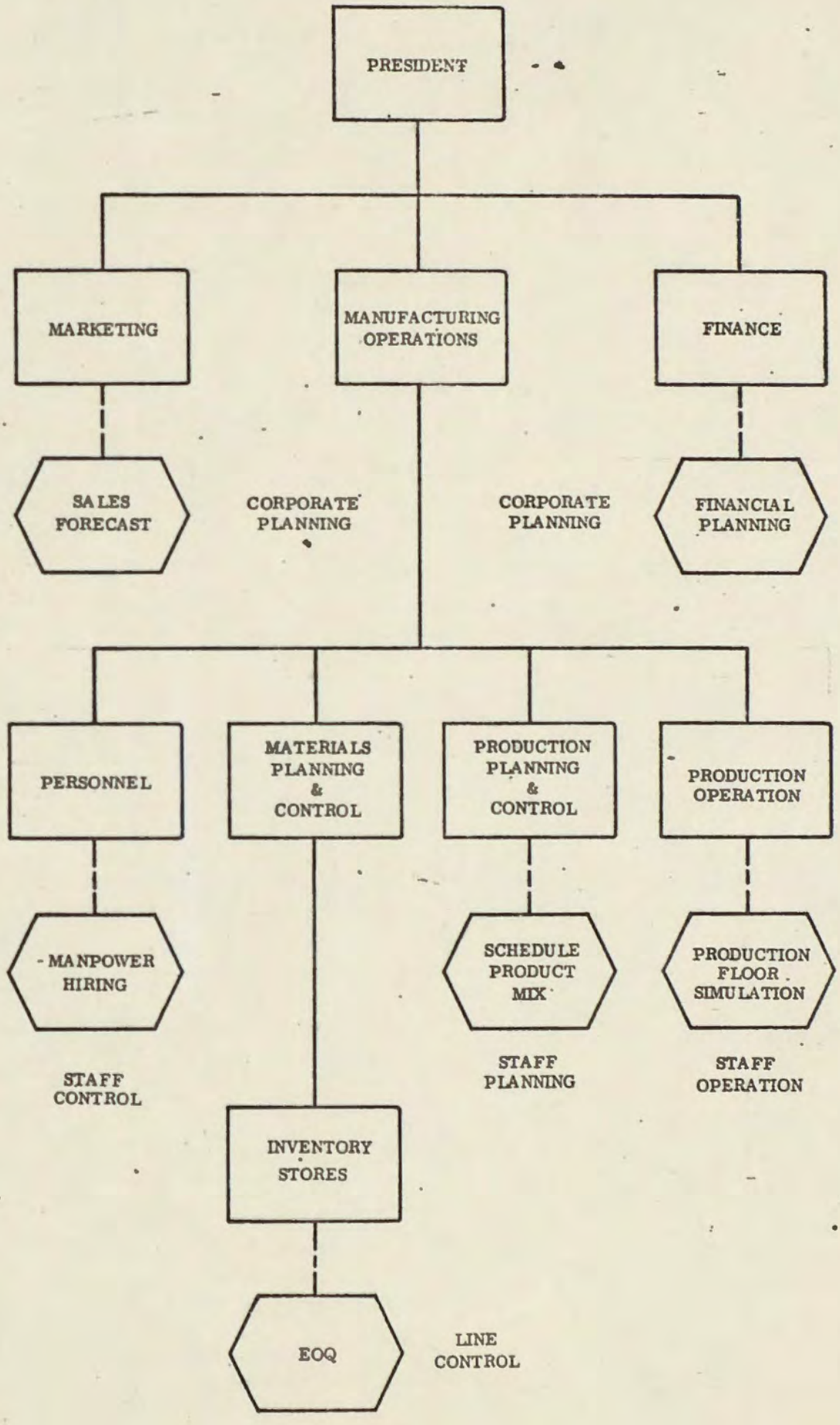
In addition to the goals, MO Company's management requires decisions and answers to the following questions:

1. What is the best tradeoff on raw stock replenishment costs with inventory carrying costs?
2. What is the most profitable product mix that maximizes production output?
3. What is the best dispatch policy for releasing work to various assembly and machine centers of the production floor to avoid costly delays?

Obviously these do not cover all the questions or the goals, but they will serve as a basis for developing MO Company's models.

The Functional Model Chart 5 shows only those areas

CHART 5
FUNCTIONAL MODEL CHART



of the MO Company's organization where modeling techniques will be applied in this application. A discussion of each model's development with suggested techniques for its solution, will follow the outline represented by Chart 5. The model information requirements, some of which interface to other models, will be developed as the building blocks of the modular design concept for MO Company's MIS system.

Sales Forecast Model

The MO Company would like to expand to new product lines and to be able to react to future changes in customer demand. The Sales Forecast Model is designed to improve the validity of Sales Forecasts and to rapidly evaluate the effect of the above goals.

The forecast model must consider the past sales history of customer orders and project this into the future. The technique of using moving averages could be applied to the customer order file. In this model, the sales order per customer for a number of periods is added and then divided by the number of periods to give a period average. The time factor is critical.

> "The longer the time period taken for the calculations of the moving average, the more stable will be the forecast and the less will be the effect of a single exceptional demand. At the same time, the more stable the forecast, i.e., the less it varies from period to period, the less responsive it will be to real change." (14)

Other factors, such as economic conditions like housing starts, can be used in forecasting. The demand for MO Company's chair and sofa frames has its seasonal fluctuations and may lag behind housing starts by six months and behind household formations (i.e., new marriages) by three months.

Another forecast model technique is exponential smoothing, which employs a weighted, moving average technique, then discounts past observations according to their age. The discounting is carried out "by using a smoothing factor in adjusting the difference between the last period's actual sales and the forecast, thus avoiding the carrying of several increments of sales history." (13) One formula of exponential smoothing that is easy to apply is the following:

> New forecast = old forecast + a factor x (difference between old forecast and actual demand in same period).[10] ...where $0 \leq$ factor ≤ 1.

Of course, no forecast model can be totally accurate in its projections. Therefore, a monitoring system must analyze the forecast errors on each product forecast and signal when the forecast is failing to respond quickly enough to changes in customer demand.

Whatever forecast model is used, it should cover the widest possible range of product groups that go through similar manufacturing operations. In this example, chair frames would be one group and sofa frames would be the other one. The model time frame should span the shortest possible planning horizon.

When the output of the forecast model is used as input to a financial planning model, it might show that

---

[10] See List of References 14.

MO Company would go out of business in a few years due to the cost of the development and introduction of a new product. An assumption would also be required regarding the new product's impact on sales of current products.

Another result might be that MO Company does not have enough manpower and/or manufacturing capacity to build all the chair and sofa frames that would be ordered. Then the Sales Forecast Model, in conjunction with a Financial Planning Model, would have to be exercised a number of times under different alternate decisions. The various sets of decisions might range from dropping marginal profit products with no plant expansion to the decision to maintain the entire line with plant expansion.

Financial Planning Model

Budget planning on the corporate level requires that the MO Company management estimate a future business plan or budget, based on the projected sales from their Sales Forecast Model. High level management wants to know the impact on their direct and indirect manpower requirements, projected costs, material requirements, cash flow, and a sample of Profit/Loss over the forecasted periods. The Financial Planning Model--Chart 6 indicates the capability for testing their alternate courses of action and for use in their tradeoff analysis. "Flexibility and timeliness, also, are of major concern in the preparation of a financial operating action plan." (15)

The model requires such information as projected sales over so many periods, profit margin rates, and cost correlations. The method is to obtain direct labor costs from total cost of sale per salable item, then calculate the difference into direct labor dollars. These direct labor dollars are then converted to hours and manpower.

The qualitative relationship for direct manpower (DIR MP) calculation in the model would be as follows:

$$\text{DIR MP} = \frac{\left\{\text{Sales} - (\text{Total Cost} \times \text{Profit Margin}) - (\text{Overhead} + \text{Material Costs})\right\}}{(\text{MP Factor}) \times (\text{Wage Rate})}$$

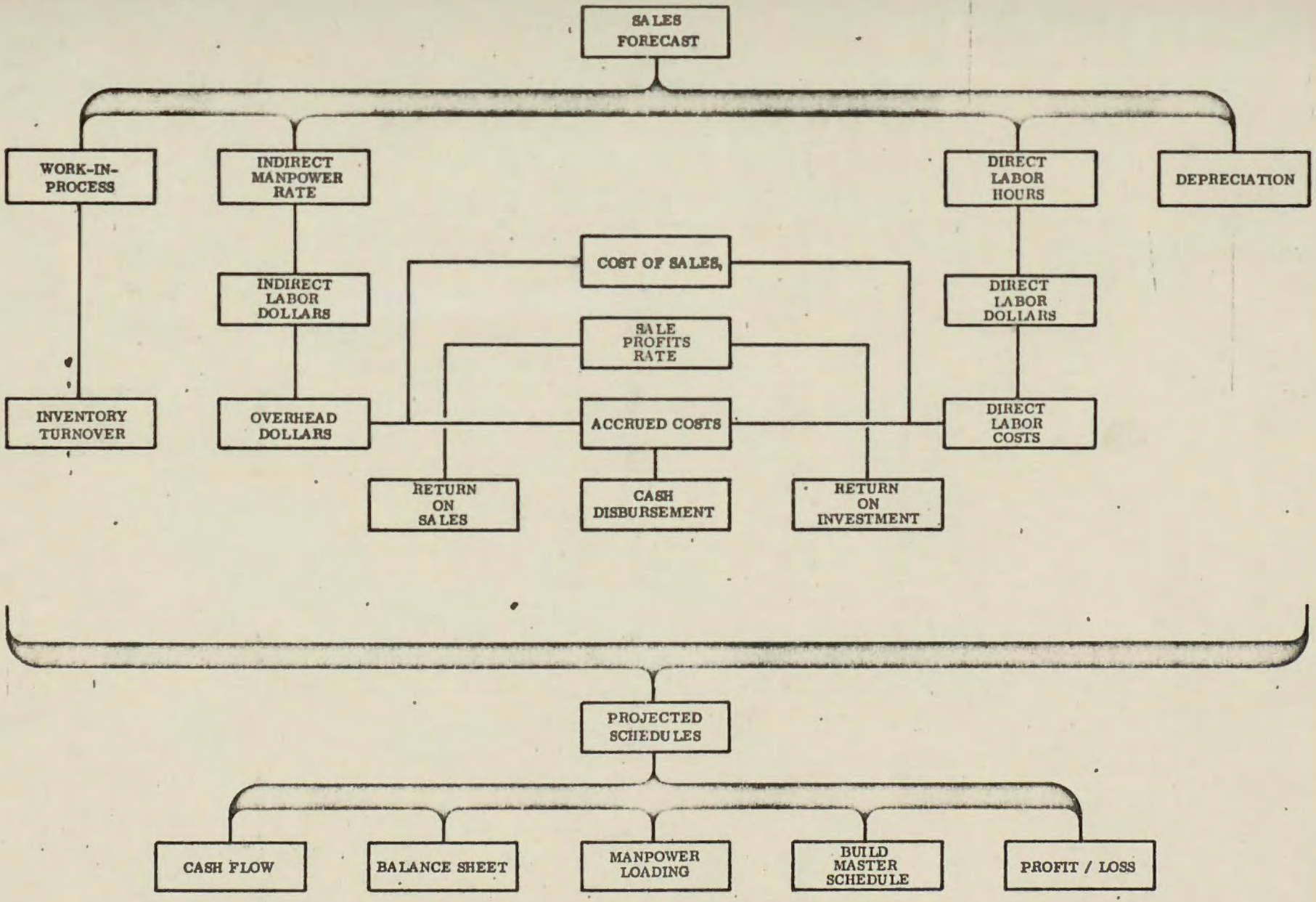


CHART 6
FINANCIAL PLANNING MODEL

With the model so structured, management can now study the effect of revisions on manpower scheduling. For example, an increase or decrease in direct manpower influences indirect manpower costs and, in turn, the cost of sales, operational costs, etc.

Also, the President of MO Company can instruct his personnel staff to construct a hiring policy to meet these projected manpower requirements, which is the objective of the next model to be discussed.

Manpower Hiring Model

Direct manpower requirements have been projected over the next five or six seasons by the exercising of the Financial Planning Model, whose input source is the Sales Forecast Model. The critical problem facing the Personnel Manager is to maintain and control a reasonably stable level of employment and to decide on a hiring policy at a minimum cost.

The manager is further constrained by the fact that the cost of training is very high, that no overtime can be authorized, and that inventories must not be built up due to year-end tax levies. This problem can be solved by using the dynamic programming[11] technique.

The following characteristics and basic features of dynamic programming were outlined in Hillier and Lieberman's text, (1967), Chapter 8. (16)

1. The problem can be divided up into stages, with a policy decision required at each stage.
2. Each stage has a number of states associated with it.

---

[11] Richard Bellman's book, Dynamic Programming, Princeton University Press, New Jersey, 1957, was the first formal exposition on this subject.

3. The effect of the policy decision at each stage is to transform the current state into a state associated with the next stage.

4. Given the current state, an optimal policy for the remaining stages is independent of the policy adopted in previous stages.

5. The solution procedure begins by finding the optimal policy for each state of the last stage.

6. A recursive relationship is available which identifies the optimal policy for each state with n stages remaining, given the optimal policy for each state with (n-1) stages remaining.

7. Using this recursive relationship, the solution procedure moves backward stage by stage--each time finding the optimal policy for each state of that stage--until it finds the optimal policy when starting at the initial stage.

The recursive relationship to be minimized for (n-1) seasons remaining has the following general form:

$$f(s,x_n) = \underset{x_n}{MIN} \left[C_{sx_n} + F^*_{n-1} \quad (x_n) \right]$$

A discussion of this relationship with respect to the manpower hiring policy problem is in order.[12] The stages to this problem are the future (n) seasons. The states (s) are described by the manpower requirements at the previous stage. The decision variables (x_n) are the number of men to be hired at each n^{th} stage from the last stated season.

---

[12] Hillier and Lieberman (1967), Chapter 8, Example 6, p. 254, solved a similar hiring policy problem. See List of References 16.

$F^{*}_{n-1}(x_n)$ is the optimal decision policy of the previous stage (or the next future season, considering that the solution procedure is moving backwards in time). The C_{sx_n} is the cost relationship, which includes the cost of carrying more men per season than are needed and the cost of hiring and laying off people.

The optimal solutions will estimate the manager's overall total cost of hiring for the projected period and will yield the best hiring decision policy, which will be no less than the required employment level.

Schedule Product Mix Model

The MO production planning and control (PP&C) management's primary function is to achieve maximum utilization of the company's production capabilities and to schedule the most profitable product mix of chair and sofa frames. Linear Programming (LP) is probably the most suitable modeling technique, since it "deals with the problem of allocating limited resources among competing activities in an optimal manner." (16)

The LP technique assumes the objective function is in linear form. This means that a small change in any decision variable causes a proportional change in the objective function. For this example, the profit per chair or sofa frame produced remains constant over the range of production. The general LP form is:

1. MAX $Z = \sum C_j \cdot X_j$ (Objective Function)
2. Subject to: $\sum A_{ij} \cdot X_j \leq B_i$ (Constraint Equations)

Where Z is the overall measure of effectiveness, i.e., profit:

C_j ...would represent the profit per i^{th} product produced.

X_j ...the decision variables representing the amount of competing products to be produced.

A_{ij} ...is the amount of the i^{th} resource (i.e., machine center or assembly line process) that each j^{th} product requires.

b_i ...the total capacity of resource i available (i.e., the available number of machine hours per week, etc.)

PP&C's problem was to determine the schedule that maximizes profit--the decision variables are thus the quantities needed to produce each of the products in a given period. Let X_1 represent the number of chair frames scheduled, X_2 the number of sofa frames, and C_1 and C_2 dollars be the respective profits. The objective function is therefore:

$$Z = C_1 X_1 + C_2 X_2$$

The problem as stated is not complete; there are restrictions, otherwise one could make an unlimited profit by producing either product without limit. Constraints on the decision variables must be set up that recognize the physical limits and restrictions on production capacity. Suppose that the production of chair and sofa frames only requires lathe machine and assemblers' time. For a given scheduling period (say, a week) we have a total of b_1 of lathing time and b_2 of assembling time. Each chair and sofa frame requires a_{11} and a_{12} hours, respectively, on the lathing machine. Also, each requires a_{21} and a_{22} hours, respectively, of assembly man-hours. The constraint equations can now be expressed as:

Lathing $\quad a_{11} \cdot X_1 + a_{12} \cdot X_2 \leqslant b_1$

Assembly $\quad a_{21} \cdot X_1 + a_{22} \cdot X_2 \leqslant b_2$

A graphic solution can be obtained from this simple example--see Chart 7.[13] However, in more complex problems the well-known Simplex Method[14] can be used.

---

[13]Redrawn from a similar graph which appeared in List of References 16.

[14]See Appendix C for a discussion on the Simplex Method.

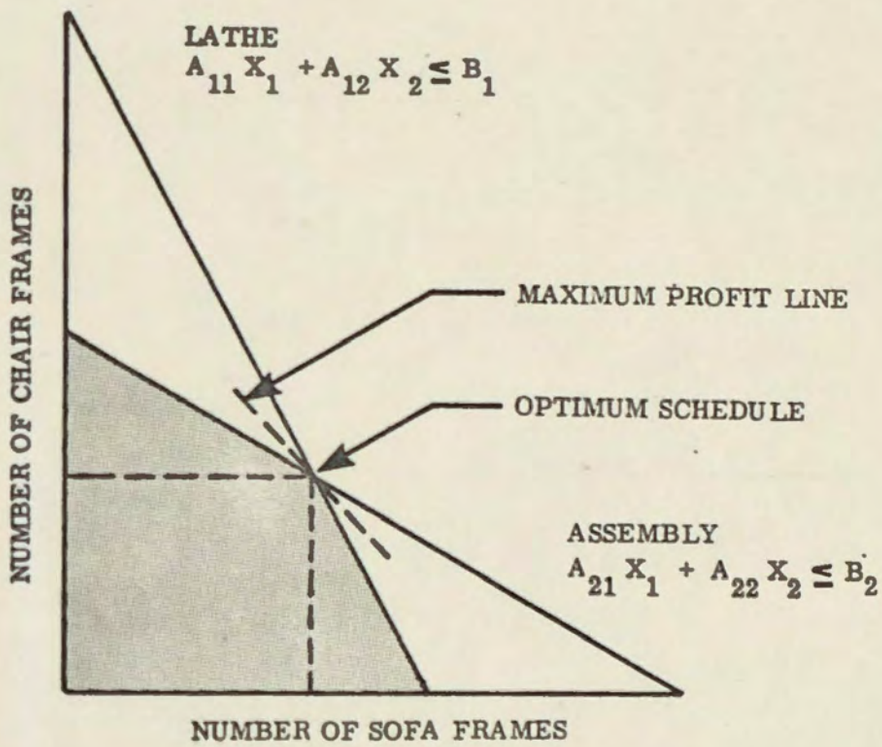


CHART 7
SCHEDULE PRODUCT MIX - MODEL
GRAPHICAL SOLUTION

Economic Order Quantity Model

The supply of raw stock in the MO Company's inventory is a central concern in the control of an uninterrupted production operation. As in any manufacturing environment, the key word at MO Company is continuous production. It is the problem of the Material Planning and Control (MP&C) management to interface with the Purchasing and Production Control group to establish policies on safety stock levels, reorder points, and economic order quantities for all raw product. These items are defined as follows:

> "Safety Stock--Additional stock that is carried to compensate for inability to accurately forecast product usage.
>
> "Reorder Point--That level of stock at which we generate a stock replenishment order. A stock replenishment order is generated when the amount of stock on hand minus the safety stock equals or is less than the projected demand during the required lead time.
>
> "Economic Order Quantity (EOQ)--An order of a lot size which balances the total inventory carrying costs per period (which increase as the lot size increases) with the total replenishment cost per period (which decreases as the lot size increases)."(13)

If raw stock usage is assumed to be level during a three-month period, and sufficient safety stock is maintained to compensate for the monthly variations in

production schedules, then a simple EOQ model can be formulated. This resolves the MO Company emphasis on production while meeting the overall goal of holding down costs. The EOQ lot size (q) becomes a function of the total costs (T). For example:[15]

$$T = \text{Periodic Carrying Cost} + \text{Periodic Reordering Cost} = q \cdot C/2 + R \cdot F/q.$$

Where C is the carrying cost per period per item of stock, R is the fixed replenishment cost, and F is the forecasted usage per period.

The above equation for T shows that the cost is a function of the lot size q and the parameters C, R, and F. T is the objective function of the EOQ model--see Chart 8.[16] This inventory model permits the use of a well-known "Maximum Principle" (18) developed in the calculus of variations.[17] The optimum EOQ becomes:

$$q = \sqrt{\frac{2 F R}{C}}$$

Probably the most serious objections in using this analytical model are: (a)"the implicit assumption that stockholding cost is directly proportional to the

---

[15]See List of References 17.

[16]This similar chart has appeared in many texts.

[17]The partial derivative of T with respect to q is set equal to zero, i.e., $\frac{\partial T}{\partial q} = 0$

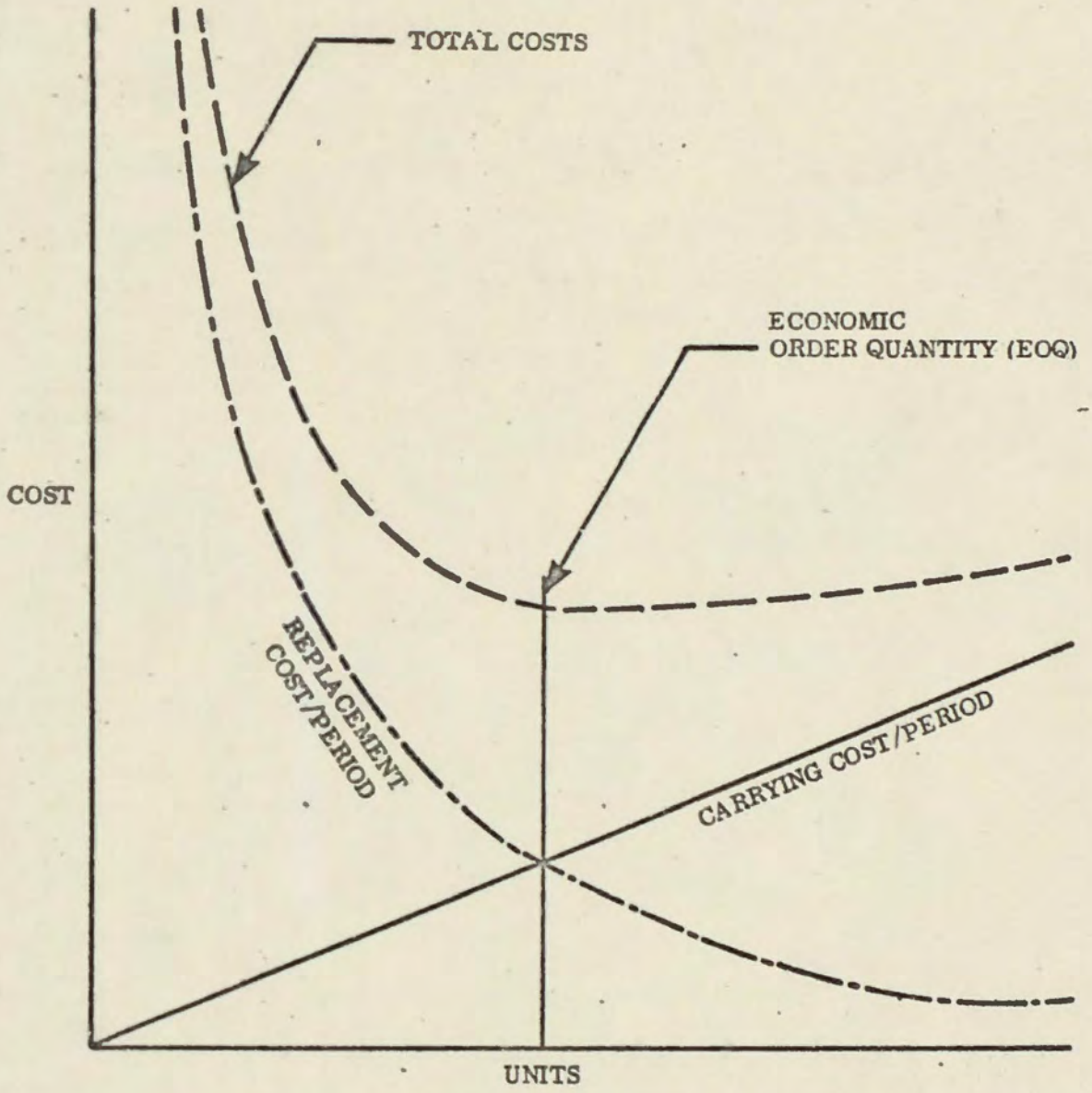


CHART 8
ECONOMIC ORDER QUANTITY

average value of the stock held, (b) in the case of items of one's own manufacture, that the batch size may be decided independently of the state of the load on the production departments," (14) and (c) it may be difficult to determine the carrying inventory C and R replenishment cost.

The carrying C cost includes interest on the capital invested in inventory, incremental storage cost, obsolescence, etc.; the annual carrying cost is therefore $q \cdot C/2$. The replenishment cost R is a fixed cost; it includes such elements as the cost of the data processing to prepare a requisition, the cost of receiving, material, labor, handling, and inspection associated with each reorder. A good MIS system can keep track of these costs per major inventory item.

The final choice of lot size on any item will be influenced by the actual cost per item as well as the vendor's volume quantity discounts. The EOQ model can still be used to achieve a better balance in the raw stock inventory control.

Production Floor Simulation

The key to successfully operating MO Company's production is to plan the assignment of work so that the plant is operating at maximum efficiency. The production floor manager's problem is two-fold: 1. minimize costly delays from machine breakdowns, and 2. study the different dispatching policies for allocating specific jobs to each of the work stations in order to prevent costly waiting lines (queues). Analytical "Queueing"[18] models cannot provide the answers when two or more unique dynamic processes are operating together. Computer simulation methods, on the other hand, when applied to these dynamic processes, can best represent the observed behavior of a production system.

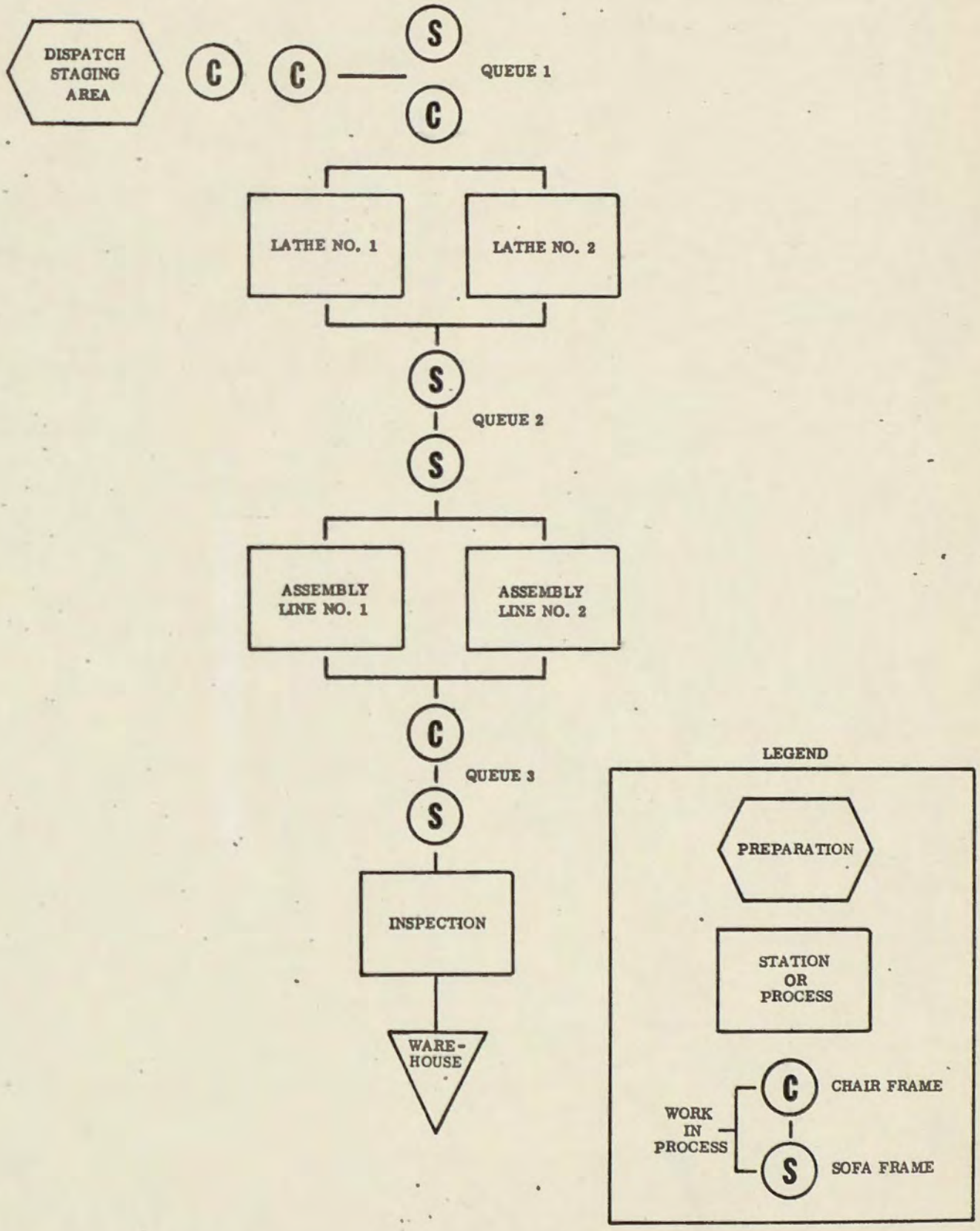
Using the Production Floor Queue Analysis--Chart 9 as a model of the overall production operation, the floor manager, with the OR analyst, can study the flow of work-in-process through both lathing machines and assembly stations. The manager could reach these decisions:

> "...changing the number of servicing stations, changing the average service time in one or more stations, splitting a single queue or amalgamating several queues, and so on. Such changes would be

---

[18]There are many fine treatments on "Queueing Theory" in the following from the List of References: 10, 11, 16, 18, and 19.

CHART 9
PRODUCTION FLOOR QUEUE ANALYSIS



> evaluated by first considering their effect on the average characteristics of the waiting line, and then translating these changes in average characteristics into changes in the chosen measure of effectiveness." (19)

Chart 9 shows three processes on the MO Company's production floor. The lathing process has two lathe machines, either one of which could break down or be out of service due to maintenance, forming a queue on the remaining machine. There are also two assembly lines, each capable of independent assembly of chair or sofa frames. Final inspection is the last process in the production operation. One hundred per cent inspection is performed on all finished chair and sofa frames.

Discrete state-change model is one method of simulating the production floor model. This entails describing:

> "...how the state (of each of the variables) changes as time moves from one instant to the next...That is, a particular variable may change only when the present state has certain characteristics. The relationships for state change therefore involve two parts:
>
> 1. "A procedure for determining whether a variable or group of variables should change.
>
> 2. "The computational procedure that makes these changes updates the variables." (20)

The Discrete Simulation Processing Logic--Chart 10 illustrates these basic procedures and processing logic, which are common to all state-change simulators.[19] In a

---

[19]Extracted from James R. Enshoff and Roger L. Sisson's book, p. 76. See List of References 20.

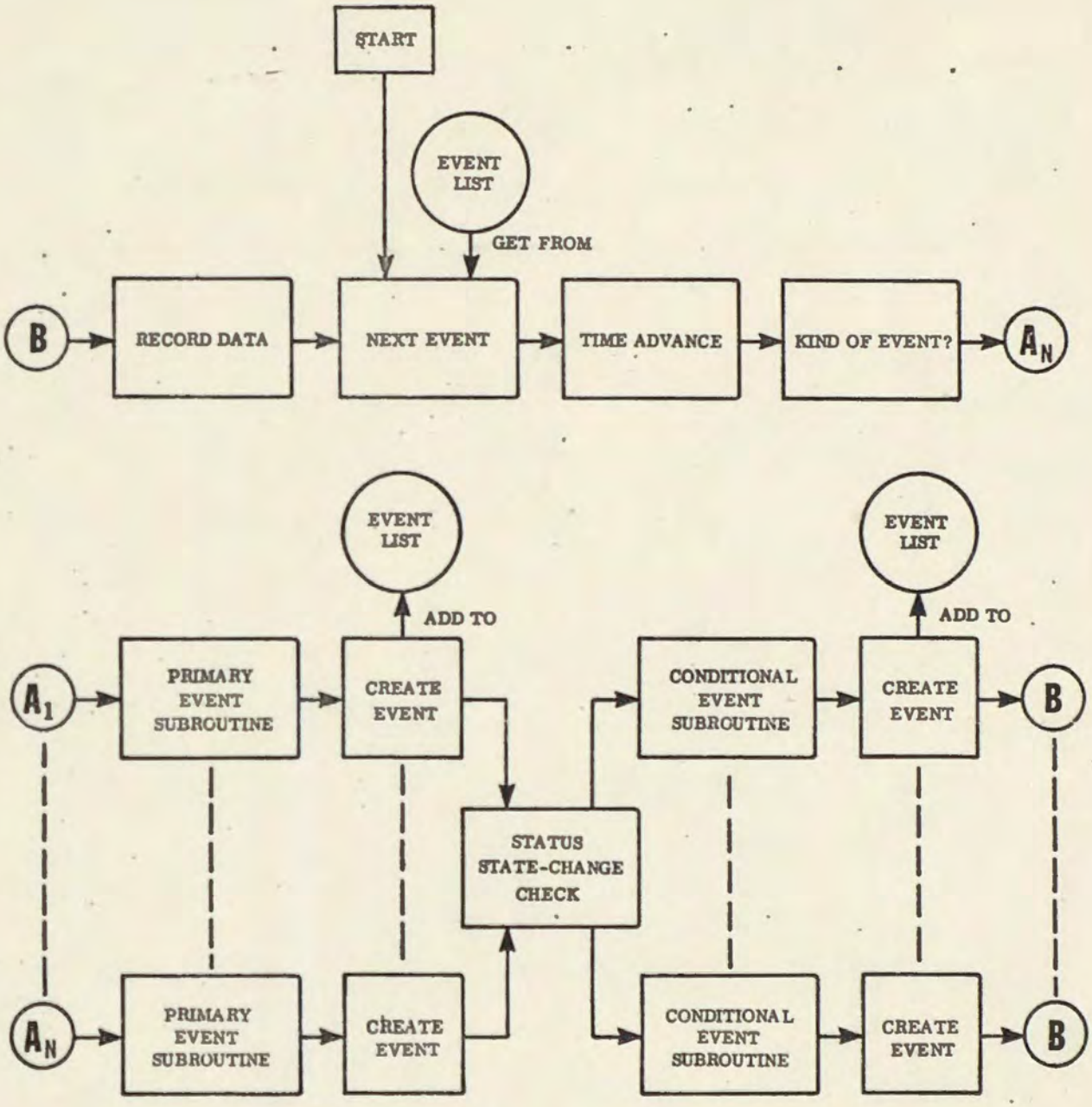


CHART 10
DISCRETE SIMULATION PROCESSING LOGIC

state-change simulation, the sequence of events occurs independent of any given time period. That is, the order of the processing logic is to: "1. find the next event, 2. update the clock, 3. update the system status, and then 4. create a future event." (20)

In this production floor model some of the state variables are:

1. Whether the lathe machine was operative or down.
2. The time it takes to service a lathe machine.
3. Whether a machine is processing material or was operative but idle.
4. Assembly line processing rates (through-put).

The following information is essential for use during the simulation:

1. Describing the jobs and their arrival rates.
2. Dispatching and routing rules on each job.
3. Starting values for all the state variables.
4. Obtaining data on lathe machine utilization and failures.
5. Tagging each job that is waiting in a queue.

This information is stored in tables called the "Job Table, Routing Table, Event Table, Machine Table and Queues." (20) The accumulation of information such as total through-put, total machine usage and other statistics is placed in the Output Table.

There are several different kinds of computer simulation languages which are available for a state-change simulation. These include:

> "GPSS[20] looks at a system in terms of items--called transactions which interact with the system resources as they pass through...(in this case, the release of work to the lathe machines) GPSS uses a rigid data structure of blocks--commands to the transactions to perform in a certain manner as they pass through the system and are analyzed." (21)

Simscript[21] is better for discrete-event simulations because each event is automatically generated and the model's internal time is advanced in occurrence with this event.

FORTRAN, a more general procedural language, is more flexible than GPSS and Simscript, which are rigidly structured and require longer computer run-times and core storage, but less programming expertise on the part of the modeler. However, FORTRAN does require the creation of such entities as the event-clocks and random number generator, which must be programmed as separate subroutines.

---

[20] General Purpose Simulation System.

[21] Developed by RAND Corporation for the Air Force in 1963. Several versions since 1963 now exist; the latest is Simscript II Plus.

Models--The Building Blocks

The testing and implementation of these formulated models are not the concern of the MIS design plan. The models serve as the building blocks of the iterative and evolutionary process for further development of MO Company's MIS system. Also, the MO management acquires a better understanding of their decision-making processes.

The specific model of each function reveals the quantitative and qualitative relationships representative of that function. Each formulated model contributes to the requirements for a federation of MIS data base files.

Chart 11--Overview of Model--Data Base Interface depicts how the models developed in this chapter interface with MO Company's data base files. The Sales Forecast Model will use history information from the Customer Order file and amounts of finished chair and sofa frames on hand from the Finished Inventory File. This model will then write the build schedule to the Customer Order file. This schedule will be used as input to the Financial Planning Model, which also retrieves information from the accounting (cost data), Finished Inventory (price data), and Labor-Machine Resource (labor-rate data) files. Thus,

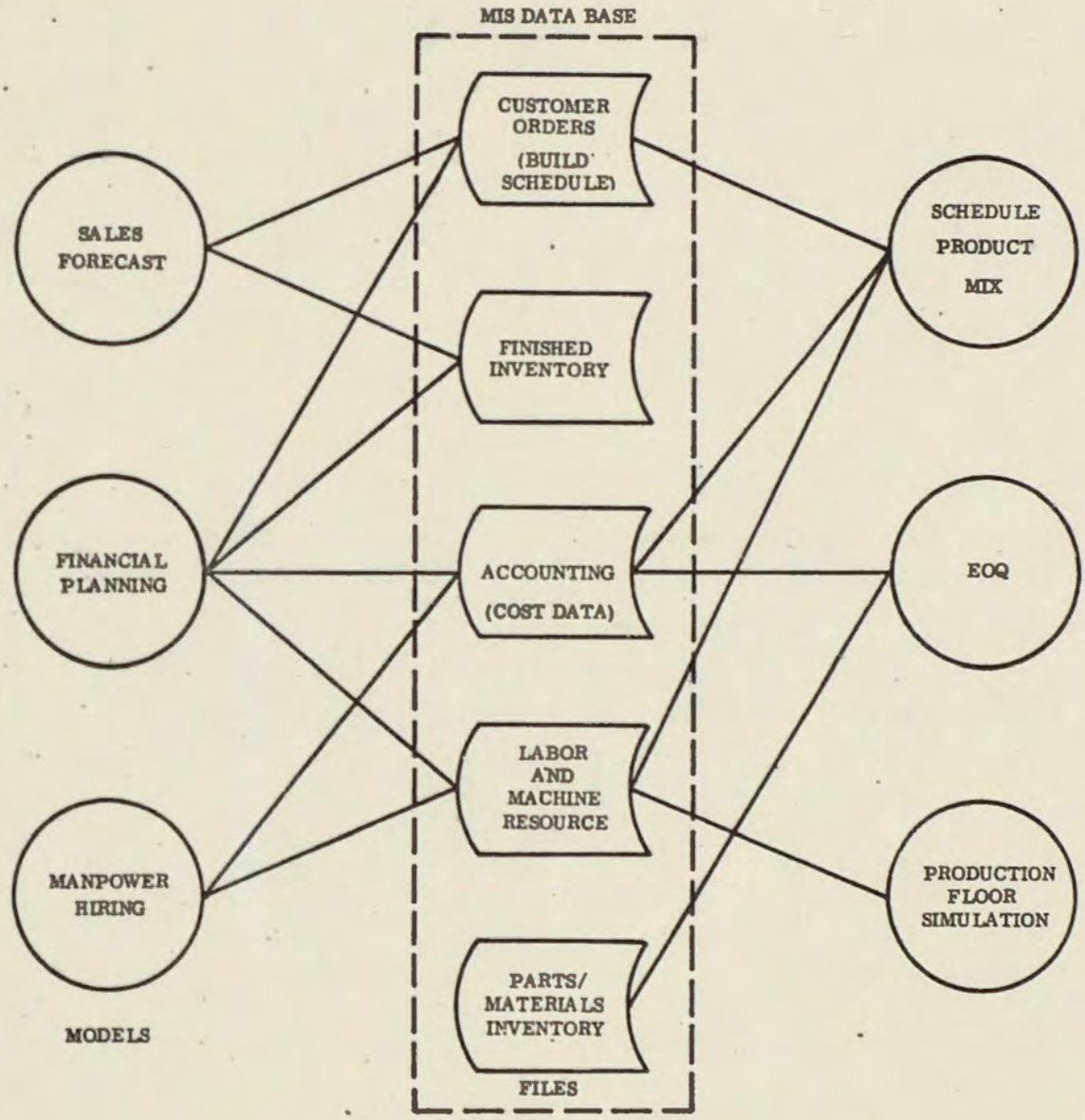


CHART 11
OVERVIEW OF MODEL - DATA BASE INTERFACE

the complexity of an all-encompassing MO Company model can be reduced to a series of interrelated models interfaced through the MIS data base.

CHAPTER IV

CONCLUSIONS

An effective and responsive Management Information System becomes a reality when the MIS, through operations research modeling, fulfills the decision-making needs of management. This comprehensive approach to MIS design takes into account the needs of management at various levels involved in a wide scope of functions.

Since the functions of an organization are complex and interrelating, the MIS which serves these functions must incorporate the information requirements of all functions. By supplying an OR model for each function, a federation of MIS sub-systems is formed, unified by the data base files containing quantitative and qualitative information. It is this model exercise that highlights the key variables in the cause-and-effect relationships to other functions of an organization.

Thus, the application of this OR approach to MIS design will produce a viable Management Information System which responds and presents timely and meaningful information for all levels of management within an organization.

LIST OF REFERENCES

1. Charles H. Kriebel, "The Future MIS", Business Automation, June, 1972, p. 66.

2. Roger Field, "MIS Comes Percolating Up The Organization", Computer Decisions, March, 1971, p. 14.

3. Franz, Edelman, Ph.D., "The Manager Looks At MIS", Computer Decisions, August, 1971, p. 14.

4. R. L. Ashenhurst, "Report Of The ACM Curriculum Committee On Computer Education For Management", Communications Of The ACM, May, 1972, p. 336.

5. M. H. Schwartz, "MIS Planning", Datamation, September, 1970, p. 28.

6. D. L. Fisher, "Management Controlled Information Systems," Datamation, June, 1969, p. 53.

7. Robert V. Head, "The Elusive MIS", Datamation, September, 1970, p. 22.

8. James P. Fry, "Managing Data Is The Key To MIS", Computer Decisions, January, 1971, p. 6.

9. Robert Farrell, "Choosing Among Models", Paper presented at seminar, Topics in Military Operations Research at the University of Michigan, July 22, 1968, Chapter V, p.24.

10. C. West Churchman, Russell L. Ackoff, and E. Leonard Arnoff, Introductions To Operations Research, (New York: John Wiley & Sons, Inc., 1957), p. 212.

11. Arnold Kaufman, Methods And Models Of Operations Research, Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1963), p. 21.

12. Myron Tribus, "Management's Risk Reducer", Business Automation, April, 1971, p. 30.

13. RCA Marketing Publications No. FA-032-0-00, A Guide To Manufacturing Information Control System, (Cherryhill, New Jersey: RCA Marketing Publications, 1971), p. 21.

14. John Birkle, and Ronald B. Yearsley, Computer Applications In Management, (New York: Brandon/Systems Press, 1970), p. 61.

15. Michael R. Tyran, "A Computerized Decision-Simulator Model", Management Accounting, March, 1971, p. 28.

16. F. S. Hillier and G. J. Lieberman, Introduction To Operations Research, (San Francisco, California: Holden-Day, Inc., 1967), p. 220.

17. James C. Emery, "Decisions Models", Datamation, September, 1970, p. 32.

18. Ronald L. Gue and Michael E. Thomas, Mathematical Methods In Operations Research, (New York: Macmillan Company, 1968), Chapter 6.

19. Maurice Sasieni, Arthur Yaspan and Lawrence Friedman, Operations Research Methods and Problems, (New York: John Wiley & Sons, Inc., 1966), p. 320.

20. James R. Enshoff, and Roger L. Sisson, Design and Use of Computer Simulation Models, (New York: Macmillan Company, 1970), p. 160.

21. Leon Gainen, "Complex Business Problems? Try Simscript, A Powerful Simulation Language.", Computer Decisions, April, 1970, p. 21.

22. C. Kerpelman, ed., CODASYL Systems Committee. "Introduction To Feature Analysis of Generalized Data Base Management Systems", Communications Of ACM, May, 1971, p. 308.

APPENDIX A

FEATURES OF GENERALIZED DATA BASE SYSTEMS

The current technical report of the Systems Committee[22] divides the features of generalized data base management systems into ten major topics. A summary of these is presented here.

General Summary

The general summary identifies a set of major features which convey an idea of the class of a system. Its inclusion is chiefly to provide identification, background, and reference material for each system included in the report.

Data Structure

Data structure is the view of the data as seen by the user of the system and excluding any details of storage techniques used, which are covered separately. An understanding of the data structure of either kind of data base system is essential to a good understanding of its capabilities. As indicated, most systems have provided a data structure capability different from that of COBOL, although the differences are on various levels.

Data Definition

This major feature is tied in closely with the previous one, the difference being that this discusses the language and/or tabular formats used to define a scheme representable within the system's capability to handle data structures. The definition of each level of data in the data structure is discussed, together with the entering of the data definition and the important concept of binding.

---

[22] These paragraphs were extracted and edited from the Codasyl Systems Committee report, "Introduction Feature Analysis of Generalized Data Base Management Systems", (22), which appeared in the Communications of the ACM, May, 1971, p. 316-318.

Interrogation

Interrogating a data base is a process of selecting and extracting some part of the whole data base for display, usually in a hardcopy printed form. One section of the interrogation function defines how the part is selected. The second part covers how operations such as computation, sorting, and formatting may be performed on the selected part. The concept of interrogation is an intrinsic self-contained capability. The implication is that the user is able to formulate a query in the language of the system without detailing the sequence of steps used to access the data base and extract the information.

Update

Updating a data base is a process of changing the value content of some part of the data base. It excludes restructuring of the data which would cause a modification to the stored data definition. Update is a process somewhat analogous to interrogation in that some part of the data base must first be selected. In most self-contained systems, the selection facilities are modeled on those used in the interrogation function. However, once the part is selected, it is changed in some defined way rather than displayed in a report.

Creation

An important preliminary to the creation function is that of data definition. It is necessary to provide a set of records to form the initial instance of a file. Other functions are data validation, security specification and storage structure control. Data base creation is considered to be one of the important functions for the data base administrator. File creation may imply a built-in processing algorithm as for interrogation and update, or it may have to be programmed in a conventional sense.

Programmer Functions

Programmer functions are defined as host language capabilities. They are functions upon which a programming user may call when writing a program in a host language. The most important programmer function statements are those which permit him to initiate data transfers between the stored data base and high speed memory. Other statements may be provided to allow him to perform file control functions such as open, close, and hold.

Data Administrator Functions

The data administrator is an individual responsible for a data base. His role is identified to some extent in both host language and self-contained systems. The important functions of data definition and file creation are each covered separately, but there are other functions which are ascribed to the data administrator. Such functions include monitoring system operation, preserving system integrity and security, and providing for restructuring the data base to accommodate new record types or new items.

Storage Structure

Each level of the data structure has a stored representation which is referred to as the storage structure. The file level storage structure defines how entries are stored in physical blocks to form the stored representation of the file. This level is often dictated by the input/output control system, which in third-generation operating systems has been given the name of data management system. File level storage structures include such techniques as indexed sequential and other ways of storing a file, and data about it, to facilitate access to its contents.

Operational Considerations

All systems which have been implemented have one or more operational environments in which they function. The environment consists of a hardware configuration, and a software environment usually provided by the operating system. This discussion is directly relevant to the capabilities of the systems themselves only to the extent that it explores the interface with other software components.

APPENDIX B

DATA MANAGEMENT SYSTEM (DMS)

Preface:

The following pages present the fundamental overview of ideas involved in development of RCA Computer Systems Division's (Palm Beach) data management and data communication techniques. It is intended to be an introduction to these techniques, not an implementation guide.[23]

I. System Concepts

The Palm Beach Data Management System is a transaction oriented system. By transaction-oriented, we mean information is supplied or action is taken upon the submission of a transaction by a user from a remote terminal. Currently, this system supports terminal (update and access) applications "on-line" (utilizing a unique overlay scheme) together with concurrent batch processing, utilizing the centralized multiple file Data Base.

II. Basic Design Philosophy

In the Palm Beach Data Management System, there are five levels of responsibility and control. They are:

A. The User Level--The user may request an add, change, or delete of any data item or record. The user always works through a Record Supervisor and may function through a COBOL batch program or a communications terminal on-line.

B. Record Supervisor Level--The Record Supervisor controls the integrity of the record. The entire

---

[23] This overview was condensed from the original design specification, The Palm Beach Data Management System, 1970, submitted by: Ms. A. E. Brenden, Mr. W. D. Harrison, and Mr. R. J. Kump under the supervision of Mr. D. C. Adee, Manager MIS Software Applications.

record is never passed to the user, only specific data items (buckets) are passed. The Record Supervisor is the controlling link between the user, the Variable Bucket Controller, and the File Supervisor.

C. Variable Bucket Control Level--The Variable Bucket Controller (VBC) is a module within each Record Supervisor. VBC insures that all data items (buckets) are kept in sequence and no invalid items enter into the record.

D. Disc File Supervisor--The Disc File Supervisor currently controls up to ten on-line files (soon to be expanded to twenty). The Disc File Supervisor responds to requests from the Record Supervisor.

E. Communications Control--The Communication Structure was designed to allow many different users to work within its framework without the necessity of constantly reassembling and relinking the communications program.

Refer to Communications System Design Flow Chart 12.

III. Detailed System Components

A. The User Level--In order to utilize the communications environment, the user must construct an overlay which will be loaded into memory when requested from a remote terminal.

Because of its nature as a self-floating module, it must be written in assembly language and not exceed 2,000 bytes in length. For more detail see Transaction Overlay Section.

B. Record Supervisor--General--The function of the Record Supervisor is to provide a link between the Applications Program (user), Disc Supervisor (DISC03) and the Variable Bucket Control Module.

The Record Supervisor is modular in design and is bound within the Applications Program during the linkage editor phase. The Applications Program works with keys and buckets, the Record Supervisor operates upon complete records, and the Disc Supervisor works with cylinders and tracks.

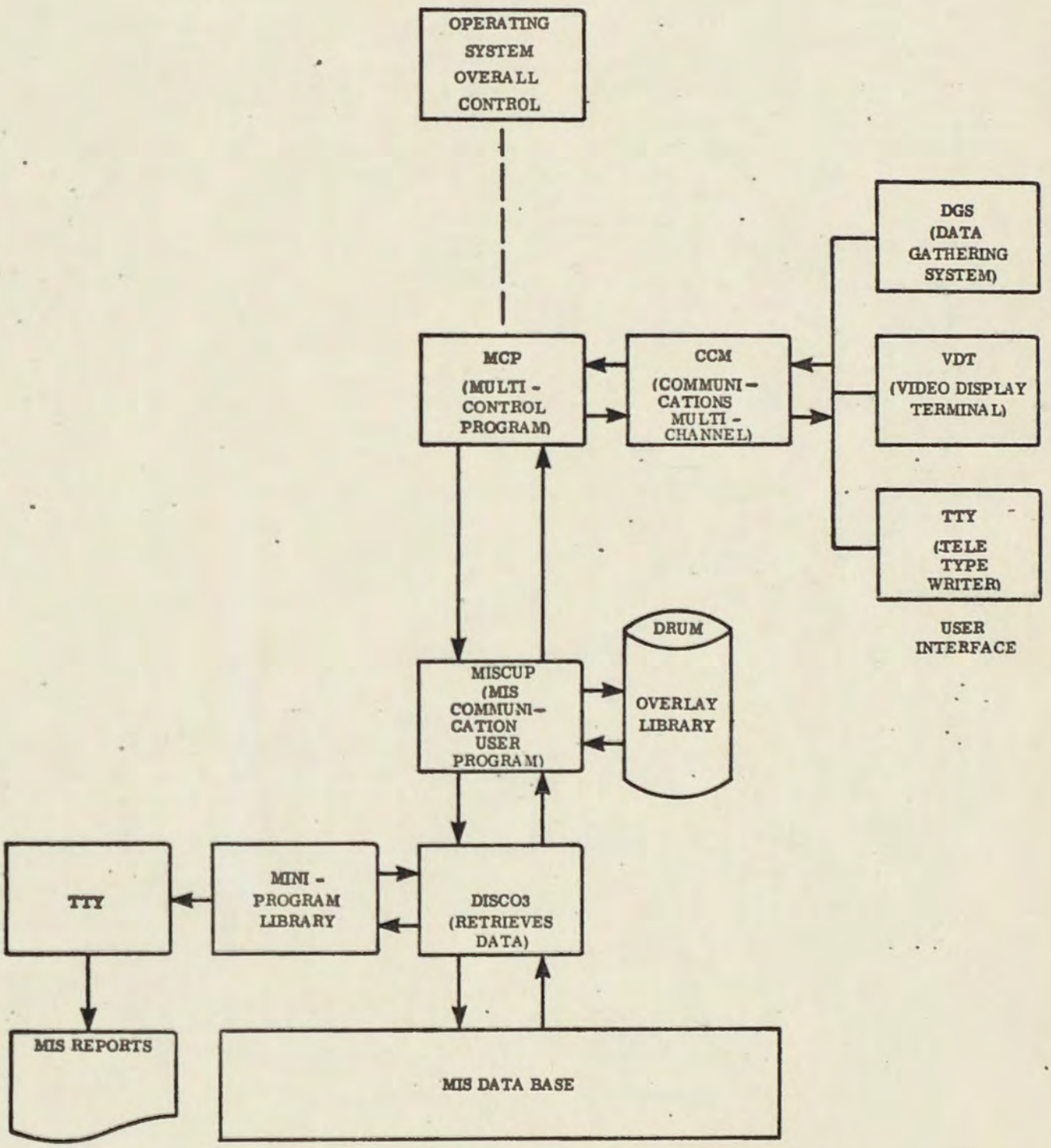


CHART 12
COMMUNICATION SYSTEM DESIGN
(PALM BEACH RCA)

The Record Supervisor communicates with the Disc Supervisor by using the common area of the Executive. The Record Supervisor translates requests from the Applications Program into binary command codes. These codes are placed into the common area along with the address of the 10,000 byte storage area. The Disc Supervisor uses this area to accomplish retrieval and updating functions.

There are four Record Supervisors: Sequential, Random, Update, and Communications:

1. Sequential Record Supervisor--links into the sequential retrieval section of the Disc Supervisor. The following calls are used by the calling program to communicate with the Sequential Supervisor:

   Open File Sequential--This is the first call.

   Get Key Sequential--The next key is made available to the user.

   Get Bucket Sequential--This call moves a requested bucket, if available, to the user.

2. Random Record Supervisor--links into the random retrieval section of the Disc Supervisor. The following calls are used to retrieve desired keys and buckets:

   Open Random--This call is the first call to the Random Supervisor and opens the requested Data Base File.

   Get Bucket Random--This call is used to retrieve the key and desired bucket with one pass.

3. Update Record Supervisor--links into the update section of the Disc Supervisor. It is used whenever it is necessary to add, change, or delete data. The following calls are used for updating:

   Open Update--This call opens the requested file.

   Get Bucket Update--This call is used prior to and for each different key to be updated.

   Add Key Update--This call is used to add a new key to the file.

Put Bucket--This call is used to change or add buckets to an existing key.

Delete Bucket--This call is used whenever a bucket is to be deleted.

Delete Key--This call is used to delete an entire record.

Execute Update--This call is used to perform the actual updating of the data base file.

4. Communications Record Supervisor--The Communications Record Supervisor is explained in section on Communications.

C. Variable Bucket Control Module (VBC)--The Variable Bucket Control Module (VBC) was implemented in order to accomplish flexibility. Using the VBC concept, every record is composed of variable length fields. A given field may contain several related but unique data items. Each field is known as a bucket. A bucket may be expanded or decreased in size at any time.

The minimum size of a bucket is five bytes, the maximum size is 44 bytes. These figures are a tradeoff between speed and memory usage. Bucket numbers range from 00 through 99. Buckets are always kept in sequence by the various VBC logic. Bucket number need not be contiguous.

See Sample VBC File of Buckets--Table 1.

The VBC logic performs the following services:

...Passes any bucket by number to the applications programmer.

...Deletes any bucket by number and compresses the record.

...Adds any bucket by number and expands the record.

...Changes the size of any bucket, if requested, and expands or contracts the record.

...Eliminates spaces from the right-hand end of any bucket and determines the new bucket length.

DATA BASE FILE NO. 01 **VBC PART INFORMATION FILE** PAGE 1

---- RETRIEVAL KEY ----

AS OF DATE 12/29/70 *** PART NUMBER ***

DATA NAME	UPDATE	RESPONSIBILITY	BUK	ELEM	LEN	DATA
BUY-MAKE-IDENTIFIER	PIFU01	SYSTEM	01	01	01	A-N
REV	PIFU01	DATA CONTROL	01	02	02	N
DESCRIPTION	PIFU01	DATA CONTROL	01	03	12	A-N
MODEL	PIFU01	DATA CONTROL	01	04	13	A-N
FAMILY	PIFU01	DATA CONTROL	02	01	01	A-N
SOURCE-CODE	PIFU01	DATA CONTROL	02	02	01	A
PLANT	PIFU01	DATA CONTROL	02	03	01	A-N
PLANNER	PIFU01	DATA CONTROL	02	04	03	A-N
ISSUE-UNIT-MEASURE	PIFU01	DATA CONTROL	02	05	02	A-N
LAST-TXN-DATE	PIFMAT	STORES	02	06	03	P-N
NPA-MATERIAL	PIFU01	DATA CONTROL	02	07	05	P-N
RESERVED			02	08	01	
INVENTORY-ACCOUNT	PIFMAT	STORES	02	09	05	P-N
ABC-CODE	PIFU01	DATA CONTROL	02	10	01	A-N
ISSUE-AS-REQ.	PIFU01	DATA CONTROL	02	11	01	A-N
COMMODITY-CODE	PIFU01	DATA CONTROL	02	12	15	N
EOQ-QUANITY	PIFU01	DATA CONTROL	10	01	05	P-N
PROC-LEAD	PIFU01	DATA CONTROL	10	02	02	P-N
MIN-QTY	PIFU01	DATA CONTROL	10	03	05	P-N
MATERIAL-HANDLING	PIFPMS	COST ESTIMATING	11	01	05	P-N
NPA-ALLOWANCE	PIFPMS	COST ESTIMATING	11	02	05	P-N
PMS-FROZEN	PIFPMS	COST ESTIMATING	11	03	05	P-N
AVERAGE-USAGE	PIFBYF	PURCHASING	11	04	05	P-N
RESERVED			11	05	02	
PURCHASING-BUYER	PIFBYF	PURCHASING	11	06	02	A-N
PURCHASING-FOLLOW-UP-CD	PIFBYF	PURCHASING	11	07	01	A-N
PMS-UNIT-MEAS	PIFPMS	COST ESTIMATING	11	08	02	A-N
STANDARD-QTY	PIFPMS	COST ESTIMATING	11	09	03	P-N
STANDARD-COST-LAST-TNX	PIFPMS	COST ESTIMATING	11	10	03	P-N
EST-CODE	PIFPMS	COST ESTIMATING	11	11	01	A-N
PMS-CODE	PIFPMS	COST ESTIMATING	11	12	01	A-N
MIN-MAX			11	13	01	A-N
BATCH-BUILD	PIFU01	DATA CONTROL	20	01	05	P-N
ASSY-LEAD	PIFU01	DATA CONTROL	20	02	02	P-N
ACCUM-LEAD	PIFU01	DATA CONTROL	20	03	05	P-N
WORK-CENTER	PIFU01	DATA CONTROL	20	04	04	A-N
TOTAL-PACK-MATL	PIFMA	COST ESTIMATING	21	01	05	P-N
TOTAL-MATL-COST	PIFMA	COST ESTIMATING	21	02	05	P-N
FULL-MA-VALUE	PIFMA	COST ESTIMATING	21	03	05	P-N
MISC-MATL-COST	PIFMA	COST ESTIMATING	21	04	05	P-N
OVERHEAD-COST	PIFMA	COST ESTIMATING	21	05	05	P-N
STD-LABOR-COST	PIFMA	COST ESTIMATING	21	06	05	P-N
PLUG-IN-LABOR-COST	PIFMA	COST ESTIMATING	21	07	05	P-N
STD-COST-TNX-DATE	PIFMA	COST ESTIMATING	21	08	03	P-N
UPDATE-CODE	PIFMA	COST ESTIMATING	21	09	01	A-N
TOOLING-COST	PIFMA	COST ESTIMATING	22	01	01	P-N
FACTORY-TEST-AUTOMATION	PIFMA	COST ESTIMATING	22	02	02	P-N
NEW-PRODUCT-LINE	PIFMA	COST ESTIMATING	22	03	03	P-N
PLUG-IN-ALLOWANCE	PIFMA	COST ESTIMATING	22	04	04	P-N
DRAWING-ALLOWANCE	PIFMA	COST ESTIMATING	22	05	05	P-N
BASE-PACKING-MATERIAL	PIFMA	COST ESTIMATING	22	06	06	P-N

TABLE 1--SAMPLE VBC FILE OF BUCKETS

D. Disc File Supervisor (DISC03)--The Disc File Supervisor controls all input/output operations of the Data Base. DISC03 can service up to ten different files which can be "Open" simultaneously. DISC03 is initiated along with communications during system load and resides as an active program of a multi-processing environment.

DISC03 is composed of four modules which employ common submodules to handle the physical reads and and writes to all direct access devices--they are:

1. CONTROL--This section of DISC03 scans the common areas searching for valid command codes and branches to the applicable routine. When command codes are non-existent, control is given to the next program in a lower priority. When no other program is running, control is given to the highest priority (MCP).

2. SEQM (sequential multiple file access)--This module is used for sequential accessing. The address of the user's reentrant area (10K) is passed through the common area. The reentrant area is built up to contain the Basic Index Records (beginning pointers), main track and overflow read-in areas, and other pertinent information used for file management.

3. RANDOM (random multiple file access)--The Random module is always used to randomly access a particular key. This module utilizes the reentrant area similar to the sequential module.

4. UPDATM (update multiple file)--The UPDATM module is used to add, change, or delete keys. In order to utilize the update functions effectively, the user program must have the current status of a key before action is taken. RANDOM is used in conjunction with and precedes the UPDATM module.

E. Communications Control--Communications Structure--In order to take the greatest advantage of a Communications/Data Base System, many different types of data and various applications must be taken into consideration.

The interacting communications programs perform the actual functions, thereby eliminating and allowing the applications program to solve the problems redundancy. Communications Control consists of two main programs: MIS Communications Program (MISCP) and MIS Communications User Program (MISCUP).

MISCUP (Palm Beach Software) performs four major functions:

1. Interfaces with MISCP to receive and transmit messages.

2. Loads the overlay into its buffer area and provides it with access to the information necessary to process the data.

3. Performs auxiliary I/O for the overlay user such as Statistics Retrieval and Disc Logging.

4. Interfaces with DISC03 via the common area to allow the overlay to access and update the various Data Base files.

DISC03 performs the I/O Control of the Data Base files using information supplied by the MISCUP program.

IV. Data Base Initiation--File and Record Control Programs

A. Tape Build Module--All files are initially prepared using the Tape Build Module which is bound into a COBOL program and produces a tape which is acceptable to the Data Base Load program. The applications programmer passes "KEYS" and "BUCKETS" to this module to build his loadable file.

B. Data Base Multiple File Control--The five elements of Multiple File Control are:

1. File Mapping--All disc space available to the Data Base must be carefully managed. The Data Base should be viewed in terms of total cylinders available rather than disc units. Managing in terms of cylinders as opposed to units results in more precise control of system resources.

2. Drum Mapping--In the Palm Beach Data Management System, the drum unit is mapped in detail. The drum unit has two major functions. They are:

   a. Store all Data Base indices.
   b. Store all communication overlays.

3. Program INDEXM--This program is used to establish all basic file indices for the Data Base. It is fundamental in controlling the Data Base resources.

4. Program LODM--This program is used to load all Data Base files.

5. Program DUMPM--DUMPM is the program used to dump any one of the files on the Data Base to tape.

C. MFO Control--This subroutine will handle all functions for the Multiple File portion of the Data Base. The various functions are designated by a one byte command code in byte 10 of the record. The functions provided are given below:

	COMMAND
Access Functions	(OPEN FILE (RANDOM)
	(GET BUCKET & KEY (RANDOM)
Update Functions	(PUT BUCKET
	(DELETE BUCKET
	(WRITE RECORD
	(DELETE KEY
	(ADD KEY
	(CLOSE (UPDATE)
	(OPEN (UPDATE)
	(GET BUCKET & KEY (UPDATE)

By setting these commands and supplying the appropriate information, the function will be performed. MFO commands are performed by the Disc Supervisor (DISC03).

V. Transaction Overlays

Essentially, each user writes a small, self-floating program (called an overlay or terminal user program) to perform a particular function. (See Sample Overlay--Table 2) It is loaded into a Buffer Area within MISCUP and supplied with a table of addresses.

PIFMAK,0587004-0000,ABC

0587004-0000 01 D-STYL-70237 70237 DOM			
SOURCE T COST DATE 00000			
BASIC MATL	000607.957	P/I	000000.000
MHX	000054.136	FAB DL	000000.000
NPA	000021.616	ASY DL	000021.495
MISC MATL	000002.735	U/T DL	000000.000
SUB TOTAL	000685.444*	S/T DL	000000.000
P/I STD	000000.000	PKG DL	000001.651
TOTAL MATL	000685.444**	SKN DL	000024.325
FTA	000000.000	TOT DL	000047.471*
TOOL COST	000000.000	TOT OH	000086.583*
NPL	000015.650		
PACK MATL	000012.000	MA VAL	000849.148**

TABLE 2--SAMPLE OVERLAY

These addresses supply information to the overlay and allow it to access subroutines that perform I/O functions for it. The overlay can be kept reasonably small and data oriented using this concept. The user is only concerned with validating his input and determining what action should be taken.

Upon completing his processing, the user formats a reply message, and returns control to MISCUP. The MISCUP program uses the information supplied by the user to send the reply to the terminal.

A. Overlay Control--In order to prepare the overlay for retrieval by MISCUP, two utility programs are provided. LOADOD will create an index for retrieval and OVLYLD stores the overlay on the drum.

VI. Backup and Restart

The Palm Beach Data Management System is provided with a series of programs that permit updating files from messages which have been logged to the disc, spooled out to tape and reentered into the communications system.

The Transaction Log is used in reconstructing the Data Base in case of System failure. The Batch log provides off-line input to batch processing programs. The DMPLOG (Dumplog) program reads the file from the disc and writes it out to tape in variable blocked format.

The output of DMPLOG can be reentered into the Communications System via COMBAT (Communications/ Batch Line) simulating on-line terminal input.

VII. Mini-Program Capability

The mini-programs by design will be small, say 20K-30K COBOL programs and will be given a higher priority slot than say a normal COBOL batch job. This will enable the user to return to the terminal within a short time and to call up his overlay to view the output. COBOL interface modules will communicate through MISCUP's common area.

APPENDIX C

SUMMARY OF SIMPLEX METHOD[24]

First iteration: Introduce slack variables to be the initial basic variables. Go to Step 3.

Step 1. Determine the new entering basic variables: Select the non-basic variable which, when increased, would increase Z at the fastest rate. This is done by checking the magnitude of the coefficients in the current objective function and selecting the non-basic variable whose coefficient is largest (or smallest, if the variables are on the left-hand side).

Step 2. Determine the new leaving basic variable: Select the basic variable which reaches zero first as the entering basic variable is increased. This is done by checking each equation to see how much the entering basic variable can be increased before the current basic variable in that equation reaches zero. A formal algebraic procedure for doing this is the following:

Let e denote the subscript of the entering basic variable, let a_{ie} denote its current coefficient in equation i, and let b_i denote the current right-hand side for this equation (i = 1,2...,m). Then the upper bound for X, in equation i is:

$$X_e \leq \begin{cases} +\infty, & \text{if } a'_{ie} \leq 0 \\ \dfrac{b'_i}{a'_{ie}}, & \text{if } a'_{ie} > 0. \end{cases}$$

---

[24] Extracted from Hillier and Lieberman, Introduction to Operations Research, Holden-Day Inc.,San Francisco, Calif., 1967., p.148-149.

Therefore, determine the equation with the smallest such upper bound and select the current basic variable in that equation as the leaving basic variable.

Step 3. Determine the new basic feasible solution: Solve the basic variables in terms of the non-basic variables by the Gauss-Jordan method of elimination and set the non-basic variables equal to zero.

Step 4. Determine whether this solution is optimal: Check if Z can be increased by increasing any non-basic variable. This is done by eliminating the basic variables from the objective function and then checking the sign of the coefficient of each non-basic variable. If all of these coefficients are non-positive (or non-negative, if the variables are on the left-hand side), then this solution is optimal, so stop. Otherwise, go to Step 1.