DYNAMIC SIMULATION MODEL

FOR

PLANNING PHYSICAL DISTRIBUTION SYSTEMS:

DISCUSSION OF THE COMPUTER MODEL[1]

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Summary

This paper deals primarily with the computerization of a dynamic simulation model for planning physical distribution systems on the Control Data Corporation 6500 computer using predominantly the GASP IIA simulation language and FORTRAN IV.

Introduction

The general class of problem considered in this paper is that of long-range planning of physical distribution systems.

The physical distribution activity includes design and administration of systems to control raw material and finished goods flow from manufacturing source to point of consumption.[2] From an analytical viewpoint, a physical distribution system consists of several interactive activity centers or subsystems among which tradeoffs in cost and service exist. These subsystems are often referred to as the components of a physical distribution system. In this research the classification of components includes: facility network, inventory allocations, communications, transportation, and unitization. With the exception of unitization, these components and the relative range of system design alternatives are familiar to the reader. Unitization, in a broad sense, involves material handling, packaging, and containerization.

The output of a physical distribution system includes measures of sales, cost, speed and reliability of customer service, and the degree of flexibility inherent in the physical distribution system configuration. The input to the physical distribution system consists of the changing business environment in which the firm operates. These inputs are expressed as management parameters and environmental factors either controllable or noncontrollable from the viewpoint of physical distribution management.

Long-range planning deals with the futurity of present decisions and is concerned with: Where are we going? (Strategic Planning); and, How do we get there? (Operational or Implementational planning). To date, a number of decision or planning models for physical distribution have been constructed in universities, by consulting firms, and by manufacturing organizations. In general, but with some notable exceptions on one or more of the following features, these models have been constructed to solve specific short-term problems, have concentrated on either the spatial or temporal aspects of a selected set of the components of the physical distribution system, have been deterministic in model structure, and have been static rather than dynamic in design.

Given these considerations and problems, a specific need exists for the development of improved planning models to aid firms in the design of total physical distribution systems over time. Such a planning model should be capable of assisting managers in analyzing the effect on expected results of alternative system configurations within the dynamics of a changing marketplace and the internal business environment. The planning model should be capable of assisting managers in the determination of the best time to implement physical distribution system modifications subject to the constraints of the available time and levels of money and personnel.

The overall objective of research conducted at Michigan State University was to provide such a physical distribution planning model. The model has been titled Long-Range Environmental Planning Simulator (LREPS). This paper deals primarily with the computerization of the model on the Control Data Corporation 6500 computer using predominantly the GASP IIA simulation language and FORTRAN IV.

Situational Analysis

A description of the dimensions of the modeled physical distribution network is presented in Figure 1. As illustrated, the problem can be defined more specifically as one involving: (1) multi-facility (re)location, (2) multi-product, multi-location unit inventory control, (3) a multi-stage communications network, (4) a transportation network, and (5) multi-location unitization. The problem thus includes both temporal and spatial considerations.

The design criteria for the model are: (1) the model must enable testing of tradeoffs among the five basic components of the physical distribution system, (2) the model must consider the sequential decision problem, and (3) the model must include a long-range planning horizon.

An outline of the experimental factors to be tested in the model is presented in Table 1.

Simulation was considered the most appropriate solution technique when considering the system characteristics and complexities plus research objectives. It is likely that a suboptimizing or satisficing technique which considers the total system will produce superior system results to those derived from the sum of the set of subsystem optimals, where each is studied independently.[3] This is especially the case for modeling systems such as physical distribution systems where the subsystems are highly interdependent.

Since the developed model must consider the sequential decision problem, it is dynamic in the sense that deficiencies and surpluses in terms of cost, service, and sales from one simulated operating period to the next are linked through feedback control loops.

Another dynamic aspect concerns the long run changes in exogenous variables, which define the marketing environment, and the management parameters relative to changes in one or more of the components of the physical distribution system. For example, the model should be capable of simulating the effect of changing within the planning horizon from a decentralized order processing system to a centralized system through the experimental factors in the communications component. This aspect, the changing environment in which the system operates is frequently neglected by systems designers.

Conceptual Model

The range of dynamic simulation involves a three-stage model illustrated in Figure 2. The first consists of the Supporting Data system run off line from the computer model's operating system. The purpose of the Supporting Data system is to analyze, prepare, and reduce the exogenous inputs for a set of simulation runs or experiments. In addition, changes in the experiment factors are introduced through this system.

The second stage simulates the operation of the physical distribution network defined in Figure 1. This stage consists of four overlapping subsystems which form an integrated physical distribution model. The four subsystems are called the Demand and Environment Subsystem, Operations Subsystem, Measurement Subsystem and the Monitor and Control Subsystem.

The primary function of the Demand and Environment Subsystem is to generate information for the Operations Subsystem related to forecasting and allocating sales, customer order generation, and the assignment of customer orders to agglomerated demand units.

In order to eliminate the processing of the needs of individual customers, customer demands are first summarized to the 560 geographic, zip sectional center areas which are further agglomerated to approximately 400 geographic demand units. Hub cities of these 400 demand units serve as points of simulated customer demand.

Stratified random samples of products and orders are selected and stored on magnetic tape. The sample of customer orders is used to develop a matrix of summarized blocks of orders. Simulated customer order generation then consists of randomly pulling sufficient blocks of orders from the order matrix to meet the daily sales forecast per distribution center based upon a set of selected, correlated independent variables such as population, retail sales, personal income, and effective buying power.

During this order generation step "pseudo" orders, with different order characteristics, can be added to the order matrix to test the effect of various levels of demand from different classes of customers, or the effect of changing buying patterns of existing classes of customers. In addition, the "pseudo" order matrix allows the introduction of new products to test the effect of significantly different products on system performance and design.

The sampled or tracked products serve as the basis for measuring the dynamics of various unit inventory control policies contained in the Operations Subsystem.

The output of the Demand and Environment Subsystem, allocated customer orders by demand unit and its assigned distribution center, serves as the input to the Operations Subsystem. Each demand unit is assigned to an in-solution distribution center based on a criteria such as minimum distance, minimum transit time, minimum transportation cost or some other heuristic rule. This assignment is done in the Monitor and Control Subsystem.

The Operations Subsystem processes the simulated customer orders through the major elements of the physical distribution system. For each facility in the physical distribution network, orders for the selected demand units are assigned a communications delay referred to as the customer order transmission time. This time delay is the first element of the customer's total order cycle. Variable order transmission times are generated from constant or average service time rings based on mileage and a variable element from discrete probability distributions.

Each of the tracked products in the orders is then processed to determine if sufficient inventory is available. If sufficient inventory is unavailable, the product is backordered. Otherwise, inventories are depleted. Order processing and preparation for shipment dispatch are assigned a combined time delay which is also based on constant and variable time elements.

The transit time from shipment dispatch until shipment arrival at the demand unit is generated from average service time rings based on the distance from distribution center to demand unit and a variable or reliability element based on a discrete probability distribution per ring. The sum of the averages of order transmission time, order processing and preparation time and the shipment transit time is defined as the average normal customer order cycle time.

As inventory reorder points or periods are triggered at end of day, multiple-product replenishment orders are dispatched to the firm's replenishment centers. The replenishments are scheduled to arrive at the distribution center after a time delay due to order transmission to, order processing and preparation at, shipping schedules at, and transit time from the replenishment center. The status of the delay time accumulators is used to generate the average reorder lead time.

The range of inventory policies in the model include a daily reorder point system, an optional replenishment system and a hybrid combination of the reorder point and replenishment systems. The information for the tracked products, in ABC categories, is extrapolated to the total line of products for the firm using a technique similar to that reported by A.H. Packer.[4]

The effect of alternative communications networks, the information flows, is tested using various values of the discrete probability density functions for the order transmission and order processing and preparation time delays in the Operations Subsystem.

The Measurement Subsystem is concerned with developing the cost, sales, service and flexibility measures for the activities processed in the Operations Subsystem. The volume of activity for each respective physical distribution component coupled with the cost parameters and mathematical transformations related to fixed facility investment, transportation, inventory, unitization or throughput, and order transmission and processing, enable the computation of total physical distribution costs for the simulated period of operation.

The fixed facility investment cost consists of a fixed dollar investment for each facility by size and type. An annual cost is calculated by using one of the standard depreciation methods assuming a known economic life for the facility.

Inbound transportation costs, from replenishment center to distribution center, and outbound transportation costs, from distribution center to the demand unit, are calculated from freight rates, in dollars per pound for point to point distances, and accumulated shipment weights for the respective product flow links. Outbound freight rates are calculated from sets regression equations based on distance. In developing the outbound regression equations consideration was given to regional differences, freight classes, weight breaks, negotiated rates, and average shipment size.

Communications costs are calculated using regression equations for distribution center, regional and domestic levels of the model. The independent variables are the number of orders and lines processed at each geographic level.

Average inventory carrying costs and reorder costs are calculated per ABC category and then extrapolated to estimate the cost of all model and pipeline inventories for the operating period.

The throughput or unitization costs for each distribution center are calculated using regression equations by distribution center. The variable cost per pound of sales and the fixed cost elements vary by size of distribution center.

Service characteristics such as measures of stockouts, total customer order cycle time, including a penalty time for stockouts, and percent of market covered within a specified normal order cycle time are also calculated for each operating period based upon output of the Operations Subsystem.

Measures of flexibility relate to the risk associated with actually implementing a specific recommended change in the physical distribution system structure.

The Monitor and Control Subsystem through information feedback compares desired levels of sales, cost, and service against the levels generated by the Measurement Subsystem. Modifications to the physical distribution system state, for example, addition or deletion of distribution centers and modified forecast sales, can then be automatically activated in the simulation model for future periods. Other management parameters and policies can be modified by exogenous periodic inputs. The modified system and policies are incorporated in an attempt to determine their effect on target variables during additional simulated periods of distribution system operation.

The Monitor and Control Subsystem contains a facility location algorithm which allows expansion of capacity at initial or new locations as necessary and/or addition and deletion of locations as required. The initial routine is "heuristic" with some aspects of the algorithm being similar to the model developed by Kuehn and Hamburger.[5] The second option being considered is a linear programming subroutine that would assist in selecting the locations. Once a location is selected for expansion or addition it is programmed to come into solution after a time delay for normal construction and start-up time. A deletion is handled in a similar manner with a time delay for closing down the center.

The third and final stage is the Report Generator system. This stage has been designed to take the output, raw data, from the simulation model and print one or more optional management reports.

Computer Model

The computer model has been designed to satisfy the needs and specifications of the abstract mathematical model, the validity of the model, the model's data base requirements and stay with the constraints of the available time, budget, and desires for model efficiency.

After the system was mathematically modeled, the formulation of the computer model required a general overview of how to interrelate all the described activities into an efficient computer model. The approach was to develop a total computer system that would efficiently and effectively produce the desired system outputs with the least amount of redundant operations as possible. This goal was especially critical when considering the large amounts of information that would be manipulated in the model where the danger was to waste much computer time and effort. In line with these desires, Figure 3 was developed to conceptually direct the overall computerization of LREPS.

As viewed in Figure 3, much of the data needed within the operating system of LREPS is prepared off-line in the supporting data system. This off-line data is read into the operating system as exogenous inputs at specified periods of time. Also supplementary or identifying information not needed in the operating system was sent directly to the report generator system.

In developing this data manipulation concept, a total system data base had to be defined. The total data base included all the information that was needed in the system in order to develop and analyze the results of simulation cycles. This data base was further segregated into two classes. The first class of data was the common data base needed within the operating system of LREPS that was to be shared among, between or used individually by the major subsystems of the model. The other class of information was the supplementary information needed by the report generator to prepare the managerial reports.

The first class of information along with the system activities described by the mathematical model served as the basis for computerizing each of the major subsystems of the model. This class of data was classified as to type of data, how often it was changed, whether it was an endogenous or exogenous change, what subsystem altered or set it, what subsystem used the data and the mode of the data. The mode was used to classify the data as integer, real or packed information. Presently, the data base contains 17,200 decimal words of computer memory composed of 40 two-dimensional, 160 one-dimensional and 90 single valued variables.

After the operating system's common data base was developed, a problem was how to control the inflow of exogenous inputs at specified time intervals without having each major subsystem inputting its own information. Therefore, the concept of an interface between the operating system and each of the other computer systems was developed. An interface was defined as the nodal point in data flow where two major computer systems interacted. The input interface was segmented into two parts. The first part was the order file. Because of the potentially large amounts of information in this file, given the decision had been made to work with individual customer orders, the orders were generated off-line in the D&E supporting data system and read in as a separate file. The other segment of the operating system's inputs was the file containing the remaining exogenous inputs.

The last file of exogenous inputs was designed to agglomerate all of the model's subsystem inputs into one file that would be inputted into the M&C subsystem. The M&C was designed as not only the supervisor and controller of the model but also as the gatekeeper controlling the flow of exogenous inputs into the operating system's common data base. Figure 3 also illustrates that the M&C subsystem is the gatekeeper controlling the outflow of information from the operating system. M&C basically wrote an output interface containing run control information, specific distribution center information and the common data base for processing by the report generator system. Finally, Figure 3 illustrates the activities of the report generator system in processing not only the operating system's output but also the supplementary information sent to it by the supporting data system. Presently, cyclic reports are prepared in this computer system.

Results Concerning Computer Research

In computerizing LREPS, eight research questions served as primary guidelines for the task. Each of these questions are discussed in relation to the operationalized, computer model.

Research Question 1

Research question one states:

> What programming languages will facilitate the development of a reliable LREPS computer model including the supporting data system and the report generator system?

In reference to the LREPS operating system of the computer model, the GASP IIA simulation package facilitated and expedited the computerization of this system.[6] The user-defined and simulation-defined concepts provided by this language assisted in the conceptualization of the computer model. The GASP EXECUTIVE routine alleviated the need to design routines to direct the model through simulated time. Additional time was, therefore, available to design the non-GASP system activities of the computer model, illustrated in Figure 4.

In selecting GASP IIA as the applicable simulation language, a set of selection criteria was needed to screen and finally select one language as the predominant computer programming language. These criteria are listed in Figure 5. In implementing the GASP IIA simulation package on Michigan State University's CDC 6500, a small delay was experienced because some of the subprograms required minor modifications. Any subprogram that used the pseudo-random number generator DRAND had to be changed to use the pseudo-random number generator, RANF, for the CDC 6500 computer operating system. In addition, the GASP IIA subprograms, TMST, COLCT and OTPUT, had not been completely modified for the floating point array, QSET. The GASP IIA subprogram DATAN had to be renamed as DATAIN since the previous name was already used by CDC as the name of the double precision, arc tangent function. In summary, the GASP IIA simulation package was sound even though it required a few minor modifications.

In reference to the supporting data and report generator systems, the use of the general compiler language FORTRAN was generally the most appropriate programming language. The primary exception to the use of FORTRAN was the use of the CDC 6500 assembly language COMPASS for tape handling. The use of COMPASS for tape handling was necessary since FORTRAN is generally an inefficient language where considerable tape handling is required. The FORTRAN tape handling routines are usually slow plus their use of magnetic tape storage space is inefficient.

In summary, a simulation language, a general compiler language and an assembly language were necessary to computerize LREPS. The complexities of the system model, the desire for efficiency in program execution and core memory untilization plus the use of magnetic tapes required the use of all three programming languages.

Research Question 2

Research question two states:

> What model building procedures will facilitate the development of the computer model, the later sophistication of the model's defined activities, the broadening of the model to encompass additional horizontal and vertical aspects of the total business system, and satisfy the strong desire for universal applicability among packaged-goods firms?

The use of building blocks as the common basis for many of the model's activities facilitated the development of the computer model. In particular, the basic building blocks programmed in the LREPS operating system served four major purposes. These purposes were:

1. The use of these blocks allowed the project team to allocate efficiently their time among the specific activities of the mathematical model.

2. The blocks facilitated the changing of the computer program when a better approach to the computer modeling of an activity was developed.

3. Basic building blocks forced the examination of the common elements of system activities. Instead of developing a subprogram for each potential DC location, the general or universal aspects of the functions of a DC were modeled and computerized. Thus, the same computer subprograms could be used for the functions of many DC's.

4. Basic building blocks saved computer memory while execution time increased very, very slightly because of the additional subprogram linkages.

In general, the use of basic building block subprograms facilitated the overall development of the computer model and especially theLREPS operating system.

Research Question 3

Research question three states:

> What computer software and hardware features will allow the structuring of the simulation model's data base and its input/output requirements that will minimize reprogramming these structures for alternative LREPS versions?

With the use of both the special hardware features and the sophisticated software features of the CDC 6500, the required reprogramming for alternative versions of LREPS was minimized. The hardware features centered on the effective use of magnetic tapes, disks and punched cards where speed and controls were needed in programming and debugging LREPS. The software features centered on the definition of the LREPS common data base plus the effective use of the program and information, storage and retrieval systems for MSU's CDC 6500. Although the use of many of these storage and retrieval systems is somewhat difficult to learn, MSU's systems were easily learned and expedited the computerization process of alternative versions of LREPS.

Research Question 4

Research question four states:

> What computer software and hardware features will promote the efficient processing of the great amounts of information that will accompany a model spanning a maximum ten-year planning horizon?

Research considering alternative methods for storing, retrieving and processing the computer model's data base of information resulted in the use and disuse of certain computer hardware and software features. The more important features that were investigated are discussed below.

Sequential, magnetic tape files were majorly used for the inflow and outflow of information manipulated in the LREPS operating system. Initial tests using random-access, disk files for banks of information related to the order file showed this method of information processing to be much slower and more expensive than the tape-handling procedure that was developed. The remaining information in the data base that could effectively be random-accessed was so small that this information was kept in high-access, core memory. The use of low-access, extended core storage (ECS) for this information was not possible since ECS was unavailable on MSU's CDC 6500.

The periodic input and output of information into the LREPS operating system via the M&C gatekeeper proved to be efficient and effective. Magnetic tape was also used as the medium for this input and output. The only exception was the limited use of punched cards and printer listings.

The use of computer program overlays for those portions of the LREPS operating system that were only referenced quarterly or less frequently was also investigated. Program overlays were not used because the present overlay procedure for FORTRAN programs on the CDC 6500 is not easily implemented and quite complicated.

The procedure of packing more than one piece of information in a computer word of memory was used. Much of the information in the model was based upon a zero-one, binary representation. Where a certain category of information was based upon this representation plus there was a considerable amount of information involved, packing was used.

Research Question 5

Research question five states:

> What is the most efficient way to write the model's output in order to provide reports of the essential data and to provide storage that can be easily accessed later as input to programs for further simulation results analysis?

The periodic output of simulation results via magnetic tape has proven to be very efficient and effective. Reports were easily prepared plus the basic simulation data is available for further analysis. Also by establishing DAILY and MONTH fixed-time events in the LREPS operating system, the use of these routines to print any additional data was easily effected.

Research Question 6

Research question six states:

> Can a LREPS model be developed that will be highly compatible among different computer manufacturing systems?

LREPS is presently machine dependent and has low compatibility among other computer operating systems. Low compatibility among computer operating systems is stressed because it would be fairly difficult to implement the present computer model on even another CDC 6500. Large computer operating systems for machines such as the CDC 6500 generally have peculiarities that have been developed by university personnel and which are the cause of conversion problems.

Considering other computer manufacturers' operating systems, LREPS' implementation would be very difficult on their systems. Because more than one piece of information was packed into many computer words, the availability of EXTENDED FORTRAN routines to unpack the information would be required. Associated with the packing of information are the differences in the physical sizes of the computer memory words among different computers. The CDC 6500 has sixty bits per word while the IBM 360 series has thirty-two bits per word. Since some of the LREPS data base variables have more than thirty-two bits of information packed into one computer word, then the LREPS data base would have to be redesigned for two words of IBM memory for base variables.

The level of the FORTRAN compiler itself would prohibit some computer operating systems from being used for LREPS. MSU's FORTRAN compiler is an advanced version that includes such features as "logical" storage and instructions, tape buffering routines, plus NAMELIST and variable formatting procedures. The use of such features requires a large, sophisticated FORTRAN compiler.

Research Question 7

Research question seven states:

> Can a model be developed that will run on medium-size computer operating systems?

The results concerning research question seven are closely related to the results of research question six. The present design of the LREPS computer model requires a large-scale system such as the CDC systems available at Michigan State University. LREPS requires a large-scale computer system for fast compilation and execution. LREPS also requires a machine with large amounts of high-access computer memory. To retain the universal aspects of LREPS, a sophisticated computer operating system that allows one to retrieve and compile quickly the LREPS program routines is also needed.

With these requirements on the size and speed of the computer operating system, a medium-size system would generally not be capable of processing effectively and efficiently the LREPS simulation.

Research Question 8

Research question eight states:

> Can a computer program of the main operating system of LREPS be developed that will:
>
> a. Cycle through a ten-year planning horizon within a total elapsed computer time of 30 minutes:
>
> b. Fit within a computer memory limitation of 36K decimal words?

In reference to the computer memory utilized in the execution of the LREPS operating system, the most sophisticated version presently requires a little less than thirty-two thousand decimal, computer words of memory. Without primarily the capability of packed computer words, the restriction of fitting the LREPS operating system within 36K decimal words of computer memory would never have been satisfied.

The first part of research question eight is concerned with the execution time of the LREPS operating system. In order to minimize the cost of executing the LREPS operating system, the desire was to develop a computer program that would process a ten-year cycle of information in thirty minutes. This execution time is in reference to both computer central processing and peripheral processing time since they are presently about equal. Examining the computer times of several test runs, the length of time for running a ten-year cycle was primarily a function of two factors. The first factor was directly related to the total sales dollar forecast for the regions processed. The second major factor affecting execution time was the average sales dollar amount per customer order. This factor had an inverse relationship to the amount of time that it took to execute a simulation cycle. If the average dollar amount per customer order was large, then the sales dollar quotas per day were filled much faster which caused the operating system to execute faster. Other factors were considered in the investigation. One of the more important factors was the number of tracked products. After running the program with twelve tracked products and then fifty tracked products, there was no appreciable difference in running time. Most of the tracked product processing was done while the order file was being buffered in.

In order to obtain some ideal as to how fast the program would run given various levels of the two major factors, the execution times of several LREPS tests were analyzed in detail to derive a formula that could be used to approximate the running time of the LREPS operating system. The formula which gives the computer time in minutes of computer central processing unit (CPU) time is:

$$T = \sum_{i=1}^{NYRS} \frac{45 \cdot TDSF_i}{ADPCO_i}$$

where;

T is the total amount of CPU time per simulation cycle,
NYRS is the total number of simulated years to be run,
$TDSF_i$ is the total sales dollar forecast (in millions of dollars) for the ith year and the market regions(s) under analysis
and $ADPCO_i$ is the average sales dollars per customer order in year i.

Considering the consumer-oriented firms who might use LREPS, the computer run times per maximum ten-year cycle might be unreasonable if they have large sales forecasts and small customer orders.

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[1]This paper has been adopted from an unpublished monograph entitled Dynamic Simulation of Physical Distribution Systems and doctoral dissertations entitled Development of a Dynamic Simulation Model for Planning Physical Distribution Systems: Formulation of the Mathematical Model and Development of a Dynamic Simulation Model for Planning Physical Distribution Systems: Formulation of the Computer Model which are forthcoming from Michigan State

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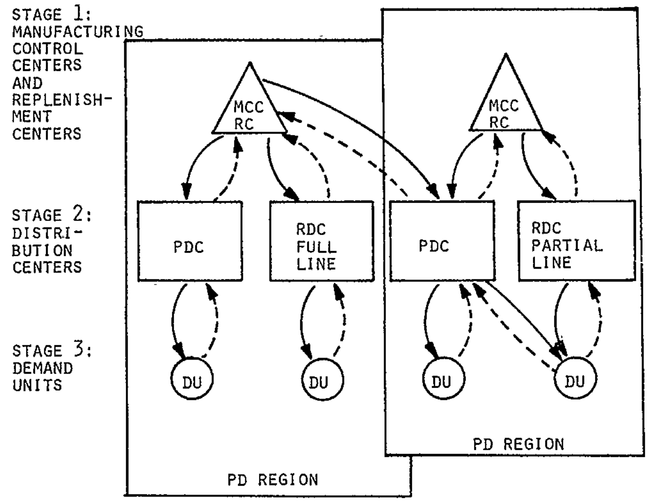

------INFORMATION FLOW ——————PRODUCT FLOW

REGION..THE REGION IS DEFINED BY THE ASSIGNMENT OF RDCS AND DUS TO A PDC.
MCC.....EACH MANUFACTURING CENTER PRODUCES A PARTIAL LINE.
RC......REPLENISHMENT CENTERS STOCK ONLY PRODUCTS MANUFACTURED AT COINCIDENT MCC.
RDC.....REMOTE DISTRIBUTION CENTER, FULL OR PARTIAL LINE.
PDC.....PRIMARY DISTRIBUTION CENTER, EACH PDC IS FULL LINE AND SUPPLIES ALL PRODUCTS TO DUS ASSIGNED TO THE PDC REGION; PRODUCT CATEGORIES NOT STOCKED AT THE PARTIAL LINE RDCS IN THE REGION ARE ALSO SHIPPED BY THE PDC.
DU......THE DEMAND UNIT CONSISTS OF ZIP SECTIONAL CENTER(S).
CSP.....CONSOLIDATED SHIPPING POINT.

FIGURE 1 -- STAGES OF THE PHYSICAL DISTRIBUTION NETWORK

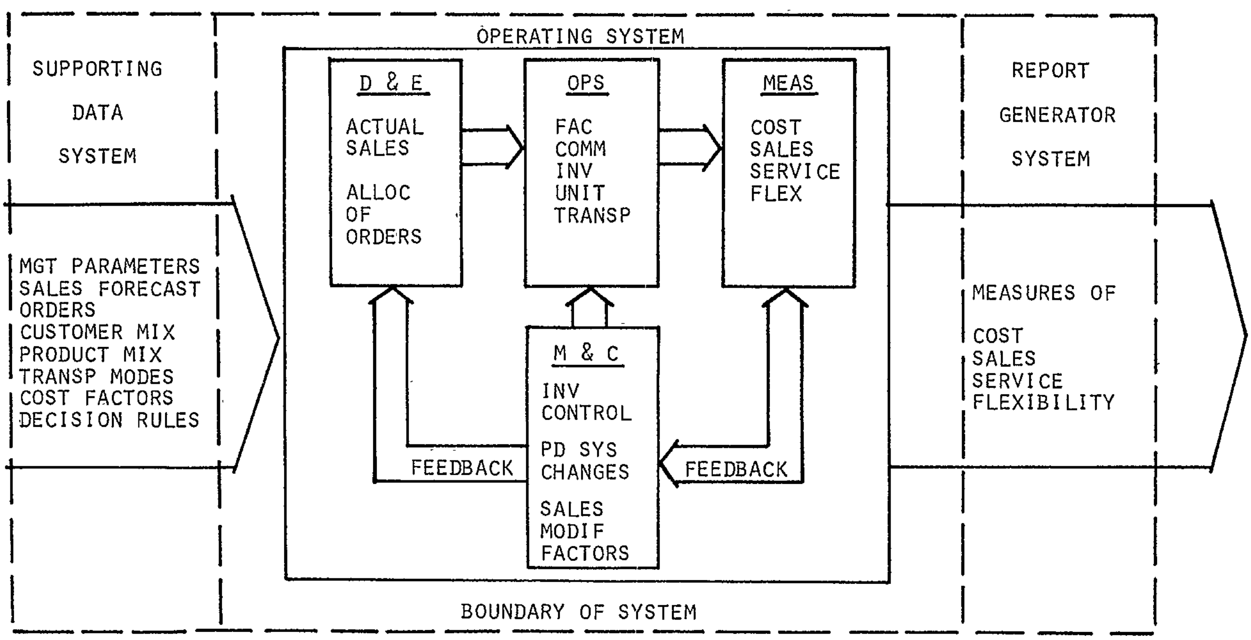

FIGURE 2 -- LREPS SYSTEMS MODEL CONCEPT

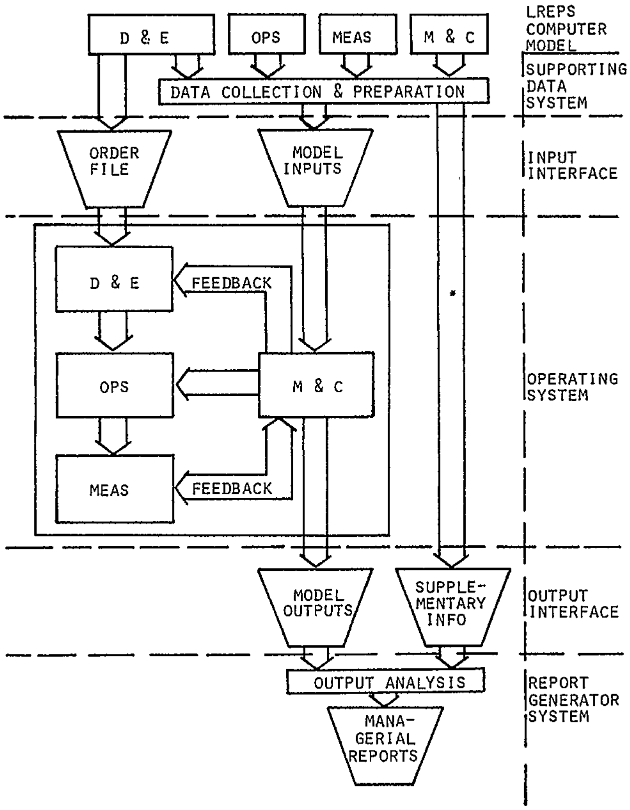

FIGURE 3 -- LREPS TOTAL COMPUTER SYSTEM FLOWCHART

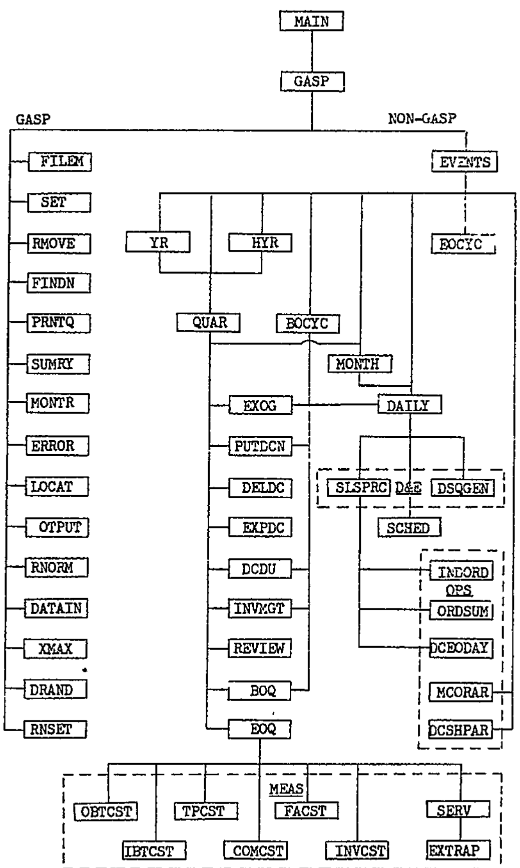

FIGURE 4 -- LREPS OPERATING SYSTEM LINKAGES

1. PROGRAMMING LANGUAGE STRUCTURE
2. LEVEL OF REQUIRED PROGRAMMING SKILL
3. EASE OF CONVERTING LOGICAL BLOCK DIAGRAMS TO COMPUTER PROGRAM
4. SIMULATION PROCEDURES ASSOCIATED WITH
   - A. INITIAL VALUES
   - B. DATA GENERATION AND MANIPULATION
   - C. TIME FLOW MECHANISMS
   - D. OUTPUT ASSISTANCE
   - E. STACKING OF A SERIES OF CYCLES
5. DEBUGGING AND ERROR ASSISTANCE OFFERED BY LANGUAGE
6. COMPUTER COSTS OF COMPILATION AND EXECUTION
7. COMPATIBILITY OF LANGUAGE AMONG DIFFERENT COMPUTER OPERATING SYSTEMS
8. AVAILABILITY OF COMPUTER HARDWARE
9. EASE OF CHANGING SYSTEM MODULES
10. APPLICATIONS OF LANGUAGE TO DATE

FIGURE 5 -- CRITERIA FOR SELECTING PREDOMINANT COMPUTER PROGRAMMING LANGUAGE

TARGET VARIABLES

- SALES
- CUSTOMER SERVICE
- PHYSICAL DISTRIBUTION SYSTEM COSTS
- PHYSICAL DISTRIBUTION SYSTEM FLEXIBILITY

CONTROLLABLE VARIABLES

- ORDER CHARACTERISTICS
- PRODUCT MIX
- NEW PRODUCTS
- CUSTOMER MIX
- FACILITY NETWORK
- INVENTORY POLICY
- TRANSPORTATION
- COMMUNICATIONS
- UNITIZATION

UNCONTROLLABLE VARIABLES

- MARKETING ENVIRONMENT
- TECHNOLOGY
- ACTS OF NATURE

TABLE 1 -- SUMMARY OF EXPERIMENTAL FACTOR CATEGORIES